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INSTITUTE FOR THE STUDY OF FREE ENTERPRISE SYSTEMS

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THE PROBLEM OF DEVELOPMENT:

Exploring Economic Development Through Free Enterprise

Proceedings of the Institute's First International Conference
May 27 - 29, 1988

PART I: Summary

by
Isaac Ehrlich
Govind Hariharan
Randall Lutter

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FORWARD

The proceedings of the first international conference of the Institute for The Study of Free Enterprise Systems, which took place at the Buffalo Hilton in Buffalo, NY, on May 27 - 29, 1988 are presented in this and an accompanying volume. During the conference, eight original papers on economic development were presented and each of these was critiqued by two discussants. The full texts of the papers and discussant's comments are presented in the accompanying volume, while this volume contains the opening remarks to the conference by Ambassador Alan Woods, Administrator of the U.S. Agency for International Development, an introduction to the conference proceedings, and a summary of the papers and discussions, both written by the authors of this volume.

CONFERENCE AGENDA AND LIST OF CONFERENCE PARTICIPANTS

1. Author: Gary Becker and Kevin Murphy.
University of Chicago
Title: "Economic Growth, Human Capital and Population"

Discussions by:
Edward C. Prescott, University of Minnesota
Henry Wan Jr., Cornell University

2. Author: Mark Rosenzweig
University of Minnesota
"Population Growth and Human Capital Investments: Theory and Evidence"

Discussions by:
Sherwin Rosen, University of Chicago
Finis R. Welch, University of California, Los Angeles

3. Author: Paul Romer
University of Rochester
Title: "Endogenous Technological Change"

Discussions by:
Robert Vishny, University of Chicago
Lawrence Summers, Harvard University

4. Author: Paul Krugman
Massachusetts Institute of Technology
Title: "Endogenous Innovation, International Trade and Growth"

Discussions by:
Gene Grossman, Princeton University
Andrei Schleifer, University of Chicago

5. Author: Robert King and Sergio Rebelo
University of Rochester and Northwestern University
Title: Public Policy and Economic Growth: Developing Neoclassical Implications"

Discussions by:
Arnold C. Harberger, University of California, Los Angeles
Stanley Fischer, The World Bank

6. Author: Dale Jorgenson and Kun-Young Yun
Harvard University
Title: "Tax Policy and U.S. Economic Growth"

Discussions by:
Kenneth Judd, Northwestern University
Christophe Chamley, Boston University

7. Author: S. C. Tsiang
Chung-Hua Institution for Economic Research and Cornell University
Title: "Success or Failure in Economic Take-off"

Discussions by:
Gregory Chow, Princeton University
Ronald Findlay, Columbia University

8. Author: Robert Barro
Harvard University
Title: "Government Spending in a Simple Model of Endogenous Economic Growth"

Discussions by:
Robert Hall, Hoover Institution, Stanford University
Daniel Gros, International Monetary Fund

PREFACE:

THE CHALLENGE OF ECONOMIC DEVELOPMENT THROUGH FREE ENTERPRISE

Remarks of the A.I.D. Administrator Ambassador Alan Woods to the first international conference of the Institute for the Study of Free Enterprise Systems". Buffalo, New York. May 27, 1988

I'm delighted to be here for the Institute's first international conference. A.I.D. is proud to have been a part of the establishment of the Institute for the Study of Free Enterprise Systems, and I am particularly pleased that you have chosen to focus on the problems developing countries are facing.

Your work can be very important for developing countries. These nations have much to gain from economic policies and practices that bring out the best in individuals and lead nations to prosperity.

Our own adherence to market principles and to a free enterprise vision keeps America on a prosperous course. Our economy is growing today and we are enjoying the longest peacetime expansion in U.S. history. As this morning's paper reported, we grew at 3.9% in the first quarter of this year. Since 1982, we have created nearly 15 million new jobs and unemployment is at the lowest level in a decade.

That's good news for us, and it's good news for other countries as well: America does not stand alone in the world. Our recession in the early 1980's sent economic shock waves around the world, and the economic performance of other countries matter to us, because when other countries have poor economic growth and heavy debts, they cannot afford the things we want to sell them.

The truth of the matter is that economic failure has been the rule, not

the exception, in developing countries. In 35 of the poorest countries in the world, the average per capita growth rate for the past twenty years has been .4%, just about zero. If you project those figures forward, it means that between 1988 and the year 2050 per capita incomes will rise $66 dollars total! What it really means is that millions and millions of people are going to live in abject poverty and millions of others will die.

If the developing countries continue to stagnate economically, while America, Europe and Japan grow, then the gap between us won't close, but rather it will get bigger, a lot bigger.

In addition, the rapid population growth and a steady pace of urbanization in these countries make their development problems more complex. The circumstances in these countries demand our attention. Left unattended, they are the breeding ground for political unrest.

In 1981 President Reagan met with the leaders of 22 developing countries in Cancun, Mexico, to talk about the importance of economic growth. He told them of our commitment to help them achieve a better, brighter future. He spoke of their responsibility for development saying:

> "History demonstrates that time and again -- in place after place economic growth and human progress make their greatest strides in countries that encourage economic freedom."

When we speak of economic freedom, we mean a reliance on individual initiative, competitive markets, and open trade. That freedom exists in America. It also underlies the economic successes of post-war Europe and Japan. Those same principles have been put to work, and have stimulated impressive economic growth, in Taiwan, Singapore and Hong Kong.

In contrast, many of the problems developing countries have can be traced to the fact that they regulate their economies rather than letting market forces and individual enterprises work to generate growth. Since

Cancun, many developing countries have begun to consider what they can do to improve their economic performance. They are starting to consider market solutions.

We have been working closely with many of these countries: helping them to identify macro-economic and sectoral policies that are holding back growth. I am pleased to report that on the policy front there have been some progress. For example: Exchange rate policies, once major problems for Costa Rica and Guatemala, have been changed. In Bangladesh, fertilizer prices have been decontrolled. In Mali, we are working with the government to liberalize the cereals market.

Governments around the world are also examining opportunities for privatization, opportunities to transfer government-owned and operated businesses into private hands. On a recent trip to Jamaica I saw results of some of that country's privatization efforts. The privatization of the National Bank of Jamaica and a cement company are giving responsibility to more people and strengthening their stake in the economy. Thirty million shares of stock were sold as part of the privatization of the National Bank, to 2,000 employees and thousands of other buyers. When the cement company went private 91 million shares were bought by 24,000 people. These people were teachers and civil servants, people who had never owned a piece of their economy before.

Similar changes are underway in a wide range of developing countries. Yet as we work with these countries, promoting a free enterprise approach, we continue to find problems that have not been adequately examined or addressed. What we are finding is that even where there is a private sector, free enterprise as we know it does not always exist. Words like capitalism, private sector, and, to a somewhat lesser degree, free markets and free

enterprise mean something quite different in developing countries than they do here. Ideas we believe in get a bad name when they are corrupted and used to make a few families rich, while locking a lot of other people out of developing country markets. Such experiences have contributed to the political upheavals in the Philippines, Haiti, Iran, and in Nicaragua.

What capitalism and the private sector have come to mean in some developing countries is favoritism and corruption: crony capitalism that forces you to take on a particular firm as a partner if you want an import license, or makes you buy inputs from a monopoly supplier whose cousin is a minister. These practices result in narrowly based commercial and industrial sectors, and political alliances and regulation that protect the favored few. These problems warrant our attention.

Setting developing countries on a path toward broad-based economic growth clearly means more than adjusting macro-economic policy and selling off a few government-owned enterprises. It means creating a vision of an open economy, a vision that doesn't exist today. It means helping countries to identify the obstacles to economic participation, obstacles that lock the ordinary citizen out of the game. We have an obligation to make a distinction between private enterprise as these countries have known it, and the kind of free enterprise system we are promoting.

Economic growth is broadly based at home, because everyone can get in the game. There are few barriers to starting up a business in America. That's why we have 5 million businesses, and 700,000 new business starts every year. About 85% of us work in the private sector, and even those of us who don't run businesses can easily acquire an ownership stake in our company. Nearly 1 out of every 4 of us owns stock in some American company.

Barriers that prevent economic participation and broad-based growth can be found all over the developing world. Barriers exist in countries that

claim to operate on free market principles, and to an even greater degree in societies that claim that socialism is the way to ensure the well being of people. Barriers can be found in the legal systems of these countries, in their regulations, and in their financial systems, and they can be seen in people's attitudes, their sense of futility and in their lack of skills. Wherever barriers to economic participation and individual initiative exist, they hinder economic growth. These are the barriers that must be eliminated. Yet, until now, we have not examined them systematically. If we don't, we may find we have helped perpetuate problems, rather than solve them.

These issues are ones on which policy makers here, and in developing countries, need help. What they really need are hard-nosed economic assessments of the effects of barriers to economic participation. Now that's where you come in. You have an opportunity to put the economic spotlight on these barriers in a way I cannot.

Let me give you a few examples of the kinds of barriers that need to be examined more fully. One obstacle that is not yet receiving enough attention is inadequate and unfair rules governing property rights. Our American constitution guarantees us the right to own property, to acquire it, and transfer it to others as we see fit. But these rights are not universal. In many African countries property rights exist for men, but not for women. Women who work in the markets and the fields cannot invest their earnings as men do. If they put their money in a bank the men in their family are free to withdraw it without their wive's consent.

In Latin America, even where constitutions protect individual property rights, governments still nationalize and expropriate private property. When it comes to intellectual property rights, the developing world is a wasteland. Most of Asia, and more recently the Latin American countries, thrive on

copied goods. Where property rights are not secure, there is little incentive for people to work hard, to save and to invest.

Weak legal systems are a second constraint. In many developing countries, governments simply don't pay the private sector for the goods and services they purchase. What is worse, firms have no effective legal recourse. Often the legal systems in developing countries do not fairly enforce rights. In the Dominican Republic a private bank tried to use the legal system to go after the collateral a firm had offered on a loan it failed to pay. After seven years of legal maneuvering the bank finally got its money, but only by settling out of court.

Sometimes it's simple logistics that deny people the opportunity to operate freely in these economies. In many developing countries, people have a very difficult time getting clear title to their land. Adequate maps simply don't exist. Without clear title, farm land and urban property cannot be sold or used as collateral to obtain credit. So why improve it? If you are rich you may find a way around this problem, but the ordinary citizen in a developing country probably cannot.

Government regulations are a third kind of barrier that can deter ordinary citizens from trying to participate fully in their economies. In Peru, Hernando de Soto has been studying what locks people out of Latin American economies. What he has learned is that the roadblocks to participation are sometimes very cleverly disguised. In theory, an individual in Peru is free to go into business. But in practice that freedom isn't real. To demonstrate this problem De Soto tried to open a clothing business legally without paying bribes along the way. It took a lawyer and three other people a total of 300 days, that's a total of 1200 man days, to complete all the forms and to obtain all the signatures that are needed to start a business. As a comparison, De Soto tried the same thing in Florida.

There it took him only three hours to get into business. Peru is not unique.

Even where government regulations are not onerous, they can be applied capriciously or changed at a moment's notice. In a lot of developing countries, this kind of red tape drives entrepreneurs into the "underground" or "informal" economy. As unregistered businesses they are often barred from obtaining bank credit. They are also vulnerable on legal grounds should governments choose to act against them.

A fourth problem area is in the financial systems of these nations. All over the developing world the financial policies of governments make it difficult for ordinary citizens to get ahead. For example, sky-high taxes on individual income and on corporations leave little room for savings and investment, and inflationary policies erode the value of what people are able to earn. For many people, lack of access to credit means lack of access to the economy. Throughout the developing world, banks avoid small loans because of their high transaction costs. For similar reasons, many banks do not extend long term credit. When they do, the rates tend to be high. Last year, for example, banks in Bolivia required up to 300% collateral on their loans. That may have been a market assessment of risk, but for many would-be entrepreneurs those terms are impossible. Just imagine how many farmers and businessmen might be able to get ahead if they could buy a new machine using the machine as collateral, the way you or I might buy a car.

These examples are only the tip of the iceberg. They only begin to outline the kinds of barriers to broad-based participation that exist in developing countries. Such barriers need to be torn down if free enterprise and economic growth are to have a chance. But that won't happen without your help. Attention must be drawn to these problems. They must be identified on a country-by-country basis, and their effects must be made known.

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Solutions must be developed and set forth in terms that policy makers can understand and act upon.

Turning the spotlight on barriers to broad-based economic growth and truly free enterprise is an important task. I believe that these are tasks which this Institute, and the noted economists assembled here tonight, should address. If you do, you will make a real contribution to the people of the developing world.

INTRODUCTION

THE PROBLEM OF DEVELOPMENT: EXPLORING ECONOMIC DEVELOPMENT THROUGH FREE ENTERPRISE

A. THE PROBLEM OF DEVELOPMENT

The collection of papers summarized in this monograph, and the conference that produced it, attempt to shed new light on an old, yet pivotal issue of economic inquiry: the problem of development. The importance of this problem is demonstrated by the large and persistent gaps in real income per capita among different countries, and by the significant diversity of growth rates of per-capita income even among countries that initially had similar economic resources. To illustrate, using World Bank data, Lucas (1988) noted that compared to the 1980 average for "industrial market economies" of $10,000 U.S., India's per capita income is $240, and Haiti's is $270. This is a difference of a factor of 40 in living standards. Rates of growth of real per capita GNP are also sharply divergent even over sustained periods. For 1960-80, for example, India grew at 1.7%, Egypt at 3.4%, South Korea at 7.0%, Japan at 7.1% and the U.S. at 2.3%. Cuba appears to have been lagging significantly behind Taiwan in terms of current levels of per-capita income, despite the fact that the economies of these countries were remarkably similar in the late 1950's. For the period 1960-80, Taiwan's rate of growth was 6.5%, but that of Cuba was 2.7% according to that country's official statistics. It is important to note that even small differences in annual rates of growth in per-capita incomes mushroom into dramatic differences in income levels within a relatively short period of time. By the statistics and sources just mentioned, incomes in India will double every 50 years, but in Korea they will double every ten years, and

in major African countries they may remain virtually stagnant. These data pose the problem of development, and tackling it involves two distinct tasks.

The first is to explain the empirical evidence, gathered through both general historical observations and scientifically assembled data, about the actual pattern of economic growth and development at different times and places. This task entails an identification of the major forces that account for the observed diversity in both levels and rates of growth of per-capita income, consumption, or other relevant measures of personal welfare.

The second is to draw possible inferences about the roles of government and the private sector in bringing about development, based on the way the first task is resolved. Such inferences help identify the possible channels through which government policies can either enhance or harm the growth and development potential of the economy. All conference papers address either one or both of these aspects of the problem.

The methodology that authors of the conference papers have adopted in resolving these issues involves the development of an explicit "model" of growth, i.e., a paradigm of varying specificity and technical sophistication that is designed, in general, to address two related questions:

1. Can a decentralized, free market economy that is guided by the force of individual incentives reach an equilibrium state of growth, usually referred to as a "balanced growth path" or a "steady state of growth", and if so, how? More specifically, the question concerns the identification of some basic factor, or "engine" of growth, which is capable of propelling the economy onto a path of persistent growth in personal income and welfare, and the "mechanics", or specific technical process through which this factor operates.

2. What are the basic "exogenous" factors that control the level and slope, or time-rate of change, of such balanced growth path? By exogenous factor is meant a variable such as an initial value of an asset or a constant technical

parameter which is determined independently of the economic system, as opposed to an endogenous variable which is a by-product of the growth equilibrium itself.

A resolution of the "problem of development" is thus attempted by this approach through a series of analytical steps. The first requires an explanation of how an economy can reach a stable steady state of growth after which it may "live happily (for economists "predictably") ever after" through its internal market forces. The second involves determining whether either the implied process of convergence into such a state or the exogenous variables identified as controlling the growth path itself can explain the real world variations in levels and rates of economic growth. Successful formulations of the problem may thus lead to concrete explanation of why some countries succeed in achieving high, self-sustaining growth rates, while others lag behind, and how government policies in the areas of taxation, trade, or direct management of economic activity affect an economy's actual path to poverty or riches.

B. THE ENGINE OF GROWTH

To explain persistent growth in per-capita levels of income or consumption, all growth models invariably resort to a feature or characteristic of the economy's production technologies, or institutional structure, which explains how in a state of "balanced" growth, where the relevant factors of production grow at a constant rate, per-capita income and consumption may grow at a constant rate as well.

If the economy's aggregate production function of final goods and services exhibits constant returns to scale in all of its relevant arguments, and if in addition effective labor and population size are proportionally related, then an equal rate of growth of all inputs would lead to the proportional growth of aggregate income without affecting the level of per capita income. Growth in

the latter must generally be explained, therefore, by one of the following types of technical possibilities:

a) Production is subject to increasing returns to scale in all privately controlled factors. This assumption implies, however, eventual monopolization of the economy and should therefore be rejected as a basis for constructing a useful growth model.

b) The production function, in either its direct or indirect ("reduced") form, exhibits constant returns to scale in some exogenously "fixed" factor determining productvity, or in specific productive assets that are fixed at a point in time and can be accumulated over time. Such assets, in turn, prove to be "engines of growth". For example, the production function of final goods may be proportionally related to the economy's level of technology, i.e., its stock of disembodied knowledge, or its accumulated human capital, i.e., stock of embodied knowledge. Per-capita consumption would then grow at a constant rate as long as technological innovations or knowledge accumulate at a constant rate in a balanced growth regime. All of the papers in this collection that develop an explicit model of endogenous growth rely on variants of this type of growth mechanism.

c) Production in the economy is subject to external economies in production, so that while firms' production functions exhibit constant returns to scale, the industry's or economy-wide aggregate production function exhibits increasing returns to scale in the same factors. If the source of the externality were human capital, for example, there would be a divergence between the social and private returns to investment, so that decentralized choices, while compatible with competitive equilibria, would lead to suboptimal growth paths. Externalities associated with the production of disembodied technological innovation and with payments of taxes for government services

play an important role in the endogenous growth models of Romer, Krugman and Barro.

C. ENDOGENOUS PRODUCTIVITY GROWTH: TOWARD A NEW THEORY OF DEVELOPMENT

The point of reference for most conference papers is the "neoclassical growth model" associated with Robert Solow's pioneering (1956) work. The model, which underwent many refinements in the 1960's, has as its basic features a closed economy with competitive markets, identical rational individuals and a production technology exhibiting constant returns to capital and labor inputs. Population and labor growth are exogenous to the model, as is disembodied technological change. Under these assumptions, the model gives rise to a "balanced" growth path in which capital per-capita is accumulated at the same rate as output or consumption per-capita, and where the savings rate as well as the real rate of interest are constant along the equilibrium growth path. In this regime, the rate of growth of per-capita income and consumption is strictly proportional to the given rate of technical change. Thus technology, although exogenously given, is the critical "engine of growth" and the only force that explains growth in per-capita income. The determinants of the propensity to save have no bearing on the equilibrium growth rate, although they do affect the per-capita levels of income and consumption. The same holds, in principle, for changes in trade barriers designed to promote international trade. Indeed, as Lucas (1988) points out, by assigning a predominant role to an exogenously available technology as an engine of growth, the theory assigns comparatively little role to any other factor. By this theory one is well justified to expect that growth rates across different countries would tend to converge on a common steady-state value, and that the actually observed rates would differ only by virtue of transitory differences in the economic position of an economy relative to its balanced growth path

("transitional dynamics"). This prediction seems to receive little confirmation from the available empirical evidence for the world as a whole, which shows little tendency for reduction in the considerable diversity of growth rates among developing and developed countries (see Baumol (1986) and Delong (1988)). Nor is there an apparent tendency for income levels to converge among all countries, although such a tendency is compatible with the thrust of the neoclassical model even allowing for variations in per-capita income due to transitional dynamics (see King and Rebelo's paper in this collection). Convergence of income levels is to be expected especially under the influence of free trade in goods and free mobility of resources among different economies.

In short, the neoclassical model, while offering a powerful framework for analyzing and quantifying the process of economic growth, and despite being consistent with major aspects of the growth experience in developed countries, does not seem to offer a sufficiently effective framework for explaining the growth experience in developing countries, or the differences in the actual growth paths between rich and poor countries.

The principal common denominator of the papers summarized in this monograph is the attempt to relax some of the more limiting assumptions of the neoclassical model with the aim of achieving a richer theory of economic development. In this regard, the conference expands the foundation of the "new economic development" literature begun by Romer (1986) and Lucas (1988). Romer identified the demand for and spillover of disembodied knowledge (research) as a principle source of endogenous growth. Lucas endogenized human capital accumulation through either deliberate and costly acquisition of skills, or learning by doing, identifying it as an economy's underlying catalyst of growth.

The conference's agenda focuses on three principle themes:

a) The analysis of population growth and human capital formation as endogenous to the economy and to the growth process itself. This permits a possible explanation of empirically observed facts concerning the interaction between population, schooling and economic growth in the development process.

b) The interpretation and analysis of technological change as the outcome of decisions influenced by market forces, rather than as a consequence of autonomous scientific discoveries that take place independently of the scope and level of economic activity.

c) The examination of government as a significant player in the growth and development process, possibly as an independent catalyst or engine of growth, but also as an initiator of policies that can have detrimental effects on the economy's growth rate, and not just the level of economic activity.

The first theme is addressed mainly in the papers by Gary Becker and Kevin Murphy, and by Mark Rosenzweig. The second theme is the focus of the studies by Paul Romer and Paul Krugman. The third theme dominates the papers by Robert Barro, Robert King and Sergio Rebelo, Dale Jorgenson and Kun-Young Yun, and S.C. Tsiang. All papers, however, invariably touch upon one or more of the central themes of the conference.

D. IMPLICATIONS OF THE MODELS CONCERNING THE PROCESS OF ECONOMIC GROWTH

Since the different models of endogenous growth summarized in this monograph make different assumptions concerning which parts of the economy are endogenous to the growth process and which are exogenous, and since they also differ in what they identify as the economy's engine of growth, it is not surprising that they reach somewhat different conclusions about the process of development. Certain conclusions, however, are common to all studies.

1. As in the neoclassical growth model, physical capital accumulation, by itself, is not seen as an engine of growth in most models. This is essentially

because output is subject to continuously diminishing returns to the capital input alone. Put differently, changes in the private sector's propensity to save are expected to cause offsetting adjustments in the steady-state capital-output ratio, which increases the level, but not the rate of growth of per-capita income. Consequently, the catalyst of growth is traced to other productivity-augmenting factors: either induced technological innovations of a disembodied form (as in Romer or Krugman) or as human capital accumulation (as in Becker and Murphy or King and Rebelo). Even where technology is identified as the engine of growth, the level of technological innovations is seen to be influenced by the economy's endowment of human capital. One of the striking differences between the new economic-growth literature and the neoclassical model is the shift in emphasis from specific forms of physical capital to human capital as the underlying cause for growth.

The only exception to this rule is Tsiang's model, where take-off into growth requires a savings rate sufficiently larger than the rate of population growth to extricate the economy from a stable "low income trap". However, capital accumulation plays this role during a take-off phase, not along an equilibrium growth path, as Tsiang's formulation does not lead to a steady-state growth path. Also, in Barro's model, where the steady state level of output turns out to be proportionally related to capital, this occurs only because of the effect of taxation and government services. The implicit engine of growth in that model is not private physical capital but complementary public spending that prevents the productivity of privately accumulated capital from falling as the latter accumulates.

2. All papers demonstrate that decentralized economies are capable of reaching a path of persistent growth in personal income and consumption even without exogenous technological innovations. Moreover, the steady-state of persistent

growth can be reached through individuals' responsiveness to incentives to accumulate the asset essential for growth. This idea is inherent in the neoclassical model as well, but it assumes a special meaning in the new growth literature which models the motion of the engine of growth itself as the result of explicit optimization by individuals in a general equilibrium context. Thus, if the engine of growth is parental investment in the human capital of children due to altruistic motives, as is the case in Becker and Murphy's model, persistent growth is assured whenever the discounted rate of return to such investment is sufficiently large. Similarly, if the engine of growth is disembodied knowledge such as scientific research or process and product innovations, as it is in Romer's and Krugman's models, growth is guaranteed whenever the rate of return to innovative activity is commensurate with the rate of return to investment in physical capital. Finally, if government economic services are presumed to be essential for the growth process because of the provision of infrastructure and protection of property rights that are critical for private accumulation of capital, as in Barro's model, self-sustaining growth can be achieved through prudent methods of taxation that simulate the implicit demand of the private sector for such services. In all of these cases, growth takes place even in the absence of "exogenous" i.e., accidental or unanticipated technological shocks, because innovation or accumulation of embodied knowledge occur predictably as a result of individuals' demand for such accumulations. Put differently, a constant rate of technical innovation or investment in human capital obtains in a steady-state not arbitrarily, or by assumption, but as a result of optimizing behavior.

3. One of the striking differences among these models of endogenous growth concerns the possibility of multiple growth equilibria including an underdevelopment or low income trap. This possibility is ruled out in the

general, competitive equilibrium model of Jorgenson and Yun, who adopt a conventional neoclassical framework, and King and Rebelo, who allow for endogenous growth due to investment in human capital. In the models of Tsiang and Becker and Murphy, multiple equilibria exist as a result of specific assumptions concerning the relations between population growth and the propensity to save or invest in future production capacity. In Becker and Murphy's model, where both population and saving and investment in human capital are endogenous to the growth process, however, the existence of a possible underdevelopment or Malthusian trap is not a reflection of classical market failure. Rather, it is the result of constrained optimizing behavior by parents who choose to trade quantity for quality of children, given their specific production and consumption possibilities (in particular, their low level of human capital). Both Tsiang and Becker and Murphy also see the movement from a low-income trap to a perpetual growth equilibrium to require a take-off stage, although for different reasons. In Becker and Murphy the intermediate development state is unstable, and the growth path about it possibly discontinuous, so that the movement to perpetual growth may require a jump. In Tsiang's analysis, the development or low income state is stable so that a strong shock is required to pull the economy in the direction of perpetual growth. In both cases the prospects for take-off may be helped, therefore, by prudent, or "pro-growth" government policies.

E. IMPLICATIONS CONCERNING THE PROBLEM OF DEVELOPMENT

How do the different models explain the observed diversity of growth paths across different countries and time periods? A rigorous, and comparatively easy answer can be obtained when the model produces an explicit solution for the magnitude of the (unique) steady-state growth rate in terms of its exogenous determinants.

In the models identifying induced technological innovations or costly human capital formation as engines of growth, the equilibrium growth rate is shown to accelerate whenever there is an increase in parameters which increase the rate of return to investment in such assets, discounted both for the ease of substituting present for future consumption and for time preference for present consumption. This shows up clearly in the models by Becker and Murphy, Romer, and King and Rebelo. In Krugman's model, the size of the economy and the ease of acquiring temporary monopoly returns on inventions are critical determinants of the rate of return to inventive activity, and thus of the growth rate. Size is important in this context because the costs of invention are independent of output, so that the unit costs of production fall with the size of the market. If the opening of bilateral trade between countries is essentially tantamount to an expansion in the economy's size, it will accelerate the rate of economic growth in both countries. This prediction follows from both Krugman's and Romer's models. Neither model considers, however, the separate influence of specialized trade patterns or the possible difficulty of appropriating monopoly returns under a free trade regime.

It may be difficult to apply some of the previous arguments in explaining the observed diversity in growth rates. Specific productivity differences may not be directly measurable. Moreover, any explanation of diversity that relies on presumed differences across countries in the parameters of disembodied technologies or in preferences for consumption may not be refutable through empirical investigation. A potentially more powerful prediction of diversity is the economy's past and present levels of human capital which are identified as important determinants of growth rates in the models by Romer and by Becker and Murphy. In the latter model, the economy's stock of human capital affects the prospect of attaining a persistent growth equilibrium path, as opposed to

an underdevelopment trap. In Romer's model, the exogenously determined level of human capital directly augments the productivity of resources employed in the production of new designs. By these analyses, countries that are rich in human resources have both better prospects of achieving a persistent growth equilibrium, and experience relatively higher rates of growth. This prediction does not hold, however, in King and Rebelo's analysis because in their model the economy can reach a unique growth equilibrium from any initial level of human capital.

Similarly, the identification of international trade as a potentially important engine of growth may provide an important explanation of the growth experience in trade-oriented economies, which the evidence included in Tsiang's paper tends to support. Krugman's and Romer's models (unlike the one by Lucas (1988)) do not allow, however, for differences in the rates of economic growth across trading partners.

The greatest apparent difference in behavioral implications offered by different models concerns the role of government. These differences arise as a by-product of each model's assumptions concerning externalities or incidents of market failure under free markets. If the mechanics of growth involve external economies stemming from the engine of growth, as is the case in Romer's and Krugman's papers, or if the private sector is incapable of producing essential infrastructure, as in Barro's model, government subsidization of research, support of temporary monopolies, or direct production by the public sector may lead to a socially optimal accumulation of the engine of growth. If a state of self-sustaining growth can be achieved within a competitive environment free of externalities, as in King and Rebelo, however, government taxation of the returns to the engine of growth will have deleterious effects on the growth rate. Even in Barro's model, where government services are essential for augmenting both private production capacity and growth, the beneficial effects

of government production depend on the existence of a benevolent and efficient government: a self-interested government will unambiguously reduce growth and welfare in Barro's model. As to the correlation between the size of government and the economy's growth rate Barro's analysis is compatible with either no systematic relationship, if governments and production technologies are similar across countries, or with a negative correlation, provided that the size of government reflects, in practice, its relative efficiency as a producer and taxes are collected via an income tax.

Alternative hypotheses in connection with the role of government as a catalyst of growth can be tested through empirical investigations of the actually observed relationship between economic growth and specific policy variables. The sophisticated empirical study by Jorgenson and Yun provides some dramatic illustrations. These authors estimate the magnitude of the excess burden from taxation of labor income to be about a dollar per dollar revenue, i.e., at the margin each dollar of government revenues costs two dollars - one dollar for the revenue raised and another dollar due to a welfare loss. They estimate the effects of the 1986 tax act to have raised national wealth in the U.S. by 2.8%, but claim that this gain would have been dwarfed by the potential gains from President Reagan's 1986 tax proposal, in which the tax base would have been largely indexed against inflation. These estimates are derived by applying a general equilibrium model of the neoclassical variety which does not account for the possible effects of taxation on the rate of growth of income per-capita. King and Rebelo argue that the impact of taxes on welfare is much larger in endogenous growth models than in the traditional models of public finance because income taxes, by inhibiting human capital accumulation, depress the rate of growth of economic activity, not just its level.

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SUMMARY OF

GARY BECKER AND KEVIN MURPHY'S "ECONOMIC GROWTH, HUMAN CAPITAL AND POPULATION GROWTH"

Becker and Murphy develop a model of endogenous growth in which both population growth and human capital formation are products of individual choice and where human capital serves as the basic source, or "engine" of growth. Their approach differs from the conventional neo-classical model of growth in which population growth is exogenous to the economic system, and growth in per-capita income occurs as a result of exogenous technological advances. Human capital formation and fertility are determined in this model by altruistic parents who care about their own well being as well as that of their children, and are assumed to have identical preferences in all generations. Also, the human capital attained by each generation of children is assumed to be proportional to their parents' human capital, augmented by the amount of resources parents devote to educating their children. Under these assumptions, a decentralized, free-market economy can achieve a state of self-sustaining growth in per-capita income and consumption.

This conclusion is qualified, however, by the specific set of production technologies and parental preferences governing the growth process. In the more general scenarios considered, the authors conclude that the economy does not have a unique equilibrium state of growth but is susceptible to multiple steady states. They identify three possible situations: a) an under-development equilibrium, or "Malthusian trap", in which there is no human capital accumulation and the rate of fertility is high; b) a development steady state in which the level of per-capita consumption remains constant over time and the rate of fertility is intermediate; and c) a perpetual growth equilibrium in which per capita income grows at a constant rate and the rate of fertility is low. The thrust of the analysis is devoted to the identification

of the specific forces that determine the feasibility and stability of these possible growth equilibria, as well as their special characteristics.

BASIC ASSUMPTIONS

A somewhat simplified description of the basic concepts and assumptions used by Becker and Murphy (BM) will facilitate the summary of their analysis and major propositions. In their economy, each person lives for one period as a child and one period as an adult. At the beginning of adult life, each person has children and invests equally in each child's human capital. The motive is altruistic: parents derive utility not only from their own life-time consumption, c_t, but from the total utility enjoyed by all of their children, n_t. Each generation of parents has an identical utility function

(1) $V_t = u(c_t) + a(n_t)n_tV_{t+1}$.

In equation (1) V_t denotes the parent's total utility, $u(c_t)$ the utility from own consumption (specialized as $u(c) = c^\sigma/\sigma$, where σ is an index of the elasticity of substitution between consumption of successive generations), and V_{t+1} the total utility of each of the children as adults. This specification of altruism thus links parents with all of their future offspring. Parents discount the future utility attained by children, however, at the rate $1/a(n)$, which BM call "the rate of altruism-time preference", and this discount rate is assumed to be increasing in the number of children (specifically $a(n) = \alpha n^{-\epsilon}$, where α and ϵ are positive constants). Put differently, as the number of children increases, each child's utility is valued less by the parents.

Adults allocate their resources (time) between working (ℓ), rearing children (v) and investing in each child's human capital (h). These uses of time exhaust the total time constraint

(2) $\ell + (v+h)n = 1$.

Adults are also assumed to have a fixed amount of unskilled labor, or physical production capacity, $\bar{H}$, and a stock of human capital H_t. Together, they augment the productivity of the time inputs devoted to the production of both consumption goods (real income) and human capital. The respective production technologies are

(3) $c_t = (d\bar{H}+H_t)\ell_t$, for consumption, and

(4) $H_{t+1} = A(b\bar{H}+H_t)h_t$, for human capital formation.

Both technologies exhibit constant returns to the time inputs involved in production. The coefficients d and b in equations (3) and (4) convert raw labor into units of human capital. They represent the relative importance of unskilled labor in the production of consumption and human capital, respectively. In equation (4), the coefficient A represents the productivity of all resources devoted to the production of human capital.

Armed with these assumptions, BM develop alternative scenarios under which an economy can achieve self-sustaining growth.

THE MODEL WITH EXOGENOUS FERTILITY

In this scenario, fertility is outside of parental control. Parents are free, however, to choose their investments in children's education. To simplify matters, BM further assume that unskilled labor plays no role in production (i.e., $\bar{H}=0$ in equations (3) and (4)). Only acquired human capital can thus contribute to earnings or the formation of the next generation's human capital.

The optimal quantity of parental investment in children is set at a level where the benefit from an increment in parental investment time is equal to its marginal cost. The marginal benefit consists of the increase in utility enjoyed by all children due to their higher stocks of human capital, discounted by the parent's rate of altruism-time preference. The marginal cost consists

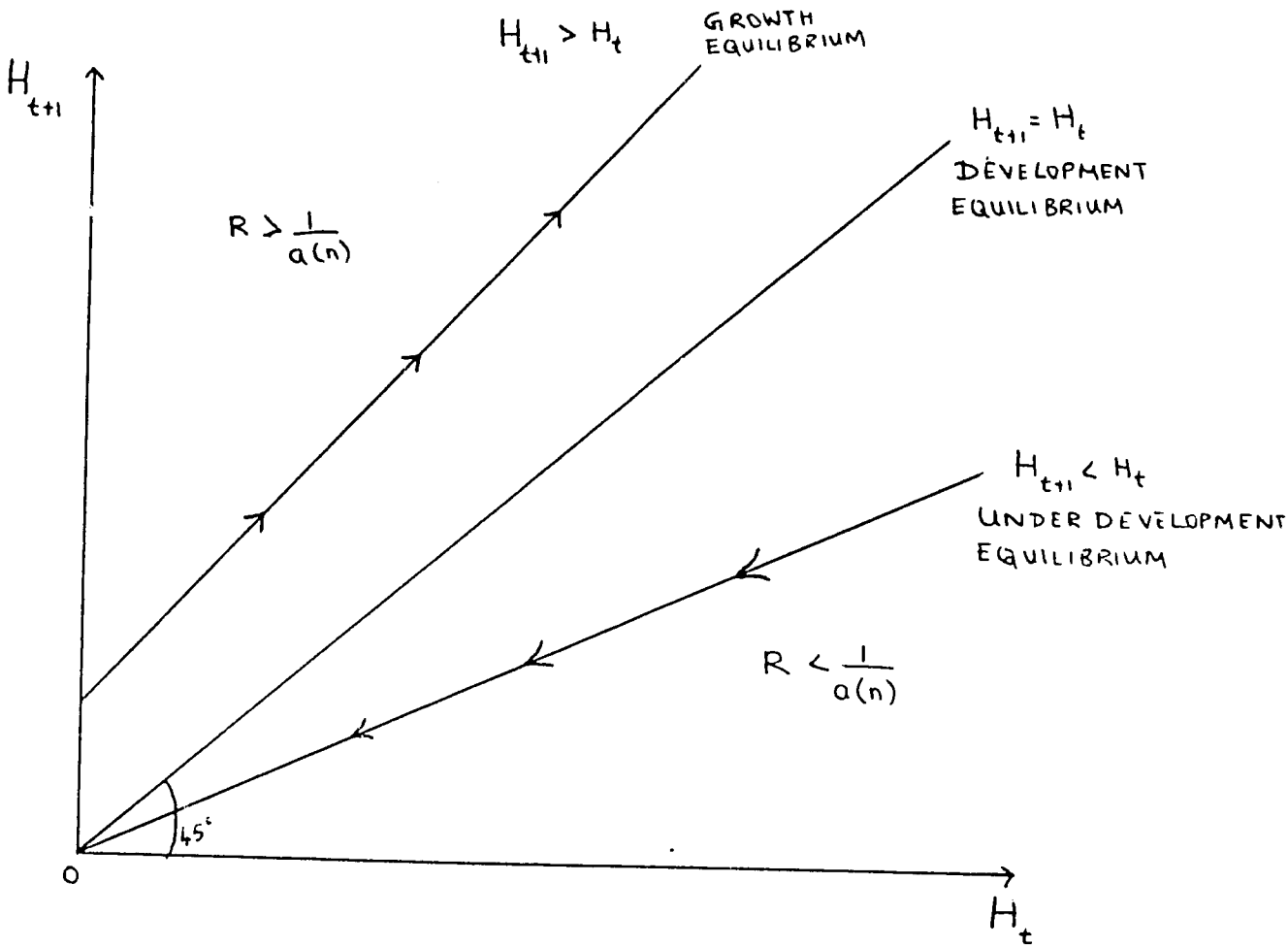

FIG. I. GROWTH PATHS UNDER EXOGENOUS FERTILITY.

of the parent's utility loss due to forgone earnings and thus (own) consumption opportunities. An intriguing aspect of the production technologies assumed in this model is that the rate of return to parental investment time is independent of both the level of a parent's human capital and the amount of time invested per child. This is because the productivity of investment time is assumed to be constant. Also, since human capital augments the marginal productivity of time allocated to both work and teaching (see equations (3) and (4)), an increase in its level raises the marginal benefit and cost of investment by the same proportion. Consequently, the rate of return to investment is found to be a constant magnitude, determined just by the productivity of investment inputs, the unit cost of rearing children, and the (exogenously given) number of children. Formally, $R = [1-nv]A$.

The relationship between optimal investment in human capital and economic growth is established by the rule that the rate of growth in per-capita consumption is related to the rate of return to parental investments, discounted by their rate of altruism time-preference. Formally, the rule is

(5) $R.a(n) = (1+g)^{1-\sigma}$,

where $(1+g)$ denotes the growth in consumption across successive generations (c_{t+1}/c_t). Whether the growth rate, g, is positive, zero, or negative, depends on whether the rate of return to investment, R, is greater than, equal to, or lower than the rate of altruism-time preference, $1/a(n)$. Unlike a perpetual positive or zero growth rate, however, a negative one cannot be a steady state, because it must ultimately lead to a depletion of any initial endowment of human capital. The economy would then wind up at an underdeveloped equilibrium of zero level of human capital. The alternative growth paths and steady states are shown in figure 1.

The reason for the dependence of the growth rate of consumption across generations on the discounted rate of return on investment in human capital is

that the latter determines the parent's incentive to undertake the cost of investment, i.e., to trade own (present) consumption for a higher level of children's (future) consumption. Such trade is also facilitated by a higher ease of substitution of consumption across generations as indicated by σ. Growth in consumption occures strictly as a result of the accumulation of human capital. Indeed, g represents the rate of growth in both per-capita consumption (real income) and human capital across generations.

This analysis demonstrates some of the essential features of the general growth paradigm developed by BM. Economic growth is achieved, technically, because human capital (knowledge) contributes to the production of knowledge by future generations, and its contribution is not subject to any diminishing returns. The specific rate of growth depends, however, on the rate of investment parents are willing to make in their children's education. Under the present scenario, when fertility is determined exogenously, the rate of growth is higher when

a) the productivity of investment inputs, A, is higher;
b) the rate of discount for altruism-time preference, 1/a(n), is lower;
c) the elasticity of substitution in consumption between future and present generations (which is positively related to σ) is higher;
d) the fixed cost of rearing children, v, is lower; and
e) the biologically determined rate of fertility ,n, is lower.

This last prediction holds because the rate at which parents discount the utility of their children's consumption, 1/a(n) is assumed to increase with the number of children in the family. Economies with higher fertility rates are thus expected to have lower growth rates because of the discouraging effect of fertility on the parental incentive to invest in children's education.

GROWTH WHEN FERTILITY CAN BE CONTROLLED BY PARENTS

In this second scenario, the authors assume that parents exercise complete

control over both fertility and investments in children, but maintain the assumption that unskilled labor has an insignificant effect on earnings and human capital formation. The analysis then focuses on the determinants of optimal fertility and its interaction with human capital accumulation in the growth process.

Optimal fertility is reached by altruistic parents at the level where the cost of having an additional child equals its marginal benefit: the utility achieved by the child as adult discounted by the parental rate of altruism-time preference. The marginal benefit from children is negatively related to the number of children because the latter increases the rate at which children's utility is discounted by parents (recall the $a(n)=\alpha n^{1-\sigma}$). The marginal cost of children is an increasing function of the parent's level of human capital since the latter determines the amount of earnings and (own) consumption parents must give up when devoting time to rearing and educating a child. It is also an increasing function of the amount of time they choose to invest in each child's education since this makes raising an additional child more costly to them. Parents' optimal investment in children's education, in turn, is governed essentially by the same set of factors already discussed in the previous section, except that this decision is now made jointly with the fertility choice.

As in the previous scenario, whether the economy grows, and at what rate (g), depends on the product of the rate of return to investment $R=[1-nv]A$ and the rate of altruism time-preference $1/a(n)$. However, since the equilibrium number of children ,n, is now a decision variable, the growth rule must be expressed in terms of the exogenous factors which dictate optimal fertility as well as the optimal investment per child. Formally, the rule is given by

$$(6) \quad Ra(n) = (1+g)^{1-\sigma} = \frac{\sigma Av}{1-\epsilon-\sigma}.$$

The growth rate of per-capita human capital and consumption in a persistent-growth equilibrium again will be higher the more productive are the resources parents devote to investment (A), and the higher the ease of substituting own consumption for the future consumption of children (σ). In contrast to the case of exogenous fertility, however, the growth rate is now higher the higher the cost of rearing a child, (v). The reason is that a higher cost of rearing a child discourages fertility, which lowers the discount rate of future consumption by children. It thus raises the incentive to invest in children's human capital -- the engine of growth in this model.

UNDERDEVELOPMENT TRAPS, ECONOMIC TAKEOFFS, AND STEADY GROWTH

In both of the scenarios developed so far, the economy is expected to reach a steady-state equilibrium within a single generation, starting from any initial endowment of human capital. Both the perpetual growth equilibrium, with human capital formation on a steady rise, and the development growth equilibrium, with a constant level of human capital and zero growth rate over time, can be stable steady states, as is ultimately the underdevelopment equilibrium with zero investment in human capital. The direct reason is that under the assumed production environment, the rate of return to investment is independent of the initial endowments of parental human capital, H_t. The economy can thus adjust its rate of fertility and human capital investments within one generation to reach a steady state. This capacity exists, however, due to the assumption that unskilled labor plays no role in the production of consumption or in education.

Once this assumption is relaxed, (i.e., $\bar{H}$ is assumed to be a large positive quantity in equations (3) and (4)), the model analyzed in the preceeding section produces the striking result that the type of growth equilibrium the economy attains depends crucially on the initial parental

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endowment of human capital. Moreover, the development steady state, where the level of human capital remains constant over time (at H_d) and the rate of growth in consumption is zero, is shown to be an unstable equilibrium: once reached, the economy will either continue on a perpetual growth path or slide back to an underdevelopment equilibrium of zero growth and low per capita income.

Why this critical influence of unskilled labor on the growth prospects? Reaching a steady state of growth means having equal rates of growth in consumption and in the accumulation of human capital across successive generations, or $C_{t+1}/C_t = H_{t+1}/H_t = (1+g)$. However, from equation (4) it is clear that such equality can be achieved only when the ratio of the endowment of unskilled labor to the attained level of human capital $\bar{H}/H_t$ approaches zero, i.e., when H_t is very high. In the short run, as long as human capital formation is still moderate, an increase in its level raises the marginal cost of bearing children relative to its marginal benefit and reduces optimal fertility. The fertility reduction, in turn, raises the rate of return on investment $R_t = [1-n_t v]A$ and lowers the rate of altruism-time preference $1/a(n_t)$, thus generating an increase in the parental incentive to invest in children's human capital. As the attained level of human capital reaches a level commensurate with a development steady state ($H_t = H_d$), the accelerated increase in the discounted rate of return on investment $R_t a(n_t)$ destabilizes the development steady state. Indeed, it is technically possible for an economy approaching a development equilibrium to even "take-off" or leap into a state of perpetual growth. In contrast, an exogenous increase in the rate of fertility around the development steady state may, by the same reasoning, move the economy backwards at an accelerated fashion towards an underdevelopment trap. There is thus a clear negative association between

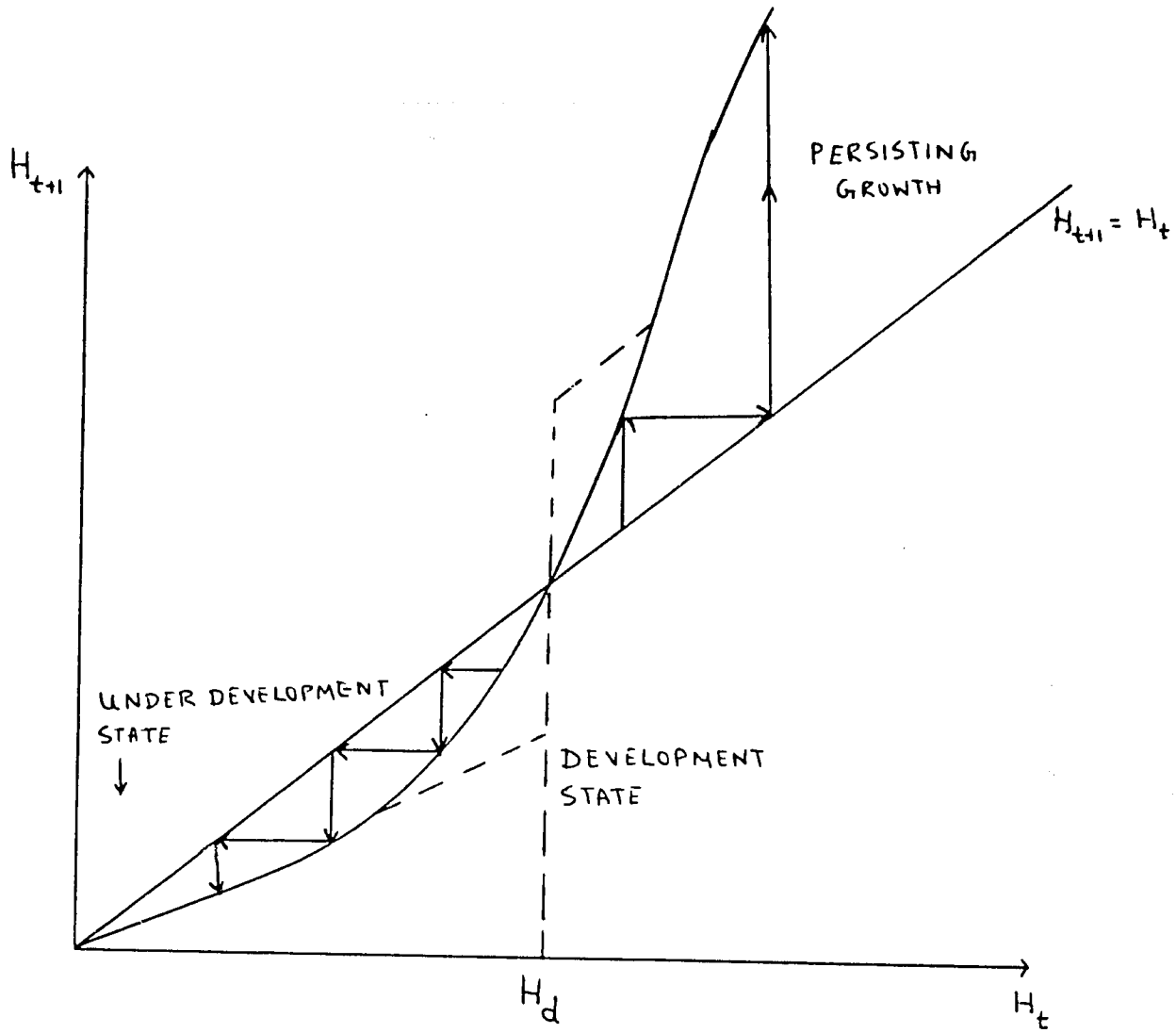

FIG. II ALTERNATIVE GROWTH PATHS

human capital (or economic) growth and fertility growth around the development steady state. Also, the rate of fertility in a perpetual growth equilibrium will be lower than that in a development equilibrium, and that in an underdevelopment (Malthusian) trap will be higher. Whether the economy can attain any of the stable steady states just described depends on the specific set of paremeters governing the production and utility functions of the model (A, σ, v, ϵ). For a wide range of parameter values, however, the outcome depends critically on whether the initial level of parental human capital is lower or higher than the level consistent with the development steady-state (H_d) (see figure 2).

The potential existence of multiple growth equilibria, including an unstable development steady state, is further underscored if unskilled labor is recognized to be more important in the production of consumption goods relative to human capital (i.e., if $b<d$ in equations (3) and (4)). As long as the ratio of unskilled labor to human capital ($\bar{H}/H_t$) is large, a higher initial endowment of the latter would increase the rate of return to investment directly, not just through its discouraging effect on fertility, because it then raises the marginal productivity of investment time relative to its opportunity cost (foregone consumption). Unless the level of human capital becomes sufficiently high to facilitate a steady state growth equilibrium, it would continue to exert a critical influence on whether the economy moves towards a perpetual growth equilibrium or an underdevelopment equilibrium. Also, the direct dependence of the rate of return on the level of human capital accumulation would further destabilize the development steady state.

The major insight into the process of development which these scenarios provide is that the economy's past may have considerable bearing on its prospects for growth. Even if all economies share identical production

technologies and intergenerational consumption preferences, those with historically greater levels of human capital are more likely to attain a perpetual growth equilibrium, or capitalize on temporary changes in productivity to achieve such growth, than economies with historically low levels of skill and knowledge. For the latter, an underdevelopment equilibrium, or Malthusian trap remains a probable outcome.

PHYSICAL CAPITAL AND GROWTH

The proposition concerning the influence of an economy's past on its future growth prospects is further enriched by allowing for the distinct productive role of physical as well as human capital. BM identify the former with fixed natural resources, an endowed technological capacity, or an accumulation of consumption goods (savings) parents bequeath to children.

The central propositions of previous sections remain valid even when the accumulation of physical capital is considered a choice variable for families, along with investments in children's education. To simplify matters, fertility is taken to be exogenously determined in this version of the model. Physical capital is assumed to be subject to diminishing returns to scale in the production of consumer goods and to have no effect on the formation of human capital. As before, the latter is a linear function of parental human capital. Thus, human capital remains the engine of growth in this, more general formulation as well. A positive rate of growth of human capital guarantees a positive rate of economic growth across generations.

A steady rate of growth in per-capita income now requires, however, that physical accumulation also grow at the same rate. In such a state, the rates of return to investment in physical and human capital must be identical. The rates of <u>growth</u> of physical and human capital will be identical, however, only if the production function of consumption goods exhibits constant returns

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to scale in physical and human capital.

An intriguing implication of this model concerns the impact of the destruction of physical capital assets as a result of natural disasters or wars. In the neoclassical growth model, such destruction would be expected to trigger an adjustment in savings that would restore the level of physical capital and per-capita income to its steady state growth path, as long as production technologies or consumption preferences remain intact. In BM's analysis, an exogenous change in physical capital may affect the economy's growth path itself through its effect on the incentive to invest in human capital.

On the one hand, a large decline in physical capital increases the rate of return to savings, and thus its magnitude and the rate of growth of consumption across generations. The increased cost of capital, in turn, will discourage investment in human capital. On the other hand, the increase in savings will also raise the wages of future relative to present generations and hence the return relative to the cost of investment in human capital. Consequently, there will be a net increase in human capital formation if the elasticity of substitution in consumption between future and present generations exceeds unity, or if the elasticity of substitution in production between physical and human capital is less than unity. In such cases, a country devastated by wartime destruction of physical capital does not merely regain its pre-war growth path, but can actually exceed it. This is one explanation BM offer for the post-World War II boom in the economies of Germany, Japan, and the Soviet Union.

CONCLUSION

The authors propose that economies can attain a steady state of persistent growth

even without any exogenous technical innovations as a result of persistent accumulation of knowledge and skills. Parental decisions play a critical role in assuring such accumulation because by contributing to children's education, they can bequeath to future generations an endowment of knowledge that surpasses their own. Parental decisions involve a co-determination of, and trade-off between, quantity and quality of children. The model thus stresses the interaction between population growth and human capital accumulation in the development process.

There is, however, no unique growth equilibrium in this model. It is possible for the economy to reach a stable underdevelopment (Malthusian) trap of no investment knowledge, high fertility rate and low and stagnant income. This trap does not represent a classical "market failure" in BM's analysis, since it is commensurate with an optimal trade-off by parents of quality for quantity of children when the parental level of human capital is sufficiently low. A steady state of perpetual growth with the opposite attributes or a development state of moderate, stagnant income, and intermediate rates of fertility and investments in education are also possible, except that the development steady state is generally unstable.

The possible existence of such alternative steady states of growth constitutes a possible explanation of the observed diversity in the level and rate of economic growth across different economies which the conference on "the problem of development" has focused on as a central issue. The unique contribution of BM's analysis in this regard is the proposition that an economy's initial level of human capital, thus an economy's history, and a variety of past shocks and events such as wars, natural disasters, technological discoveries, and government policies, may determine whether an economy achieves a take off into a steady state of persistent growth or sinks into an underdevelopment trap. The role of prudent government policies is

important especially around the intermediate, unstable development-steady state, where accumulated knowledge is just sufficient to maintain a moderate, stagnant level of per capita income over time.

SUMMARY OF

MARK ROSENZWEIG'S "POPULATION GROWTH AND HUMAN CAPITAL INVESTMENTS: THEORY AND EVIDENCE".

An inverse relationship between fertility rates, on the one hand, and per capita incomes and indicators of human capital, on the other is a striking feature of some recent international cross-sectional and time series studies, but theoretical models of economic growth which incorporate fertility and human capital have offered different interpretations of this correlation. In this paper, Rosenzweig reviews and presents findings from micro-level empirical analyses of international data on the relationship between rates of return from schooling (a proxy for technological advances) and fertility and schooling. An important underlying cause which accounts for the correlations in less developed countries, according to Rosenzweig, is "child labor": the contribution of children's earnings to family income. He tests for the empirical importance of this factor using data from India, the Philippines and Indonesia. He also reviews empirical findings on the importance of health characteristics of the population and fertility control in explaining changes in human capital accumulation.

THE EFFECTS OF ECONOMIC GROWTH ON FERTILITY AND SCHOOL INVESTMENT

A. TECHNICAL CHANGE, RATES OF RETURN TO SCHOOLING, AND FERTILITY: THEORY

In this section, Rosenzweig builds a theoretical model, and derives empirically testable hypotheses concerning the relationships among the costs and returns to schooling, fertility, and investments in the human capital of the children. He assumes that the family's welfare function which parents seek to maximize is given by

$$u = u(i,h,n,y),$$

where i is the average income of children when they become adults, h is the

per-child human capital, n is the number of children and y is a composite consumption good. Parents care about the income of their children, the number of children, and the schooling of each (as represented by h). Human capital in each child is produced with time spent at school, t, purchased schooling inputs, x, and exogenous ability of the child, v. The income of the family consists of the parent's income and children's income when at work (not in school). This income is spent on the consumption good, and on children. The cost of bringing up children includes the cost of schooling inputs, direct costs of having children, and transfers from parents to children. Holding the effect of family income constant, an increase in children's wage increases the opportunity cost of sending children to school and hence lowers schooling levels. Moreover, if family size and the schooling level are pure substitutes, an increase in the child wage rate increases family size. The model therefore predicts a negative relationship between child wage and schooling levels, and a positive relationship between child wage and fertility, after accounting for changes in family income.

Rosenzweig concentrates on a case where parents care only about each child's income, and not about its level of human capital per se. Rosenzweig assumes children pay for their schooling, using their income and transfers from parents. Parents are able to determine, however, the actual schooling and human capital levels of children through judicious use of transfers, b. The actual level of schooling and family size thus reflects the optimal choice from the perspective of the parent.

The benefit from an additional unit of schooling is the product of the rental rate of human capital, α, and the amount of human capital, h, produced by this unit of schooling. Utility maximization implies that this benefit must be equated to the cost of an additional unit of schooling, the child wage rate,

w. The elasticity of schooling with respect to w is therefore equal to the elasticity of schooling with respect to α. Moreover when schooling is wage elastic, increases in α not only increase schooling levels but also reduce family size. This is because if schooling were inelastic with respect to w, then an increase in the child's wage income would decrease parental transfers to children. Lower parental transfers, in turn, lower the margianl cost of children to parents and fertility then increases. This prediction, however, depends on the existence of transfers from parents to children. Many forms of such transfers, including children's schooling, dowry payments, or bequests of land, are indeed common in low-income countries.

The direct cost of bringing up children is incurred by parents regardless of whether the children go to school. According to Rosenzweig's model, therefore, this cost does not affect the parent's optimal investment in their children's human capital. Family planning interventions should therefore have no effect on human capital accumulation since they only affect the direct cost of children. Similarly, the parent's income does not bear on this choice, if the choice is made efficiently.

B. ESTIMATES OF CHILD WAGE EFFECTS

Using data from India, Philippines and Indonesia, Rosenzweig tests the predictions of the theoretical model about the effect of changes in child wage rates on schooling and family size. In all three countries, he finds that fertility is higher and schooling lower in areas where the child wage rate is higher, as the theory predicts. However the elasticity estimates in all three countries show that child wage elasticities are small whereas adult male wage elasticities are significant in predicting a positive relationship between schooling and adult income. The model's hypothesis concerning what constitutes an efficient choice of schooling by parents is therefore rejected: parents seem to care about the schooling of their children as well as the latter's income.

C. THE INDIAN GREEN REVOLUTION EXPERIMENT

To assess whether the magnitudes of the child wage elasticity estimates are consistent with the time-series evidence on the effects of technological change (via increased returns to schooling), on schooling and fertility, Rosenzweig uses data on the "Green Revolution" in India during 1961-71. During the "Green Revolution" period, new agricultural techniques were made available only to a select number of districts (IADP districts) providing spatial variations in key variables. Wage growth in these districts was substantially higher than in other districts over this period. Moreover, within these districts, farmers with higher levels of schooling were found to be significantly more likely to adopt the new technology.

Rosenzweig's empirical analyses show that contributions of schooling to family income were higher at each schooling level in these districts. Moreover, comparing the pre and post "Green Revolution" cumulative fertility experiences of comparably aged women across IADP districts and non-IADP districts, he finds that in 1961 the average number of children ever born to women aged 25-34 was about one-third higher in IADP districts, but by 1971 it was almost equal across IADP and non IADP districts. This implies that there were significantly greater declines in cohort fertility in IADP districts where technological advance occured.

A similar cohort comparison of primary school attendance showed that the proportion of men with no schooling fell slightly more in IADP areas relative to non-IADP areas. Technological advance therefore led to substantial reductions in fertility and contributed to increased human capital investments, without direct family planning interventions.

Although the author's theoretical model predicts that schooling is unresponsive to adult income, he finds that an increase in adult male wage, by

itself, increases schooling, when other exogenous variables, such as return to schooling remain unchanged. The model's hypothesis of efficient schooling allocation is therefore rejected.

CONSEQUENCES OF CHANGES IN THE COST OF FERTILITY

A. BIOLOGICAL ASPECTS OF HUMAN REPRODUCTION

For many family planning advocates and demographers, imperfect information about the biological aspects of reproduction is the principal reason for high fertility levels. To test this hypotheses, Rosenzweig adds a reproduction function which has as its basic explanatory variables the amount of resources used to control births, and an exogenously determined number of births that would occur if there were no fertility control. He then includes the number of children in the human capital production function as an additional explanatory variable to incorporate the notion that an inefficiently controlled family size will by negatively related to the investment of human capital per child. Lowering fertility then directly benefits children, provided that other parental behavior is the same.

The higher is the per-unit cost of fertility control and the less efficient fertility control resources are, the higher is fertility. If parents are ignorant about fertility control techniques, the efficiency of fertility control is low and hence fertility will be high. Also, if fertility and human capital of children are substitutes (and parents are ignorant about family planning techniques), human capital per child will be low when family size is high.

B. IMPERFECT FERTILITY CONTROL AND FERTILITY: EVIDENCE

Rosenzweig tests the hypothesis that the inability of couples to control fertility is a principal cause of low levels of investment in human capital in low income settings, and that the dissemination of birth control information

would encourage human capital accumulation. He analyzes the various methods by which such a hypothesis could be tested:

1. A survey could be used to determine the number of unwanted births. This information, however, is collected "ex-post" and hence may be a function of unrealized expectations. The willingness to bear "excess" children will itself depend on the net cost of children, and it is likely to be correlated with economic circumstances.

2. One might estimate the effect of variation in the cost of contraception on human capital investments. Studies following such an approach show only small such effects, but the data they use are unconvincing since the cost of contraception depends partly on government programs for fertility control which may be established where the demand for such control is highest.

3. One could exploit the "natural" experiment associated with the variability in fecundity in the human population, i.e., the number of births that would occur without any fertility control. Two methods have been used to measure fecundity a) comparing the behavior of couples experiencing multiple births to those not experiencing such births to obtain unbiased estimates of "excess" births or b) comparing couples with a twin on the first pregnancy to other couples. Couples experiencing a twin on their last (planned) pregnancy cannot adjust their family size no matter what the cost of contraception. These methods require large sample sizes, however, since very few couples have multiple births.

In an earlier paper Rosenzweig and Schultz used detailed information on contraceptive use and conception and a different approach to measure "fecundity". By that approach, the difference between a couple's actual number of births and the one predicted on the basis of their use of fertility control is considered to be the number of births that is beyond the couple's control.

Using data from the United States and Malaysia, they found that in both countries, variations in fecundity was found to account for a small portion of the variability in actual births. This suggests that little of the variation in fertility is due to factors outside of the couple's control.

Based on studies by Rosenzweig and others in three low-income countries, an estimate was obtained of the effect on children's schooling attainment of an exogenous increase in fertility by one birth. All these studies confirm that contraceptive control is not perfect, and that the inability of parents to perfectly control fertility lowers, on average, the human capital of children. The estimates obtained from these "natural" experiments suggest that improvements in contraceptive technology that reduce completed fertility by one child would have non-trivial effects on human capital investments.

The author also finds on the basis of data from Colombia and Malaysia that the weight of children at birth (an important determinant of infant mortality) and the spacing of children do not seem to affect human capital investments very much. Biological aspects of fertility do not seem to have any important consequences for human capital accumulation.

CONCLUSION

In this paper, Rosenzweig derives several predictions about fertility and human capital accumulation and tests their empriical validity. His model predicts: a) a positive relationship between child wage rates and fertility and a negative relationship between child wage rates and level of schooling, and b) schooling, if obtained efficiently, should be invariant to the direct cost of having children, including fertility control and parental income. After conducting different "natural" experiments to test these predictions Rosenzweig concludes that there exists a positive relationship between child wage rate (a determinant of returns to schooling) and fertility and a negative

relationship between child wage rate and schooling levels, in accordance with the theoretical predictions. However the study rejects the hypothesis that schooling is determined efficiently by parents given the model's specification of parental objectives. He also finds that the cost of fertility control and the biological characteristics of fertility have a rather trivial effect on human capital accumulation.

SUMMARY OF

PAUL ROMER'S "ENDOGENOUS TECHNOLOGICAL CHANGE"

Romer argues in this paper that the economic growth of wealthy countries over the several past decades is too fast to be attributable to growth in labor hours, physical capital and human capital alone, but should be ascribed, in part, to changes in "disembodied" technology: i.e., the set of instructions and designs used to combine raw materials into final goods and services. For example, between 1950 and 1979, Japan increased total output by a factor of 10, but a six fold increase in output per hours worked remains unexplained even after allowing for increases in the labor force, capital stock and education.

Growth models since Solow's work in 1957 have focused on technological change as the primary "engine of growth", and most have assumed that technological change is exogenously given and unresponsive to changes in economic incentives. Romer extends Solow's model to incorporate explicitly a research or design sector that develops new technologies and is responsive to changes in relative prices, which may be caused, for example, by taxes or subsidies. In Romer's model the engine of growth consists of increasing returns to scale in the research or design sector, combined with constant returns to the number of intermediate goods used in the production of final goods. Romer suggests that the availability of skilled human resources capable of creating new designs affects the growth rate of technology and thus the equilibrium growth rate of the economy. He also demonstrates that in his model, as is the case in Solow's model, policies which promote capital accumulation affect only the level of economic activity, not its rate of growth. Romer argues finally that growth is accelerated by policies that promote the development of new technology, and by participation in international trade, since trade increases the skilled human resources

available for employment in the research sector.

THE ECONOMY

The economy has stocks of physical capital, human capital (training, education, skill, etc.), labor, and a set of designs or instructions. The flows of services from physical capital, K, from human capital, H, from labor, L, and designs, A, are used in the production of various intermediate and final goods. Unlike physical capital and designs, human capital is embodied in a person and only its services can be bought and sold. Since Romer assumes human capital is distinct from labor, human capital can be thought of as educated workers, and labor as uneducated workers, and both types of workers make up the representative family. Romer assumes that the amounts of L and H available to the economy are fixed.

In Romer's economy, production of new designs requires inputs of both human capital devoted to research, H_2, and the existing stock of knowledge, A. Specifically, the economy's output of new designs, or the addition to knowledge, $\dot{A}$ is the product of these two inputs, multiplied by δ, a factor that affects productivity: $\dot{A} = \delta H_2 A$. For any given amount of A, the number of new designs is proportional to the amount of human capital used. Returns to scale, however, are increasing in the sense that if both A and H_2 are doubled, A will quadruple.

To produce an intermediate input of type i requires one design. With this one design any amount of the intermediate good can be produced using a constant amount of physical capital, K, per unit. All types of intermediate good technologies require the same amount, η, of physical capital per unit of the intermediate good. The technology for the intermediate good production, given that one design has been purchased, is $x(i) = K_i/\eta$ for all i, where x(i) is the amount of intermediate good of type i, η is the amount of physical capital

required per unit of output, and K_i is the amount of physical capital used in producing x(i).

The final good is produced using the different types of intermediate inputs x(i), labor L, and human capital devoted to production H_1. The technology for producing the final good Y is given by a modified Cobb-Douglas function

$$Y = H_1^{\alpha} L^{\beta} \int_0^{\infty} x(i)^{1-\alpha-\beta} \, di$$

where α, β, and $1-\alpha-\beta$ are positive constants, and x(i) is the amount of each intermediate good. This technology exhibits constant returns to scale in that doubling the amounts of all inputs, including each intermediate good, doubles output, and it has diminishing returns to increases in the amount of any one input separately. However unlike the traditional neo-classical technology, output is proportional to the number of intermediate inputs in use. If the range of i over which x is positive doubles, while the quantity of each x(i) in use is held constant, then output also doubles.

THE MODEL

The economy consists of households and three competitive production sectors: a design-producing sector that engages in research and development, a sector producing intermediate goods, and a sector producing final goods.

The many identical households are endowed initially with fixed stocks of labor and human capital, and physical capital which may grow with savings, and they own the firms in all three production sectors. Households earn income from the provision of labor and human capital services to the firms, and from interest on capital, and use their income to purchase the final good, which may be either consumed or saved and used as physical capital. Households decide how to allocate their human capital between the final goods sector and the research sector, and how much of their income to save or consume.

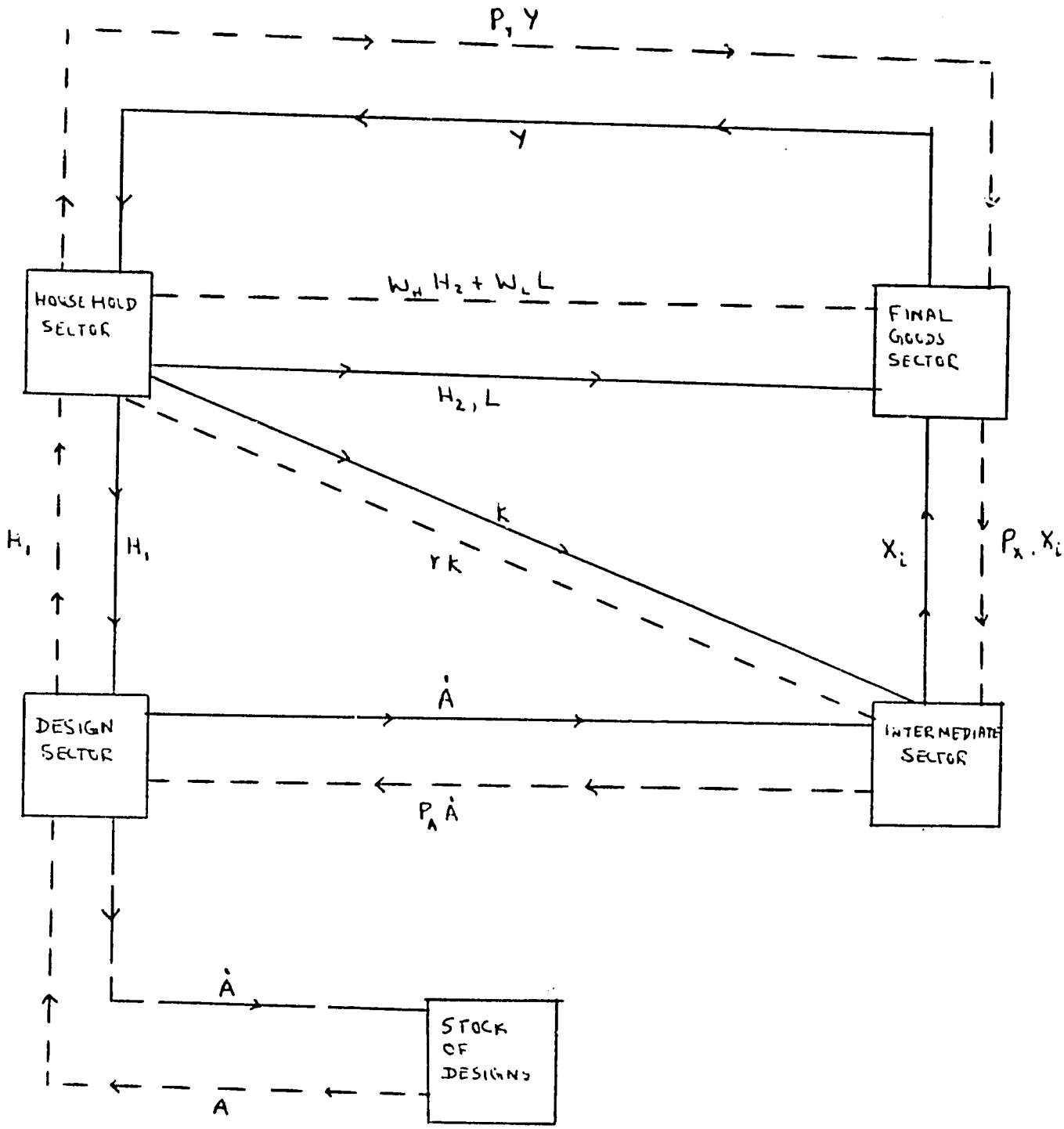
$P_1 Y$
Y
HOUSEHOLD SECTOR
$W_H H_2 + W_L L$
FINAL GOODS SECTOR
H_2, L
K
rK
H_1
H_1
X_i
$P_x . X_i$
DESIGN SECTOR
$\dot{A}$
INTERMEDIATE SECTOR
$P_A \dot{A}$
$\dot{A}$
STOCK OF DESIGNS
A

DIAGRAM I

The structure of this economy is described in Diagram 1. In the diagram, the short dotted lines indicate the flow of payments for inputs and outputs, while the solid lines are the flow of goods and inputs. The long dotted lines indicate how the flow of new designs increases the existing stock of designs available for use in the production of new designs. In the design sector many firms purchase human capital services, H_2, from the households, and use them to create new designs, which are then sold to the producers of intermediate goods. The market for creating new designs is characterized by increasing returns to scale and is subject to an externality. Returns to scale in the production of new designs are increasing in that if both the number of existing designs and human capital services in research double, then the number of new designs produced increases four-fold. The productivity of human capital in the production of new designs, δA, is independent of the amount of human capital employed but is proportional to the stock of existing designs A. The externality arises due to the assumed non-appropriability of the right to use an existing design in the production of a new design. Thus at any point in time the stock of existing designs, A, is freely and immediately accessible to anyone who wants to create new designs, and this benefit is external to the firm which created the design. To maximize profits each firm in the research sector decides how much human capital to employ, taking as given the price of new designs, and the wage rate for human capital. With a large number of firms engaged in research, each earns no economic profits in the competitive equilibrium.

Romer assumes that firms in the intermediate goods industry buy new designs from the research sector, and use them and some physical capital to produce intermediate goods, which are sold to the final goods sector. The purchase of a new design which is necessary to produce any amount of one

intermediate input is a cost which is fixed after the firm makes the decision to produce the new intermediate good. With declining average total costs, only one firm produces each type of intermediate good, and it is assumed to be able to exercise monopoly power. Specifically, each intermediate good producing firm takes the price of designs and the interest rate as given while deciding when to buy a new design or to begin production of a new intermediate good, and what price to set for the intermediate good in order to maximize profit. However, the many sellers of similar intermediate goods competitively bid up the price of the designs they purchase and the interest rate, whenever profits are positive, and thereby prevent any positive economic profits. Thus in equilibrium, each firm's profit maximizing output earns revenues over operating (capital) cost just equal to the interest charge of the design.

In the final goods sector, firms produce final goods to be sold to households, using the set of available intermediate goods, and labor and human capital. Firms take as given the price of their output, and employ profit maximizing amounts of labor, human capital and each of the intermediate inputs. Competition in the output market implies that firms earn zero profits.

These various production relations can be combined to express the production of final goods in a "reduced form". Using the idea that each intermediate good requires one design, and that the quantities produced of all intermediate goods are equal, final output is

$$Y = H_1^{\alpha} L^{\beta} A\bar{x}^{1-\alpha-\beta},$$

where $\bar{x}$ is the amount of output of each intermediate good in production and A, the number of designs, is also the <u>number</u> of intermediate goods. Since for given A, the total amount of capital required in production is $K=A\bar{x}\eta$, the final goods production function becomes

$$Y = H_1^{\alpha} L^{\beta} A[K/\eta A]^{1-\alpha-\beta}, \text{ or equivalently}$$

$$Y = \eta^{\alpha+\beta-1}(AH_1)^{\alpha}(AL)^{\beta}(K)^{1-\alpha-\beta},$$

In this, "reduced form" specification of the final goods production function, A appears as a type of technological change which augments both labor and human capital.

Equilibrium in this economy corresponds to a path of prices and quantities which satisfy the following conditions:

a) Consumers mal e savings and consumption decisions taking interest rates as given, and allocate their human capital between final goods and the research sector.

b) Final good producers take the output price as given and choose input use such that for each input, the value of the marginal product equals the price of the input.

c) Firms producing intermediate goods maximize profit, taking the interest rate, the price for designs and the demand curve for their outputs as given.

d) Firms producing designs employ human capital such that its wage equals the value of its marginal product, taking for granted the wage of human capital and the price of designs.

e) Supply equals demand for all goods.

f) Profit is zero in all production sectors.

BALANCED GROWTH EQUILIBRIUM

Romer examines the properties of an equilibrium called the balanced growth path because the stock of designs, the stock of physical capital and final output all grow at the same rate, g. Restricting his attention to this growth path he derives the equilibrium prices and quantities using conditions from the optimizing behavior of the agents in the different sectors, and also the condition that supply equals demand.

Since Romer assumes a design technology such that the growth rate of new designs is proportional to the human capital employed in the design sector, the growth rate is constant if the allocation of human capital to designs is constant.

Mobility of human capital ensures that human capital wages and hence

productivity, are equal in the two sectors using human capital: the design sector, using H_2 units, and the final goods sector using H_1 units. Romer's design technology and final goods technology are such that the marginal products of human capital in each sector are proportional to the number of designs, A, and the number of intermediate goods, respectively. As a result, as A grows the productivities of human capital in the two sectors grow at the same rate, and the wage for human capital also grows at that rate. Thus an allocation of human capital which equates its productivity in the design and final goods sectors in one period, equates human capital productivities in all periods. In a steady state of blanaced growth therefore, H_1 and H_2, remain constant over time.

Since final goods production is proportional to the number of intermediate goods, A, final goods output must grow at the same rate as A.

Household preferences are assumed to be of a form, whereby utility maximization implies a constant interest rate, given a constant rate of growth of consumption.

Capital is employed only in the intermediate goods sector, so $K=A\bar{x}\eta$, and K and A must grow at the same rate. Finally, the definition of consumption as income less savings implies that along the balanced growth path consumption relative to income is constant. Therefore, the growth rate of consumption equals the growth rate of income and of capital.

Profit maximizing behavior among intermediate goods producing firms implies, for a given interest rate, r, a profit maximizing output $\bar{x}$ for each intermediate good, and so a profit maximizing margin π between current revenue and current operating expenses. Competition among the intermediate goods producing firms means that they will bid down to zero the profits from producing a new intermediate good. In equilibrium, the difference between

revenue and operating costs, given profit maximization, must equal the interest cost on the price of the design: $\pi = rP_A$. Since the interest rate was shown to be constant, and the production of each of the intermediate goods is also constant, the price of the new design must be constant.

Thus in the balanced growth path, all prices are constant and output, capital, consumption, and the number of designs all grow at the same rate g.

THE DETERMINANTS OF GROWTH

Given the mathematical forms of the production technologies and household preferences, Romer can solve explicitly for the equilibrium balanced growth rate,

$$g = \frac{\delta H - \Lambda\rho}{\Lambda\sigma + 1},$$

where $\Lambda = \alpha/(1-\alpha-\beta)(\alpha+\beta)$, ρ is the rate of time preference, and σ is a parameter denoting the intertemporal elasticity of consumption. The factors influencing growth are discussed below. Determinants of the growth rate which are of particular interest are the stock of human capital, H, and a parameter δ for the productivity of human capital in the design sector.

The rate of economic growth in the balanced growth equilibrium is higher the greater the stock of human capital, because any increase in the total stock of human capital increases the allocations of such capital to each sector. More human capital in research implies a greater number of new designs created, more new intermediate goods produced, and thus faster growth in the economy. As a result, if an economy were opened to free trade with another identical economy, the increased amount of human capital in this integrated world implies that more human capital would be devoted to research, since both economies use the same number of intermediate goods and designs, and both economies would grow at a higher rate, as a result of the higher rate of induced technological innovation.

A key parameter in the growth process is δ, which determines the productivity of human capital in design for a given stock of knowledge, A. The greater this productivity level, the greater is the growth rate of designs for any level of human capital employed, and the greater the growth of the economy.

The growth rate does not depend on the labor supply and hence population growth cannot increase the rate of growth of the economy. Similarly, any changes in the capital stock affects only the level of economic activity, but not its rate of growth.

The rate of growth attained in a competitive equilibrium is not the highest achievable, since new designs have both internal as well as external benefits. Creators of new designs receive payments only for the internal benefit, and therefore they produce less than ideal numbers of new designs.

Subsidization of research, if financed by lump-sum taxes, allocates more human capital to the research sector and less to final goods production, and so implies faster growth. No welfare conclusions are possible however, without analyzing the transition path from one steady state to another. In this economy, a government subsidy for physical capital formation does not change the growth rate, which depends on the level of human capital and not on the level of physical capital. However, a subsidy of physical capital will raise the level of economic activity, if financed by lump-sum taxes, since the increase in savings and capital formation increases the level of output produced per person.

CONCLUSION

In this paper Romer studies the causes of economic growth by introducing a research sector that creates new technologies in response to economic incentives. His model shows that diversity across countries in their rates of economic growth could be explained by differences in the skilled human

resources available to develop new technologies or in the types of government policies affecting the research sector or the formation of skills. The long run rate of economic growth is shown to be independent of taxes or subsidies on the formation of physical capital. An analysis of the impact of an expansion of the market shows that the gains from participating in a larger market include faster balanced growth rates.

SUMMARY OF

PAUL KRUGMAN'S "ENDOGENOUS INNOVATION, INTERNATIONAL TRADE AND GROWTH"

The neo-classical model of economic growth has identified technological advances as a major source, or engine of economic growth, but treated their incidence as a product exogenous to the economy. Some recent attempts at making technology an endogenous part of the growth process, according to Krugman, have treated innovations as "an accidental by-product of economic activities undertaken for other processes". In this paper Krugman adopts a "Schumpetarian approach" to explain the occurrence of innovations and to derive insights about its basic determinants, impact on growth, and welfare implications. The basic incentive for innovation, by this approach, is derived from temporary monopoly profits to the innovating firms in the period following their inventions, before the latter are adopted by competing producers. Although the temporary monopoly achieved by the innovators causes a static economic inefficiency, because of the distorted allocation of resources, this is a price worth paying in the context of Krugman's Schumpetarian analysis, because it results in the economy's achievement of ultimate dynamic efficiency, i.e., a higher level of per capita consumption than would be achieved without innovation. A major implication of Krugman's model of endogenous innovation is the importance of free international trade, since international integration, by expanding the size of the market, enhances the incentive to innovate, and therefore accelerates economic growth as well as world-wide economic development.

THE ECONOMY

Krugman's economy is comprised of N goods and a fixed population of L identical individuals who live through three "relevant" periods. In the first

period, the economy is competitive and firms must decide whether to undertake innovative activity. In the second period, each firm that innovates enjoys an exclusive monopoly over (the use of) its superior technology, and thus earns monopoly profits. In the third period these monopoly gains dissipate as the improved technologies become public goods and are shared by producers of the same goods. Individuals possess one unit of labor in each period and spend the income they earn on N different consumption goods. Their preferences are such that their spending is divided equally among these N goods in any given period (technically, this is because all goods have unitary income elasticities of demand).

The N goods are produced in N different sectors by a large number of firms. Given competition among the many producers of each good, and constant production costs, the price of each good equals the unit cost of production. Assume that labor is the only input required to produce these goods. The unit labor requirement to produce each good depends on whether any investment has been made in improving the technology. Without any such investment the unit labor requirement for producing each good is 1. With investment in technological improvement, the unit labor requirement is a fraction of that cost, γ, (where γ is greater than zero but less than 1). No other investments are possible.

In the first period, all firms produce using the technology that has a unit labor requirement of 1. Labor in this period can be used to produce goods for current consumption or to invest in innovation. These investments require F units of labor in the first period. Firms which invest in such innovation in the first period will have a superior technology in future periods and will consequently need to employ only γ units of labor per unit of the good. Firms which do not invest in innovation possess the old technology in the second period, but in the third period may freely copy the innovation for their own

use. Hence in the second period, only innovating firms which have a temporary monopoly over the new technology produce, and these have a per unit cost of γ units of labor. In the third period, the new technology becomes common property, and all firms in sectors where innovations occurred produce with a per unit cost of γ units.

INTERTEMPORAL EQUILIBRUIM

Suppose that there were innovations in n sectors in the first period. These improved technologies will be available to all the firms in these n sectors in the third period. Hence the economy in the third period will consist of n sectors where the unit labor requirement is γ, and N - n remaining sectors where the unit labor requirement is 1. Given the model's assumption, under competition prices must equal the unit (labor) cost of production. Hence, the price of goods in the n innovating sectors will be γ units of labor while in the N-n remaining sectors, where there are no innovations, the price will be one unit of labor.

In the second period, in the n sectors where innovations occurred, the new technology is available only to the innovating firms, thus allowing them to establish temporary monopoly positions. Since in each one of these n sectors there is a large number of firms which produce if the price is not less than their per unit cost of 1 dollar, the monopolist innovator in each sector can produce at a per unit cost of γ units of labor and sell each unit at a price just less than 1 unit of labor. The difference of $(1-\gamma)$ units of labor is the per unit rent received by the monopolist. Monopolists in these n sectors charge the same price as others even though they possess a more efficient, less costly technology. None of the gains from this innovation is passed on to the consumers in the form of lower prices. If there were no monopoly power and the improved technology became common property in the second period, the price

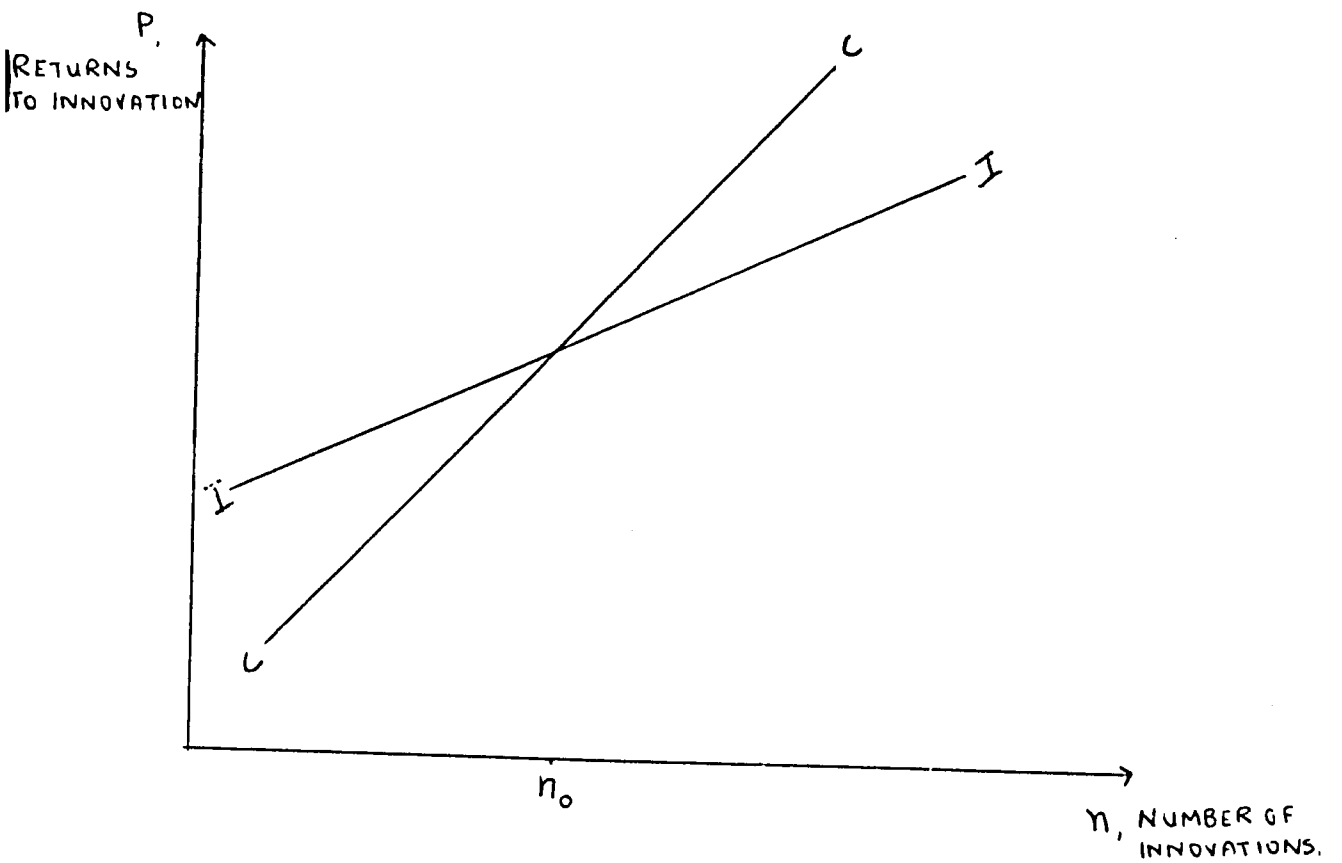

FIGURE I

65

would be reduced to γ units of labor and consumers would receive the benefits instantaneously.

In the first period, firms must decide whether to innovate. If a firm decides to invest in innovation it has to spend F units of labor in the first period. However, it receives a rent of $(1-\gamma)$ per unit sold in the second period. The incentive to innovate is therefore generated by the rent the firm receives in the second period. As long as the total discounted rent is larger than the cost of investing in innovation, the firm has an incentive to innovate. The model further predicts a relationship between the return on a dollar invested in innovations and the equilibrium number of innovations (i.e., the number of sectors in which innovations take place).

Since the rent constitutes additional income that is spent on additional consumption of all goods, the greater the amount of innovations, the larger is consumption and hence the market for <u>each</u> good. The rate of return to innovation then increases. This relationship between the return to innovation, P, and the volume of innovation, N, is shown as curve II in Fig. 1.

The return on investment in innovation must provide sufficient compensation not just to producers but to consumers as well, since optimal intertemporal allocation of consumption is achieved when the return on investment in "capital" (here taking the form of innovation) equals the marginal tradeoff between present and future consumption. In Krugman's analysis, the latter tradeoff -- the opportunity cost of investment in innovation in terms of trading present for future consumption -- increases with the volume of innovations, n, because as n increases more resources must be diverted from present consumption to the production of innovations. Hence the return on innovations necessary to compensate consumers, P, must be an increasing function of the volume of innovations, n, and this relationship is represented by the upward sloping CC curve in Fig. 1.

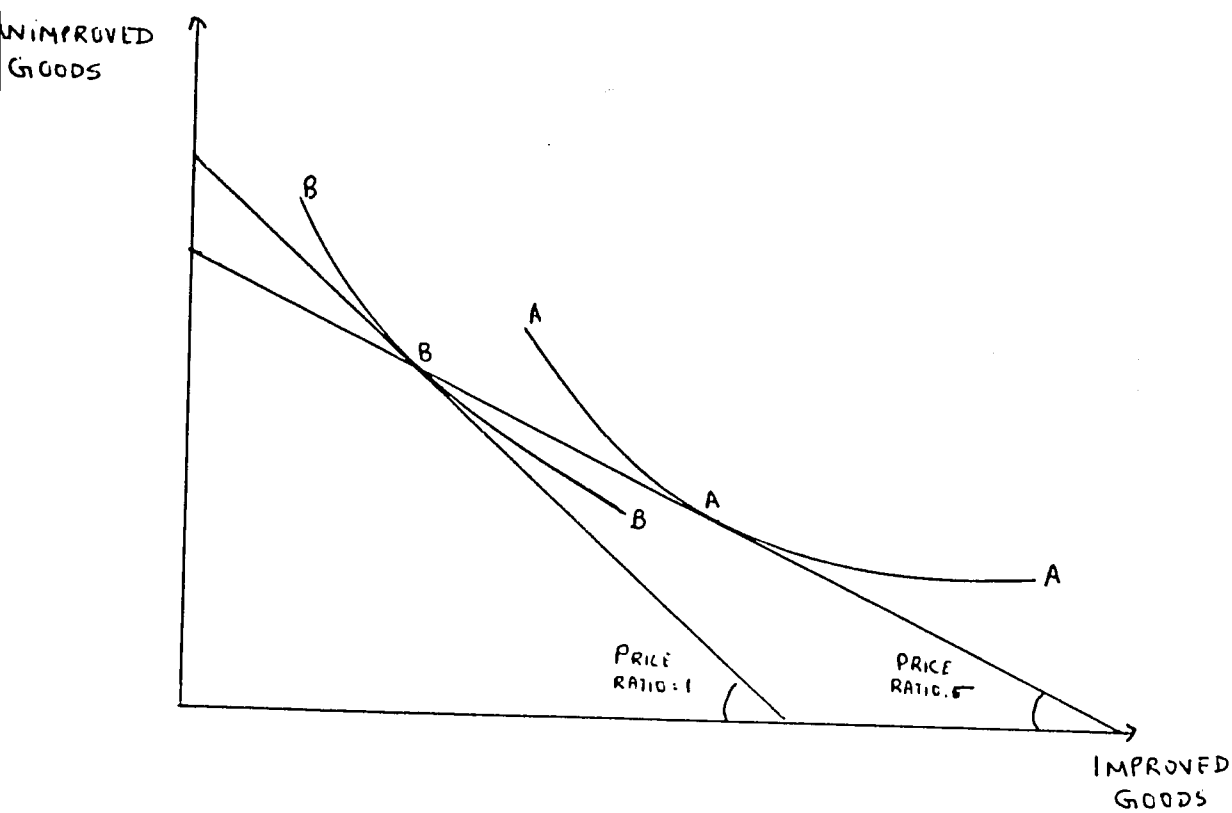
UNIMPROVED GOODS
B
A
B
A
B
A
PRICE RATIO: 1
PRICE RATIO: .5
IMPROVED GOODS

FIGURE II

From Fig. 1, the equilibrium volume of innovation occurs at a level in which the curves II and CC intersect, i.e., where the marginal return to producers equals the return required by consumers for trading present for future consumption. As long as the return required to induce consumers to release resources to innovation is initially lower than the returns achieved by producers from innovation (invention activity would take place, resulting in a positive amount of innovating industries n_o).

WELFARE ECONOMICS OF MONOPOLY

Recall that in Krugman's model the incentive to innovate is created by the existence of temporary monopoly power for the innovating firm. As is generally the case under monopoly, its profit maximizing decisions result in inefficiency, since the price that consumers pay does not reflect the real cost to society, and hence there is underproduction in the commodity controlled by the monopolist from a social point of view. However, in this model these costs of monopoly are shown to be outweighed by the benefits from monopoly-induced innovations, so that the temporary monopoly does more good than harm.

Krugman analyzes the welfare implications of monopoly-inducing innovation. There are n sectors using an improved technology in the second period, while N-n sectors use the unimproved technology. In the production of the improved goods the unit labor requirement is reduced to γ units while for unimproved goods the unit labor requirement remains 1 unit. The Production Possibility Frontier (PPF) in Fig. 2 shows the maximum possible amounts of the improved and unimproved goods that can be produced given the technology and the available resources. If there were no monopolies in the improved goods sectors, consumers would face a relative price γ and could have consumed the bundle A. However since the monopolies operating in the improved goods sector charge a price of 1 rather than γ unit of labor for these goods, consumers purchase an

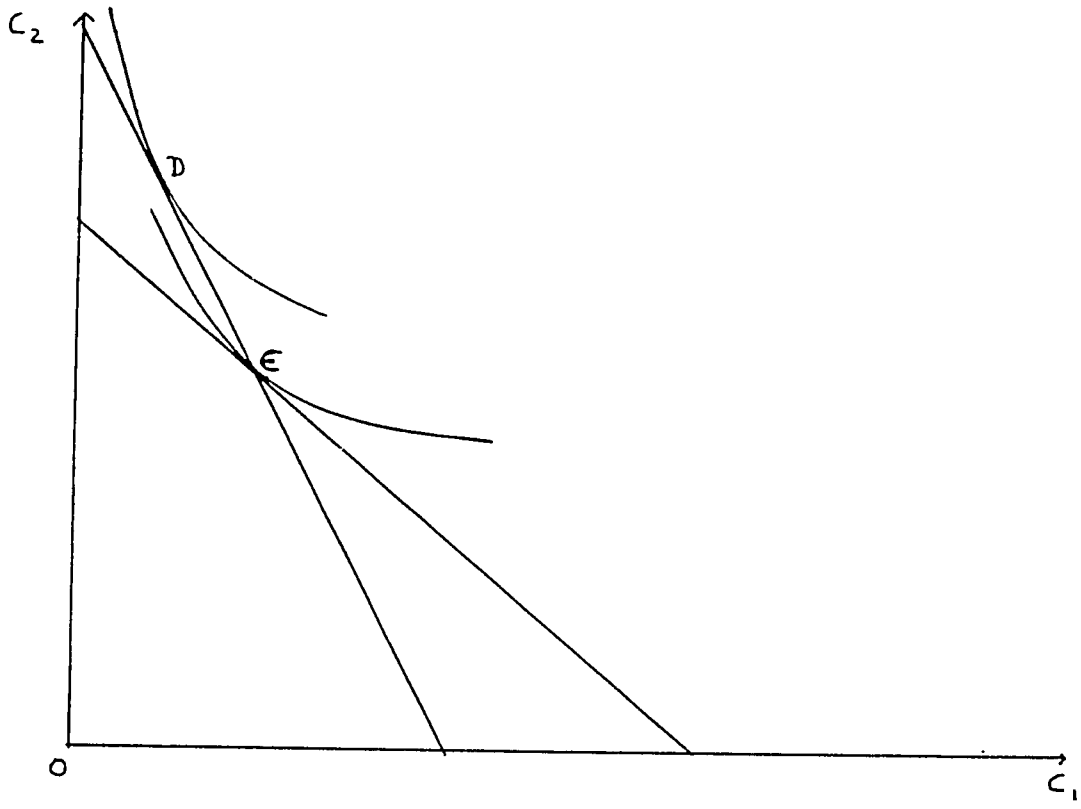

FIGURE III

inferior consumption basket represented by B. If monopoly power was disallowed but innovation somehow took place, the consumption bundle at A would have been attainable. However, with monopolies, the economy can achieve only the inferior bundle at B. This analysis illustrates the static efficiency loss to the economy in the second period due to monopoly.

Krugman first considers the intertemporal allocation of consumption across the first two periods. During these two periods, the price of consumption of any good in terms of labor is 1. Each individual is endowed with one unit of labor every period and since storage of goods is not possible, each consumes one unit of the good in each period if innovations do not take place.

This "endowment" point is denoted as E in Fig. 3. C_1 and C_2 in that figure denote the amounts of consumption in the first and second period, respectively. If innovation takes place, then it must be true that the return on innovation is larger than the cost in terms of postponing consumption. It must therefore be possible for individuals to trade their initial endowment for a superior consumption basket at D. By reducing present consumption, C_1, and investing in innovation they are able to increase their future consumption by an amount that more than compensates them for their sacrifice in postponing consumption. The economy is therefore better off with the monopoly-induced innovation.

This two-period gain is not the total gain to the economy. In addition to the second period gain, the innovation becomes public property in the third period so that all the firms in the n improved sectors produce at the lower cost of γ labor units. The economy is able to consume the bundle A in Fig. 2 since there is no monopolization from period 3 on and the improved technology is available to all. Monopoly power which occures as a result of innovation helps rather than hinders social welfare.

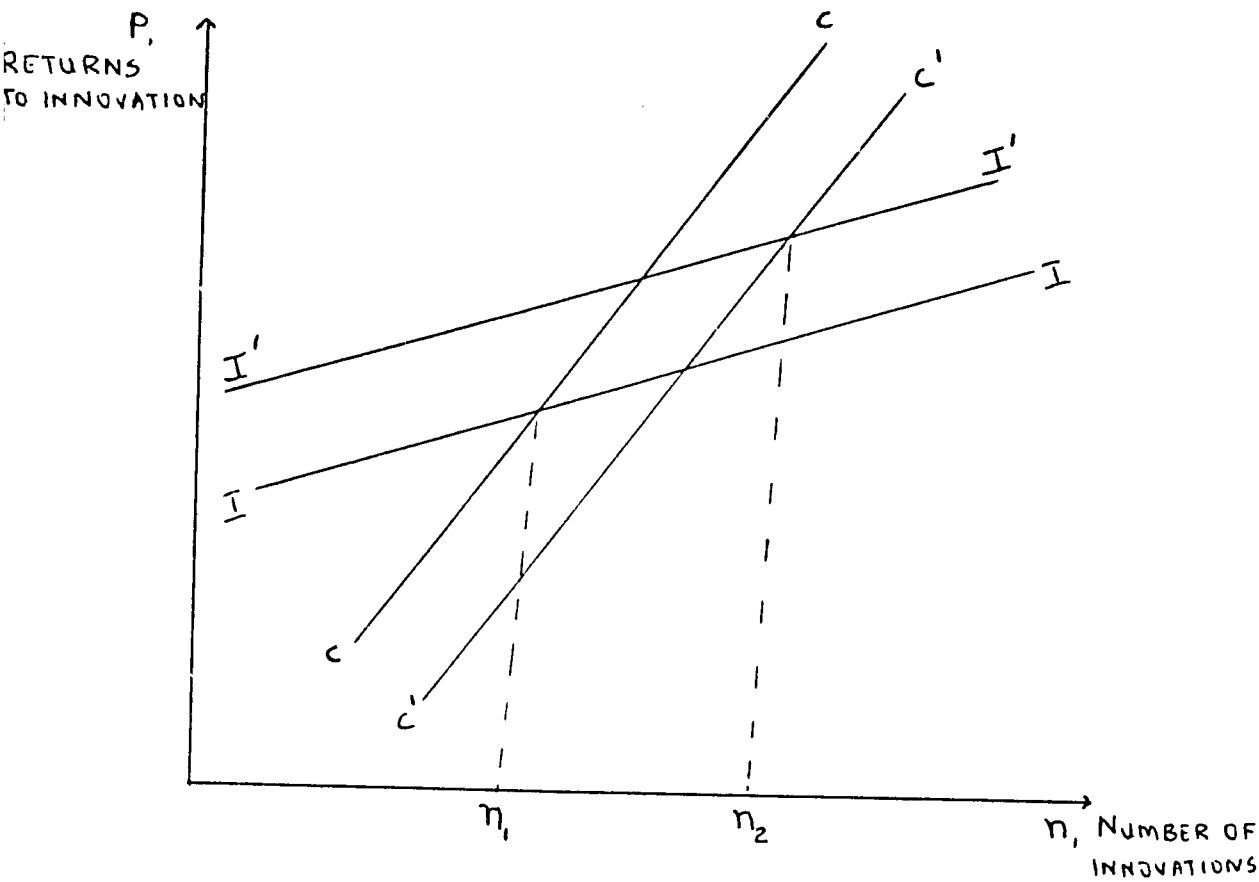

FIG. IV. THE EFFECT OF INTEGRATION.

71'

INTERNATIONAL INTEGRATION

What is the effect of free trade on innovation? Krugman addresses this question by considering a world with two countries which are identical in tastes, original technology and innovation costs. He shows that opening both countries to free trade has a positive impact on the total number of innovations. Assume that the temporary monopoly power granted to an innovating firm in one country extends to the entire world. On the one hand, the II curve which depicts the relationship between the number of innovations and the producer's return to innovation will shift up to I^1 I^1 in Fig. 4. Free trade expands the size of the market and the monopolist is thus able to generate a larger rent by selling more units than would have been possible with a closed economy. On the other hand, the cost per person is smaller, since the fixed cost per innovation of the F units of foregone consumption in the first period is spread over a larger population. This shifts down the CC curve which depicts the relationship between the cost of foregone present consumption and the number of innovations, to C^1 C^1 in Fig. 4. The number of innovations per country in an integrated world economy is higher, at n_2, than the number of n_1 under isolation. Since the number of innovations is larger, consumers are necessarily better off under an integrated world economy.

LONG TERM GROWTH

Krugman's model so far has included only 3 rigidly defined periods. He also considers a situation of continuous growth where for a particular industry, innovation, monopolization and diffusion of innovations occur simultaneously. Consumers still allocate equal shares of their income in every period to consuming the N goods. Innovation requires an investment of F units of labor and lowers unit labor requirement to γ units in subsequent periods. At every point in time, there are n firms spending F units of labor on

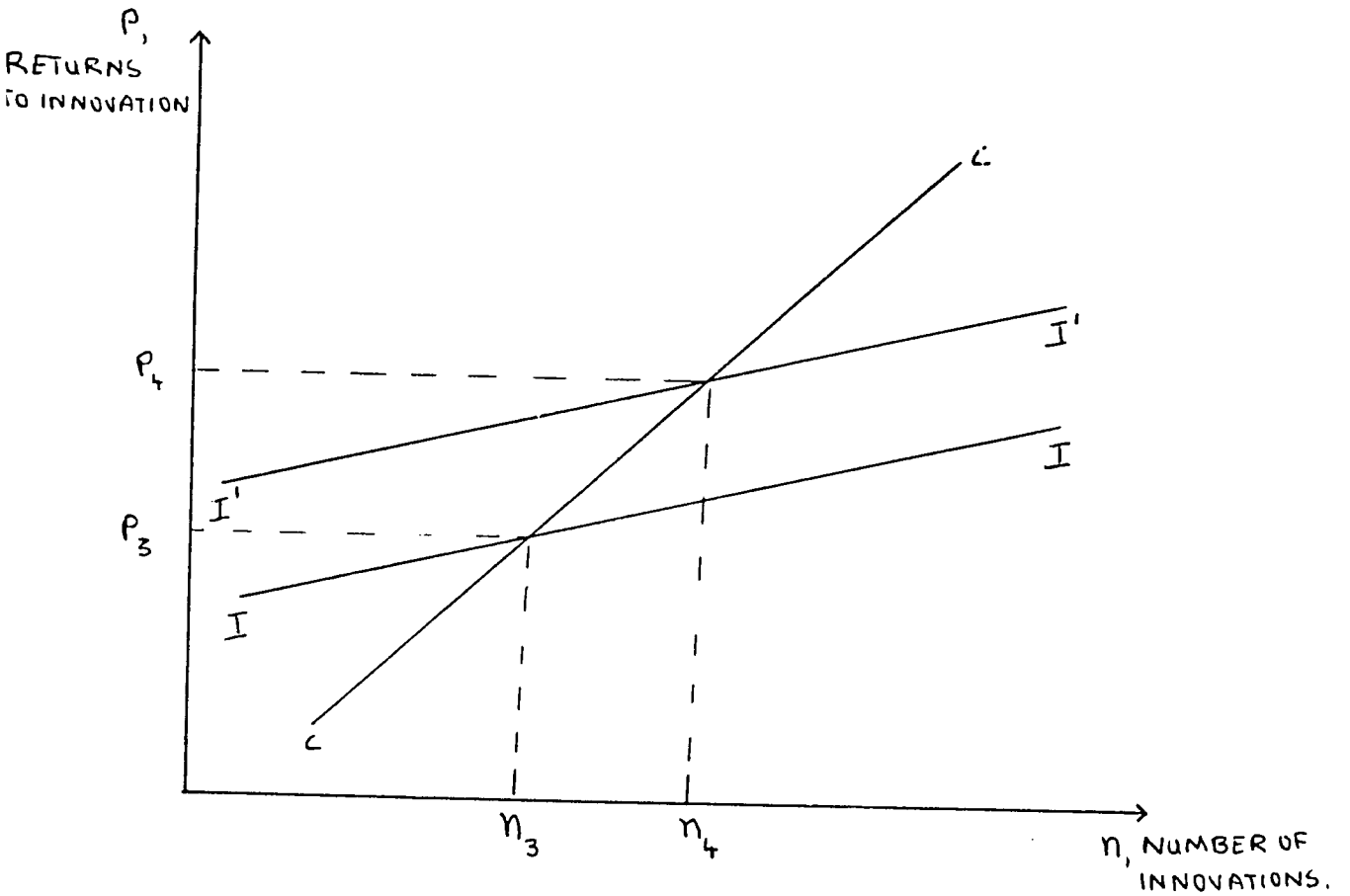

FIG. V THE EFFECT OF INTEGRATION WHEN INNOVATIONS OCCUR IN EVERY PERIOD

innovation, there are n goods where one firm has an improved technology developed in the previous period, and there are n goods where an innovation which took place two periods before is now public property.

A steady state in such an economy is described as one where innovation takes place every period in n sectors. In such a steady state the rate of growth of consumption as well as the real wage rate will grow at a steady rate. As in the earlier model, it is possible to obtain a CC schedule with the property that the higher the rate of innovation, the higher is tomorrow's consumption relative to today's consumption, and hence the higher is the rate at which the sacrifice in today's consumption for increased future consumption must be valued. This is depicted by CC in Fig. 5. Similarly the producer's return to innovation as a function of the volume of innovation is depicted as II in Fig. 5. A fraction of the sales in every period is collected by the monopolists in that period as rent. However since the real wage rate is rising, labor next period is more costly than labor this period, and consequently, the real rate of return to innovation is now lowered. The II curve can still be depicted as an upward sloping curve, however, as long as a one percent reduction in present production brings forth an increase in future production larger than one percent. In this diagram n_3, p_3 and n_4, p_4 denote the equilibrium rate of innovation and the rate of return before trade and after trade, respectively. An increase in the size of the economy due to free trade will again result in a shift of the II curve to I^1 I^1 since more labor is available. The CC curve will now remain unchanged, however, as the market size increases, unlike the situation in the earlier analyses. Previously, innovations took place just in the first period, and hence an increase in the population of consumers due to trade reduced only the fraction of first period resources that must be sacrificed for investments in future consumption. In this version of the model, however, innovations occur at the

same rate every period, and thus an expansion of the population reduces the fraction of resources that must be diverted towards innovation in all periods. Consequently, the rate at which present consumption is traded off for future consumption remains unchanged.

CONCLUSION

Following the Schumpetarian analysis of the process of innovation, Krugman argues that innovations take place as a result of the force of incentives introduced by temporary monopoly gain to innovating forms. Such temporary monopoly power benefits the economy because by facilitating innovate activity it results in a higher level of future income and consumption per-capita. Krugman takes this idea one step further by identifying induced technological innovation as an engine of growth. In his analyses, a steady-state rate of innovative activity results in a stready-state rate of economic growth. Therefore economic conditions that affect the level of innovation affect the rate, not just the level of growth.

One such condition is the free trade among nations. International integration, by increasing the size of the market for inventions, encourage the rate of innovations beyond its level in a closed economy, and this induced innovative activity generates additional gains from trade. Policies that allow temporary monopoly power through patent rights, which remain in force over a limited time period, and policies that encourage free trade are therefore beneficial to economic growth.

SUMMARY OF

ROBERT KING AND SERGIO REBELO'S "PUBLIC - POLICY AND ECONOMIC GROWTH: DEVELOPING NEO-CLASSICAL IMPLICATIONS"

King and Rebelo examine the power of the neoclassical growth model associated with Robert Solow to explain the key facts of economic growth, and explore in detail the quantitative implications of alternative tax policies in their own model of endogenous growth, using a series of computed examples. The authors claim that the neoclassical model, which has as one of its basic inferences the prediction that rates of economic growth would converge across countries over time, is inconsistent with the observed facts. Moreover, the path along which economies actually move toward a steady state according to that model has implication for magnitudes of economic variables that are inconsistent with Kaldor's stylized facts covering the process of development. They point out that the neoclassical model can offer no explanation of persistent differences in growth rates of income per capita, because it assumes that the source of such growth, technological change, is exogenous to the model.

Models of endogenous, steady state growth have been developed recently by Rebelo, and King and Rebelo here explore the welfare and policy implications of such models. In these models, endogenous growth occurs because the production of a final good is assumed to have constant returns to scale in reproducible inputs, i.e., physical and human capital, and hence increasing returns in these inputs and labor together. They show that in general the effects of taxes on economic activity and welfare are several times greater than in the neoclassical model, because in the latter, government policy, by assumption, affects only the level, but not the rate of growth, of economic activity.

STYLIZED FACTS OF ECONOMIC GROWTH

The authors review new data about some of the generalizations concerning economic growth and development which Kaldor called stylized facts when he first presented them almost 30 years ago. They claim that the variance in real per capita income growth is quite high: since the Second World War, some countries have achieved annual growth rates of almost 6%, while others have declined at about 1% annually. In addition, longer run data show little evidence for any secular decline in growth rates among industrialized countries. The relation between the size of government and the rate of economic growth is negative, but is especially sensitive to the sample period in question: the correlation is essentially zero from 1950 to 1969 but is -.33 from 1970 to 1981. Finally, the authors present abundant evidence, from the U.S. and other countries, to show that the interest rate has remained approximately stable over long periods.

COUNTERFACTUAL IMPLICATIONS OF THE NEOCLASSICAL MODEL

King and Rebelo (henceforth KR) criticize the basic neoclassical model associated with the work of Robert Solow by arguing that it can not be reconciled with the observed diversity of economic growth rates among different countries without either 1) assuming different, exogenously given rates of economic growth, or 2) generating counterfactual implications about real interest rates, prices of capital, or international capital flows.

They present a version of the neoclassical growth model in which the only sustainable growth rate for income, investment and per capita consumption, arises from an exogenous, labor augmenting technological change. They also assert that the per capita incomes of different countries should converge to the same level. The countries which are initially poorly endowed with capital must grow faster in order to catch up, so this "catch up" growth implies a

negative correlation between the initial level of per capita income, and the rate of growth of per capita income. The fact that this correlation is not observed in the data is sometimes interpreted as a strong criticism of the neo-classical model, but the authors argue that this criticism is unconvincing because the neoclassical model can be reconciled with a diversity of growth rates if countries differ not only in their initial endowments of physical capital, but also their technologies, preferences and public policies. They argue, therefore, that the neo-classical growth model cannot be rejected without a more complete evaluation of its properties in light of the historical data on economic growth.

KR analyze the implications of the neoclassical model for interest rates, assuming that all growth in income per capita results from the accumulation of capital, and not from a change in the exogenous technology. They consider first a Cobb-Douglas production function which has constant returns to scale in the use of the two traditional inputs, physical capital and labor.

(1) $Y = AK^{\alpha_k}N^{1-\alpha_k}$

Output is denoted by Y, capital by K and labor by N. The overall productivity is measured by A, and the exponents, α_k and $1-\alpha_k$ are the output shares of capital and labor respectively. KR solve for capital use as a function of interest rates by assuming that labor's share $1-\alpha_k$, is 1/3, and that capital is paid the value of its marginal product. Substituting this expression for capital into the per capita production function, $Y/N = AK^{\alpha_k}N^{-\alpha_k}$, and assuming that per capita income now is seven times greater than one hundred years ago, King and Rebelo compare the interest rate today with the rate predicted by the model for the period one hundred years ago, assuming that technology, A, has not changed. The prediction is that the real rate 100 years ago should have been almost 800% per annum, if the appropriate real rate today is 6.5%, and if the rate of depreciation of capital is 10%. Since interest

rates of this order of magnitude have never been observed, they argue that this implication is counterfactual and that therefore the neoclassical model should be rejected, in that its transitional dynamics can not be the main source of growth in real world economies.

KR consider several alternative parameterizations of the neoclassical model which differ from the baseline case just presented. Provided that the values for capital share, depreciation and current interest rates are chosen to reflect the data accurately, values for early interest rates are less than 50% per annum only if transitional dynamics are assumed to account for less than 25% of growth, and increases in technology for at least 75%. An alternative production function, which allows different elasticities of substitution between capital and labor, is shown also to imply that either initial interest rates are too high, or that capital's share of output grows in a manner contradicting one of Kaldor's stylized facts.

The authors continue to explore the implications of the neoclassical model by specifying preferences so that the paths of all prices and quantities in competitive equilibrium can be calculated. They assume first that preferences are such that the elasticity of consumption is constant, and as a result, interest rates are constant for a constant rate of growth of consumption. Using numerical methods to solve the system of two nonlinear first order differential equations which describe the growth of the economy, they compute values for the real interest rates, capital growth and output growth for the different periods. As in the baseline case where interest rate changes were calculated without regard to preferences, interest rates are extremely high, greater than 125% on average, during the first five years. Lower intertemporal substitution in consumption implies lower economic growth in early periods but even more implausible interest rates. Changing the form of preferences so that they are

Stone-Geary, i.e., consistent with a subsistence consumption level, implies that interest rates in early periods are even higher than in the other models considered.

To investigate whether the adverse implications for the behavior of real interest rates are a consequence of the one-sector nature of the models under consideration, KR also consider the implications for interest rate behavior in a two sector model, where the sectors differ in the intensity with which each uses the factors of production. In an exercise which parallels the baseline case described above, the authors show that the only way to get plausible values for the early interest rates is to assume that the share of capital in the capital sector is .9, i.e., there are almost constant returns to capital. Since this is inconsistent with abundant data that the share of capital is less than .4, they conclude again that the implications for interest rates are strongly at odds with the facts.

Modern investment theory has postulated that one reason that capital does not adjust instantaneously to its optimal, long run value is the existence of adjustment costs which may be positively related to the growth rate of the capital stock. In the analysis of adjustment costs, an important ratio, dubbed q by James Tobin, is the stock market valuation of capital relative to its cost of replacement. With positive adjustment costs, this ratio may be greater or less than one but has rarely been estimated to exceed 2.0. The introduction of adjustment costs into the model implies that initial interest rates are much lower, but that q in initial periods is at least 13, and hence a value that is strongly at odds with available data.

KR also consider the implications of these numerical results for economies that engage in international trade. The seven fold difference between US per capita income today and one hundred years ago is comparable to the difference between per capita income today in the US and in poor developing countries.

Given the seven-fold difference in per capita income levels between rich and poor countries today, and assuming that different countries have the same level of technology, the model predicts international differences in interest rates so large that enormous international capital flows should result, and these would nearly instantaneously eliminate the differences in per capita income.

KR conclude, therefore, that it is impossible to explain observed patterns of growth by the transitional dynamics of the neoclassical model without generating false implications for the behavior of key endogenous variables such as interest rates, the ratio q, or the share of capital. If, however, the diversity in growth rates is not a consequence of transitional dynamics then it can be explained in the neoclassical model only by assuming whatever particular pattern of exogenous growth rates is necessary to explain the facts, and this amounts to assuming the very pattern they are trying to explain.

POLICY AND ENDOGENOUS GROWTH

The authors point out that in the traditional neoclassical model, growth occurs either through transitional dynamics, shown above to be unimportant empirically, or through technological progress occurring at a rate exogenous to, and independent of, relative prices and government policy. Such a model is a particularly inappropriate environment in which to address either positive questions about why some countries grow so much more slowly than others, or normative questions about what types of government policies might serve to encourage faster growth.

They argue that the variable A denoting technological efficiency is in fact dependent on formal education, on-the-job training, basic scientific research, product development, innovation in systems and management, etc., and that all of these components of technology respond to prices, incentives, and changes in government policies. If these components of technological progress

could be summarized by a single composite variable, called human capital, then a key decision in the growth process is the rate of accumulation of this variable.

The authors extend earlier work and develop a growth model in which human capital, a determinant of efficiency, may be produced using labor and physical capital. They illustrate the economic implications of such a model in a series of environments in which the number of variables which are endogenous to the system is increasing, and in which several assumptions about the nature of technology are successively relaxed.

INDIVIDUAL HUMAN CAPITAL ACCUMULATION

Drawing on earlier theoretical work by Sherwin Rosen and Gary Becker on the microeconomics of the accumulation of human capital, KR show that if both the rate of return to human capital investment and the wage rate are exogenous to the representative individual, then the efficient allocation will be characterized by complete specialization. Investment in human capital occurs by taking some wage income and spending it, e.g., through schooling, on human capital production, with investment being either positive or zero, depending on whether the wage rate is greater or less than the net return on investment to human capital.

Specialization in human capital production is not observed in aggregate economies, so to ensure that the model's assumptions do not result in specialization, King and Rebelo modify the problem of investment in human capital to include adjustment costs, so that the capacity to grow at any point in time is diminishing in investment. Their assumption about human capital formation is

(2) $H_{t+1} = \theta(I_t/H_t)H_t + (1-\delta)H_t$

where H_t denotes the human capital stock at time t, $\theta(I_t/H_t)$ is a

function denoting the adjustment costs, and δ is a parameter denoting the depreciation of human capital. The function θ is assumed to have a positive slope in I/H which decreases as I/H increases, so that investment is increasingly less efficient as investment grows relative to a fixed human capital stock.

The authors solve the household's problem of selecting an optimal path of investment in human capital in order to maximize utility, assuming that there are some costs of adjustment of raising the stock of human capital, that the wage rate for labor is proportional to the stock of human capital, and that efficient capital markets permit the household to borrow against future earnings at a given interest rate. They show that the optimal rate of human capital growth depends on the wage rate relative to the price of human capital, the real interest rate, the rate of depreciation of human capital, and the specification of adjustment cost.

PRODUCTION STRUCTURE & A SMALL OPEN ECONOMY INTERPRETATION

The authors explore the implications for growth of an economy identical to the one in III.1 above, except that it produces two outputs, which may be traded internationally. The production of each output is characterized by constant returns to scale in both labor (in efficiency units) and capital. The first output is a commodity good, and the second is gross investment in human capital production. Physical capital in each sector is assumed to grow with investment and to decline with depreciation, and the economy-wide investment in any period must equal total savings, or the amount of the commodity good which is not consumed.

Considering first the implications of static efficiency, KR show that the tax rates on capital and labor inputs in this two-sector model influence the price of human capital.

GENERAL EQUILIBRIUM DETERMINATION OF INTEREST AND GROWTH RATES

In a general equilibrium model, the effects of tax policies depend upon assumptions about preferences, in addition to the assumptions about technology which were all important in determining growth rates in the earlier section. The general equilibrium can be interpreted as depicting either an economy that does not trade with the rest of the world, or the world economy as a whole. Given a particular form of preferences and the maximization of household utility a relation exists between the growth rate of consumption and the interest rate. The relation is

(3) $\beta g^{-\sigma} = 1/(1+r)$,

where r is the real interest rate, g is the growth rate of consumption, β is the rate of time preference; and σ is a parameter denoting the ease of substitution of current consumption for future consumption.

POSITIVE IMPLICATIONS OF TAXATION FOR ECONOMIC GROWTH

The authors use numerical methods to explore how the growth rates of this general equilibrium model respond to alternative specifications and assumptions about technology and preferences, and to different types of taxes.

Two different production activities are specified. The inputs in both activities are capital, and labor measured in efficiency units, NH, where N is the number of worker hours and H is the stock of human capital. The first sector produces a good which can be either consumed, or saved and invested as physical capital. The second sector produces an investment good, I_H, which can be used only to accumulate additional human capital. In both sectors returns to scale are constant in the use of physical capital and number of workers alone, and increasing in the use of physical capital, and labor measured in efficiency units. In addition, returns to scale are constant in

the use of the two reproducible factors of production: physical capital and human capital. The assumptions guarantee the continuous, endogenous growth in the model.

The assumed technologies in both sectors have the property that the proportional increase in one input required to keep output constant after a hypothetical decline of the other input is constant. Both sectors are subject to proportional taxes on sectoral output, and the proceeds from these taxes are redistributed in a lump sum manner. The employment of labor and physical capital in the two sectors is constrained not to exceed the available stock of these inputs.

The growth in physical capital from one period to another depends on the depreciation of previously existing physical capital, and the investment, or savings from the output of the first production sector. The growth of human capital similarly depends on the depreciation of pre-existing human capital, and on investment in new human capital. KR use the assumptions about adjustment costs developed earlier, which imply that the returns to investment in human capital goods are diminishing at any point in time. As a result, it is never optimal to specialize solely in human capital production or in final goods production.

KR conduct their simulation studies using a benchmark case marked by parameter values which they claim are chosen to reflect available data as closely as possible. Accordingly they assume that labor's share of income in sector one is 2/3, that the intertemporal elasticity of substitution in consumption is 1, that the steady state real interest rate is 6.5%, and that the depreciation rate of physical capital is 10%. The adjustment cost function is assumed to be quite linear. If adjustment costs were negligible then the function $\theta(I/H)$ in equation (2) should coincide with I/H.

Since there is considerable uncertainty about the measurement of the

output and inputs of sector 2, which produces the human capital investment good, the authors explore at some length the implications of different assumptions for the technology of this sector, and argue that the particular assumptions made have little bearing on their conclusions regarding tax policies.

(4) $I_H = A_2 K^{\alpha_k} (HN)^{1-\alpha_k}$.

The effects of alternative tax policies on the steady state rate of economic growth are presented using a series of computed examples, assuming human capital depreciation is 10%, so that the minimum feasible economic growth is -10%. Tax policies are in the form of levies proportionate to the outputs of each of the sectors, and the proceeds are assumed to be rebated in a lump-sum manner. (Thus, if tax rates are negative, the rebates amount to lump-sum taxes). Assuming that labor shares in each sector are 2/3, and that the technology parameter accounting for total factor productivity in the production of human capital, A_2 is .0834, the endogenous growth rate rises from -2.3 to 2.9 as the tax rate imposed on each of the two sectors falls from 50% to -10%. Since the benchmark case was defined with parameters such that the endogenous growth rate was 2%, both tax rates are then assumed to be zero. If the tax rate on sector 2 output is kept equal to zero, while the tax rate on sector 1 output declines from 50% to zero, then the growth rate grows from 0.19% to 2%.

In another series of calculations, labor's share in the human capital sector 2 is increased to 90%, and the parameter A_2 is changed to .0918 to ensure that the benchmark case still generates growth equal to 2%. In this case, as the tax rates in both sectors decline from 50% to -10%, the endogenous growth rate rises from -1.2% to 2.8%. If the tax rate on the human capital sector is kept constant and equal to zero while the tax rate on sector 1 output falls from 50% to zero, then the growth rate rises from 1.3% to 2%.

The authors also consider a case in which the elasticity of substitution in consumption is now 5, instead of 1, as was assumed in the earlier examples. If the labor shares in both sectors are equal to 2/3, then as the tax rate in both sectors falls from 50% to -10%, the growth rate rises from 1.1% to 2.1%. If the tax rate on the human capital sector is fixed at zero while the tax rate on sector 1 drops from 50% to zero, the rate of growth of the economy increases from 1.6% to 2%.

Finally, the authors consider the case of an open economy, able to borrow and lend freely to the rest of the world at a constant interest rate. They calculate an example where in the absence of any taxes there would be no trade, or borrowing and lending, because the domestic economy would have prices identical to world prices, and both economies would grow at the benchmark rate of 2%. With tax rates in each sector as low as 2.5%, the accumulation of human capital is completely shut off, and growth is its lowest feasible value, -0.0128.

WELFARE IMPLICATIONS OF TAXATION

The authors consider the effects of alternative tax policies on welfare using their endogenous growth model. In general the effects of taxes on welfare are much larger in endogenous growth models than in the traditional models of public finance precisely because the taxes affect the rate of growth of economic activity, not just its level.

They define a measure of the welfare loss associated with a a choice between a benchmark path, where consumption begins at C_0 and grows at rate g, and an alternative, general path of consumption into the future. Their measure can be thought of as the answer to the question, what fraction of the initial consumption of the benchmark case would the individual need to have in order to be indifferent between this benchmark case and the alternative path?

A LINEAR TECHNOLOGY EXAMPLE

The authors illustrate their method for measuring the welfare implications of alternative taxes with a simplified endogenous growth model subject to a linear technology. Output is assumed to be proportional to capital, and capital grows with savings, i.e., the part of output which is not consumed. In this case, with the intertemporal substitution in consumption set equal to 1, increasing taxes from 0 to 10% causes a 35% decline in initial consumption. In general, the effect of taxes on consumption is greatest when σ is small and individuals are willing to substitute over time. KR claim that the two sector endogenous growth model will have similar welfare implications if the adjustment costs are negligible and the sectoral production functions have identical labor shares.

TAXATION IN THE NEOCLASSICAL MODEL

Since the neoclassical model discussed in section II above is the workhorse of all of modern public finance, KR compare the implications of taxes on growth and welfare in their endogenous growth model with the implications of taxes in the neoclassical model. Since the neoclassical model responds to tax changes both in transitional dynamics and in different steady state levels, the authors point out that the long-run steady state effects alone are inappropriate for an evaluation of tax policies. Relative to the linear example of the endogenous growth economy mentioned above, the neoclassical model has much smaller welfare losses associated with taxation. In particular, with intertemporal substitution equal to 1, the effect of changing the tax rate from 20% to 30% leads to a decline of the utility-equivalent consumption path of 13.6% in the endogenous growth model, but a decline of only 1.6% in the neoclassical model. Thus by their measure of utility changes, the neoclassical model understates the effect of tax increases on utility by 88% according to

their example.

TAXATION IN THE TWO-SECTOR ENDOGENOUS GROWTH MODEL

The authors show that the comparison between the neoclassical model and the endogenous growth two-sector model is very similar to the comparison between the simple linear, one sector endogenous growth model, and the neoclassical model.

CONCLUSION

KR argue that the substantial cross-country variation in rates of growth can not be explained by the neoclassical model, in which all growth occurs either through transitional dynamics or exogenous technological change. Neoclassical transitional dynamics can be made consistent with the variation in growth rates only by contradicting Kaldor's stylized facts, and technological change cannot offer an explanation of variations in growth rates, because in the neoclassical model such change is exogenous by assumption. Simulation exercises with endogenous growth models developed earlier by the authors show that policy can have large effects on growth rates, and consequently affects welfare more severely than in the neoclassical model. In the endogenous growth model they develop, where taxes affect not only levels of economic activity but also rates of growth, differences in policy may provide the key explanation of the cross country variation in growth rates. Policy is all important partly because growth rates do not depend, as in some other models, on the initial endowment of physical or human capital.

SUMMARY OF

DALE JORGENSON AND KUN-YOUNG YUN'S "TAX REFORM AND U.S. ECONOMIC GROWTH"

Jorgenson and Yun evaluate the impact of the Tax Reform Act of 1986 on U.S. economic growth, and the potential impact of two tax proposals advanced by the Department of Treasury and by President Reagan which figured prominently in the debate leading up to the 1986 tax reform. They also assess the potential impact of a number of hypothetical tax reforms that embody notions of neutrality in the treatment of different kinds of income. They conclude that the insulation of tax structures from the effects of inflation should be a continued objective of tax reform, and that a consumption-based tax would help achieve further reductions in allocative inefficiencies.

As savings may be affected by changes in tax policy, Jorgenson and Yun (JY) use a dynamic, general equilibrium model where the capital stock is endogenously determined. They extend the notion of efficiency in the allocation of resources to encompass intertemporal allocations. Major tax legislation like the Tax Reform Act of 1986 can produce substantial alterations in the rate of accumulation of capital and the allocation of capital among sectors and types of assets. An assessment of the impact of tax reform depends not only on the changes in tax policy but also on the elasticities of substitution along all the relevant margins, including for example, the allocation of resources between present and future consumption.

The authors assume that a single representative producer employs capital and labor services to produce outputs of consumption and investment goods. The single capital good is perfectly malleable and is assumed to be instantaneously and costlessly allocated so as to equalize after-tax rates of return to equity in the corporate, noncorporate, and household sectors.

Further, the stock of investment goods is also assumed to be costlessly

and perfectly mobile between sectors. A representative consumer supplies labor services, demands consumption goods, and makes choices between consumption and saving. Consumers maximize an intertemporally additive utility function that depends on levels of full consumption in all time periods. Full consumption is an aggregate of consumption goods, household capital services, and leisure. To simplify the representation of preferences the representative consumer has an infinite lifetime and perfect foresight about future prices.

The equilibrium is characterized by an intertemporal price system that clears the markets for labor, capital services, and consumption and investment goods. The past and the future are linked through markets for investment goods and capital services. Assets are accumulated as a result of past investments, and the price of an asset equals the present value of future capital services. The time path of consumption satisfies the conditions for intertemporal optimality of the household sector under perfect foresight. Similarly, the time path of investment must satisfy the requirements for the accumulation of assets by both business and household sectors.

The government sector raises revenues through taxes on income from capital and labor services. Corporate capital income is taxed at both corporate and individual levels, noncorporate capital income is taxed only at the individual level, and household capital income is not subject to income taxation. In addition, the government sector imposes sales taxes on the production of consumption and investment goods and property taxes on assets held by the business and household sectors. Taxes insert wedges between demand and supply prices for investment and consumption goods and for capital and labor services. These tax wedges distort private decisions and lead to losses in efficiency.

Given perfect foresight, the model generates a unique transition path to a balanced growth equilibrium corresponding to any tax policy and any initial

level of capital. The transition to balanced growth is implicitly non-instantaneous because additional capital is obtained through reductions in consumption, which are increasingly costly in terms of utility. Capital may shift, however, between sectors in a manner assumed to be costless and instantaneous. The growth path consists of a plan for consumption of goods and leisure by the representative consumer at every point in time, and a plan for production of investment and consumption goods from capital and labor services at every point in time by the representative producer. These plans are made consistent by the intertemporal price system.

Associated with each tax policy and the corresponding intertemporal equilibrium is a level of welfare for the representative consumer, which can be interpreted as a measure of potential social welfare. Actual social welfare depends also on the distribution of welfare among consumers. To evaluate changes in policy in terms of efficiency, the authors translate changes in potential welfare into an equivalent change in private national wealth. They consider the time path of the price of full consumption associated with current tax policy. Finally, they evaluate the difference in wealth required to attain levels of potential welfare before and after the change in tax policy at prices prevailing before the policy change.

THE 1986 TAX REFORM

The 1981 Tax Act, passed during the Reagan Administration's first year, introduced multi-year cuts in statutory tax rates at both individual and corporate levels with the aim of improving incentives "to work, save, and invest, consistent with the goal of eliminating the Federal budget deficit by 1984". Statutory tax rates for individuals were cut by 23 perc . over the years 1982-84 -- 10 percent in 1982, another 10 percent in 1983, and a final five percent in 1984. The range of marginal tax rates for individuals was narrowed

from 14-70 percent of taxable income to 11-50 percent, while corporate tax rates for the lowest two income brackets fell from 17 to 15 percent and from 20 to 18 percent over the years 1982-83.

In outlining the key features of the Tax Reform Act of 1986, the authors describe the pre-existing tax law which they call Tax Law 1986, in order to provide a basis for comparison. The average marginal tax rates for a variety of income sources are presented in Table 1 for the Tax Law of 1986, the proposal of the Treasury, the proposal of the President, and the Tax Reform Act of 1986.

The first column in Table 1 gives average marginal tax rates for different types of income under the 1986 Tax Law for zero, six, and ten percent annual inflation rates. The tax rate on each type of income is a weighted average of marginal tax rates paid by taxpayers in all income tax brackets. Average tax rates on different types of income reflect differences in the distribution of each type of income over the tax brackets.

The average marginal tax rate on labor income, the average marginal tax rate on income under the corporate income tax, and the average tax rate under the individual income tax are also shown in Table 2. All tax rates include taxes levied at both Federal and state and local levels and take into account the deductibility of state and local taxes at the Federal level. In projecting U.S. economic growth under the 1986 Tax Law the authors take the average marginal tax rates on each type of income and the average individual income tax rate as fixed. Tax revenues received by the government are generated by applying these tax rates to streams of income generated endogenously within JY's model of U.S. economic growth.

TAX REFORM AND ECONOMIC GROWTH

The authors estimate the impact of the alternative tax policies on

TABLE 1a TAX RATES

1. AVERAGE MARGINAL TAX RATES OF INDIVIDUAL CAPITAL INCOME

A. 0% Inflation

	1986 LAW	TREAS	PRESID	1986 ACT
Corporate Equities	0.2555	0.2261	0.2240	0.2029
Non Corporate Equities	0.2934	0.2427	0.2572	0.2494
Corporate Capital Gains	0.0303	0.0596	0.0325	0.0562
Non Corporate Capital Gains	0.0293	0.0607	0.0332	0.0624
Interest Income to Corporate Debt	0.1533	0.1452	0.1532	0.1285
Interest Income to Non-Corporate Debt	0.1971	0.1805	0.1912	0.1670
Interest Income to Household Debt	0.2717	0.2252	0.2387	0.2310
Interest Income to Government Debt	0.2205	0.1868	0.1970	0.1852

B. 6% Annual Inflation Rate

	1986 LAW	TREAS	PRESID	1986 ACT
Corporate Equities	0.2559	0.2261	0.2240	0.2033
Non Corporate Equities	0.2934	0.2427	0.2572	0.2494
Corporate Capital Gains	0.0303	0.0596	0.0600	0.0562
Non Corporate Capital Gains	0.0293	0.0607	0.0643	0.0624
Interest Income to Capital Debt	0.1730	0.1452	0.1532	0.1434
Interest Income to Non-Corporate Debt	0.2151	0.1805	0.1912	0.1807
Interest Income to Household Debt	0.2722	0.2252	0.2387	0.2314
Interest Income to Government Debt	0.2260	0.1868	0.1970	0.1894

C. 10% Annual Inflation

	1986 LAW	TREAS	PRESID	1986 ACT
Corporate Equities	0.2560	0.2261	0.2240	0.2034
Non-Corporate Equities	0.2934	0.2427	0.2572	0.2494
Corporate Capital Gains	0.0303	0.0596	0.0600	0.0562
Non-Corporate Capital Gains	0.0293	0.0607	0.0643	0.0624
Interest Income to Corporate Debt	0.1806	0.1452	0.1532	0.1492
Interest Income to Non-Corporate Debt	0.2222	0.1805	0.1912	0.1861
Interest Income to Household Debt	0.2724	0.2252	0.2387	0.2315
Interest Income to Government Debt	0.2282	0.1868	0.1970	0.1910

2. MARGINAL TAX RATES OF LABOR INCOME, CORPORATE INCOME AND AVERAGE PERSONAL TAX RATES

	1986 LAW	TREAS	PRESID	1986 ACT
Average Marginal Tax Rate of Labor Income	0.2967	0.2512	0.2536	0.2517
Corporate Income Tax Rate, Federal, State and Local	0.5084	0.4006	0.4006	0.3847
Average Tax Rate of Individual Income	0.1315	0.1203	0.1223	0.1233

The Treasury proposal, the President's proposal, and the 1986 Tax Reform Act are assumed to reduce the average tax rate of individual income by 8.5%, 7.0%, and 6.2%, respectively.

3. TAX RATES HELD CONSTANT ACROSS THE ALTERNATIVE TAX POLICIES

Property Tax Rates of Corporate Assets	0.0100
Property Tax Rates of Noncorporate Assets	0.0096
Property Tax Rates of Household Assets	0.0100
Sales Tax Rates of Consumption and Investment Goods	0.0579
Sales Tax Rates of Consumption and Investment Goods	0.0579
Rate of Personal NonTaxes	0.0229
Effective Rate of Wealth Taxation	0.0006

TABLE 2. WELFARE EFFECTS OF TAX REFORM

Rate of Inflation	Revenue Adjustment	1986 Tax Law	Treasury Proposal	President's Proposal	1986 Tax Act
0%	Lump Sum Tax	724.0	1489.6	1691.4	1561.8
	Labor Income Tax	478.2	1468.8	1642.4	1565.0
	Sales Tax	400.3	1452.9	1614.6	1558.7
	Individual Income Tax	374.5	1456.1	1619.1	1563.1
6%	Lump Sum Tax	0.0	1907.6	2452.2	448.4
	Labor Income Tax	0.0	1711.4	2170.4	746.9
	Sales Tax	0.0	1600.1	2104.9	901.2
	Individual Income Tax	0.0	1595.8	2007.9	999.4
10%	Lump Sum Tax	-447.1	2060.4	3015.6	-200.8
	Labor Income Tax	-333.7	1791.6	2584.7	267.3
	Sales Tax	-285.2	1623.5	2356.4	517.0
	Individual Income Tax	-221.9	1604.8	2353.1	748.6

Note: In 1987, the national wealth (beginning of the year) and GNP are projected to be $15,920.2 and $4,488.5 billion dollars respectively. Units are billions of 1987 dollars.

U.S. growth by comparing the resulting level of welfare with that attainable under the "base case" given by the 1986 Tax Law.

They consider four alternative methods for adjusting tax revenues so as to keep the budgetary position of the government sector the same as in the base case. The first method is to increase or decrease government revenues by means of a "lump-sum" tax or subsidy. They also consider three methods for adjusting government revenues that involve changes in tax-induced distortions. These include proportional adjustments to labor income taxes, sales taxes on investment and consumption goods, and taxes on income from both capital and labor.

EFFECTS OF THE TAX REFORM ACT OF 1986

JY summarize the results of their simulations of U.S. economic growth in Table 2 which shows that the Treasury proposal, the President's proposal and the Tax Reform Act of 1986 all improve potential economic welfare substantially. In their central case with six percent inflation and a lump-sum tax adjustment, the President's proposal would have generated a welfare gain of $2452.2 billion, while the Treasury proposal a gain of $1907.6 billion, and the Tax Reform Act of 1986, again of only $448.4 billion, all measured in 1987 dollars.

Another perspective on the economic impact of the alternative tax reform proposals is provided by a comparison of the welfare gains from tax reform with the private national wealth. The nominal value of the U.S. private national non-human wealth at the beginning of 1987 was $15,920.2 billion. The welfare gains from the Treasury and the President's proposals would have been equivalent to increases of 12.0 and 15.4 percent, respectively, of U.S. private national wealth in 1987. The welfare gain from the Tax Reform Act of 1986 is equivalent to an increase of only 2.8 percent of the national wealth.

It is worth recalling that inflation reduces the interasset tax wedges and

increases the intertemporal tax wedges under the 1986 Tax Law and the Tax Reform Act of 1986. Under the Treasury and President's proposals, inflation has little effect on the interasset wedges but tends to reduce the intersectoral and intertemporal tax wedges.

Table 2 also shows how the welfare effects of alternative tax reforms would be affected by the rate of inflation. It is useful to focus on lump-sum tax adjustments since distortionary tax adjustments result in a reallocation of resources due to substitutions in production as well as to changes in the rate of inflation. Economic welfare improves with higher inflation under the Treasury and President's proposals. On the other hand, welfare declines with inflation under the 1986 Tax Law and the Tax Reform Act of 1986. This is due to the fact the tax burden on capital income is reduced with higher inflation under the two proposals, while it increases with inflation under the 1986 Tax Law and the Tax Reform Act of 1986. An increase in the rate of inflation from zero to six percent is sufficient to alter the welfare ranking between the Treasury proposal and the Tax Reform Act of 1986

ALTERNATIVE APPROACHES TO TAX REFORM

The authors consider alternative approaches to tax reform based on the elimination of tax wedges among different types of assets. As before, the growth path of the U.S. economy under the 1986 tax law is taken as a basis for comparison so the potential gains in economic welfare are relative to levels of welfare under the 1986 Tax Law.

For the purposes of this analysis JY distinguish between atemporal (i.e., time-independent) tax wedges and intertemporal tax wedges. The elimination of an atemporal tax wedge implies that the social rates of return on the corresponding assets are equalized within a given time period. More precisely, they equalize the social rates of return associated with balanced growth

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equilibrium under the 1986 Tax Law, using the balanced growth proportions of assets as weights.

To model the integration of the corporate and individual income taxes they set the social rates of return on corporate assets equal to those on the corresponding noncorporate assets. This procedure does not affect the private rates of return in the two sectors which differ for two reasons. The first is that debt/asset ratios differ across sectors. The second is that average marginal tax rates on individual income vary from sector to sector due to the differences in the distribution of asset ownership among taxpayers in different income tax brackets.

The authors eliminate five sets of tax wedges: (1) the interasset tax wedges within the corporate and noncorporate sectors, (2) intersectoral tax wedges between assets of the same type held in the corporate and noncorporate sectors, (3) intersectoral tax wedges among assets of the same type held in the corporate and noncorporate and household sectors, (4) all the atemporal tax wedges in the business sector, and (5) all the atemporal tax wedges in the business and the household sectors.

Elimination of an intertemporal tax wedge requires equalizing the social and private rates of return, so that the effective tax rate on the corresponding assets is reduced to zero. They consider the elimination of intertemporal tax wedges resulting from income and property taxes, which leaves the sales tax on investment goods at its level in the base case, while reducing the effective tax rate on capital income to zero. Second, they eliminate the tax burden on capital altogether by removing the sales tax on investment goods as well as the taxes on income from capital and property taxes.

WELFARE IMPACTS OF TAX REFORM

The authors summarize the welfare impacts of the eight hypothetical tax reform proposals in Table 3. Beginning with "lump-sum" tax adjustments, they find that the welfare gain from elimination of interasset tax wedges that exist under the 1986 Tax Law is $443.9 billion. The elimination of intersectoral tax wedges between the household and business sectors, however, results in an estimated gain of $2262.6 billion at a six percent rate of inflation, which is much larger than the gain the authors have estimated for the Tax Reform Act of 1986. Given the substantial tax wedges between business and household assets under the 1986 Tax Law, this result is not surprising.

The welfare gain from eliminating the interasset and intersectoral wedges among just business assets is estimated to be only $326.4 billion under the 1986 Tax Law. The welfare gain from eliminating all the atemporal tax wedges in the private sector of the U.S. economy is estimated to be $2663.7 billion. This gain is much larger than the welfare gain resulting from elimination of interasset distortions for all sectors. In view of the relative magnitude of these effects, the authors attribute most of the welfare gain to elimination of intersectoral tax wedges between business and household. The elimination of intersectoral tax wedges between assets in the corporate and noncorporate sectors unambiguously reduces the effective tax burden on corporate assets and results in an estimated welfare gain of $1313.1 billion, about half of that attainable by eliminating all intersectoral tax wedges.

The elimination of intertemporal tax wedges generates huge welfare gains under lump sum tax adjustment. When sales taxes on investment goods are also abolished, the welfare gain becomes $4128.1 billion.

If a proposed tax reform is roughly revenue neutral, so that the magnitude of the required adjustment in tax revenue is small, the welfare ranking of alternative policy changes does not depend on the method for adjusting tax

TABLE 3. WELFARE EFFECTS OF TAX DISTORTIONS OF THE 1986 LAW

1. Within Sector Interasset Distortion	
Lump Sum Tax Adjustment	443.9
Labor Income Tax Adjustment	248.1
Sales Tax Adjustment	168.7
2. Intersector Distortion: C and NC Sectors	
Lump Sum Tax Adjustment	-93.3
Labor Income Tax Adjustment	-416.7
Sales Tax Adjustment	-523.8
Individual Income Tax Adjustment	-715.5
3. Intersector Distortion: All Sectors	
Lump Sum Tax Adjustment	2262.6
Labor Income Tax Adjustment	2156.9
Sales Tax Adjustment	2118.6
Individual Income Tax Adjustment	2067.7
4. No Tax Distortion: C and NC Sectors, All Assets	
Lump Sum Tax Adjustment	326.4
Labor Income Tax Adjustment	69.2
Sales Tax Adjustment	-29.1
Individual Income Tax Adjustment	-169.7
5. No Tax Distortion: All Sectors, All Assets	
Lump Sum Tax Adjustments	2663.7
Labor Income Tax Adjustment	2606.9
Sales Tax Adjustment	2572.4
Individual Income Tax Adjustment	2547.2
6. Corporate Tax Integration	
Lump Sum Tax Adjustment	1313.1
Labor Income Tax Adjustment	493.4
Sales Tax Adjustment	238.1
Individual Income Tax Adjustment	-274.5
7. Consumption Tax Rules (Zero Effective Tax Rates)	
Lump Sum Tax Adjustment	3853.9
Labor Income Tax Adjustment	2045.4
Sales Tax Adjustment	1749.3
Individual Income Tax Adjustment	2045.4
8. Consumption Tax Rules (Zero Effective Tax Rates) No Sales Tax on Investment Goods	
Lump Sum Tax Adjustment	4128.1
Labor Income Tax Adjustment	1988.0
Sales Tax Adjustment	1722.1
Individual Income Tax Adjustment	1988.0

Note: Inflation is fixed at 6% per year. C denotes corporate and NC denotes non-corporate.
Units are billions of 1987 dollars.

revenue. For a change in tax policy that involves substantial rate cuts with no compensating enhancement of tax revenues through base broadening, the welfare measures under the lump sum tax adjustment can be interpreted as upper bounds of the welfare gains that may be achieved. Any realistic tax reform involving revenue adjustment through changes in distortionary taxes would result in welfare gains well below those attainable under the hypothetical lump sum tax adjustment.

The fact that the estimated welfare gains from the elimination of the intertemporal tax wedges is in the range of four trillion dollars suggests that the potential welfare gain from replacing the current system of income taxes with consumption-based taxes is very large indeed. Although the welfare gains are reduced by approximately half under the more realistic assumption that revenue losses are offset by distortionary tax adjustments, the latter welfare gains are still impressive. JY conclude that improvements in the efficiency of intertemporal resource allocation must be carefully weighed against possible worsening of atemporal resource allocation as a consequence of distortions associated with taxes on consumption.

CONCLUSION

The Tax Reform Act of 1986 increases the effective marginal tax burden on income from capital at any positive inflation rate. Nonetheless, the change in economic welfare relative to the 1986 Tax Law is positive. The welfare gain is $448.4 billion at a six percent rate of inflation, which amounts to 2.8 percent of U.S. private national wealth in 1987. The 1986 Tax Act substantially reduces interasset tax wedges within the business sector, so that potential welfare gain from further reductions is small.

An important feature of the Treasury and President's proposals is that the tax base would have been largely indexed against inflation. Since with a six

percent inflation rate the president's proposal would have resulted in a welfare gain of $2452.2 billion dollars, which dwarfs the corresponding gain from the Tax Reform Act of 1986, the authors conclude that insulating the tax system from the effects of inflation should remain a top priority for future tax reform.

The largest welfare gains from tax reform would have been obtained by transferring part of the tax burden on business capital to household capital, although there are obviously important political obstacles to such a transfer. The welfare gain from a tax policy that treats all forms of capital income symmetrically would have been $2663.7 billion dollars at a six percent inflation rate which exceeds the gain from the 1986 Tax Act by $2215.3 billion dollars and outranks the gains from the Treasury and President's proposals

An alternative approach to equalizing the tax burdens between business and household assets would have been to replace the 1986 Tax Law with a tax system based on consumption. At a six percent inflation rate, the welfare gain that would be achieved by shifting to a consumption-based tax system from a system primarily based on income would have been much larger than the gain from the Tax Reform Act of 1986. This conclusion holds for any of the alternative methods JY have considered for maintaining government revenue at the same level as under the 1986 Tax Law. The prospective revenue losses associated with elimination of capital income taxation would have required large increases in distortionary taxes. However, the resulting welfare losses would have been outweighed by gains in efficiency from eliminating capital income taxes.

SUMMARY OF

S.C. TSIANG'S "SUCCESS OR FAILURE IN ECONOMIC TAKE-OFF"

Since the second World War, the pattern of economic growth in different countries has been characterized by extreme diversity. For example, the per capita income in Taiwan in 1950 was only 40% that of certain Latin American countries, while today, the relative income levels have reversed, with Taiwan's per capita income 2.5 times that of its Latin American counterparts. In his paper, S.C. Tsiang looks at the reasons for this diversity. On the basis of a theoretical model he concludes that the key catalyst or "engine of growth", is the rate at which income is saved and invested relative to the rate of population growth. An empirical section substantiates his theoretical arguments with a detailed look at the role of savings and population in economic growth.

THE MODEL

Tsiang's analysis follows closely the Nobel prize winning work of Robert Solow.

Tsiang concentrates on a single representative good, the production of which depends on the existing level of technology and the available amounts of labor, capital, and land. His analysis differs from Solow's by assuming that population growth is not fixed but varies positively with income per capita, by specifying that savings is not a constant proportion of income but instead varies with income, and by allowing a role for land. With the amount of technology fixed, an economy can generate increases in the amount of goods produced by increasing the amount of capital and labor used. Equivalently, an increase in the production of goods per worker Y can come about only with an increase in the amount of capital per worker R, provided there are constant

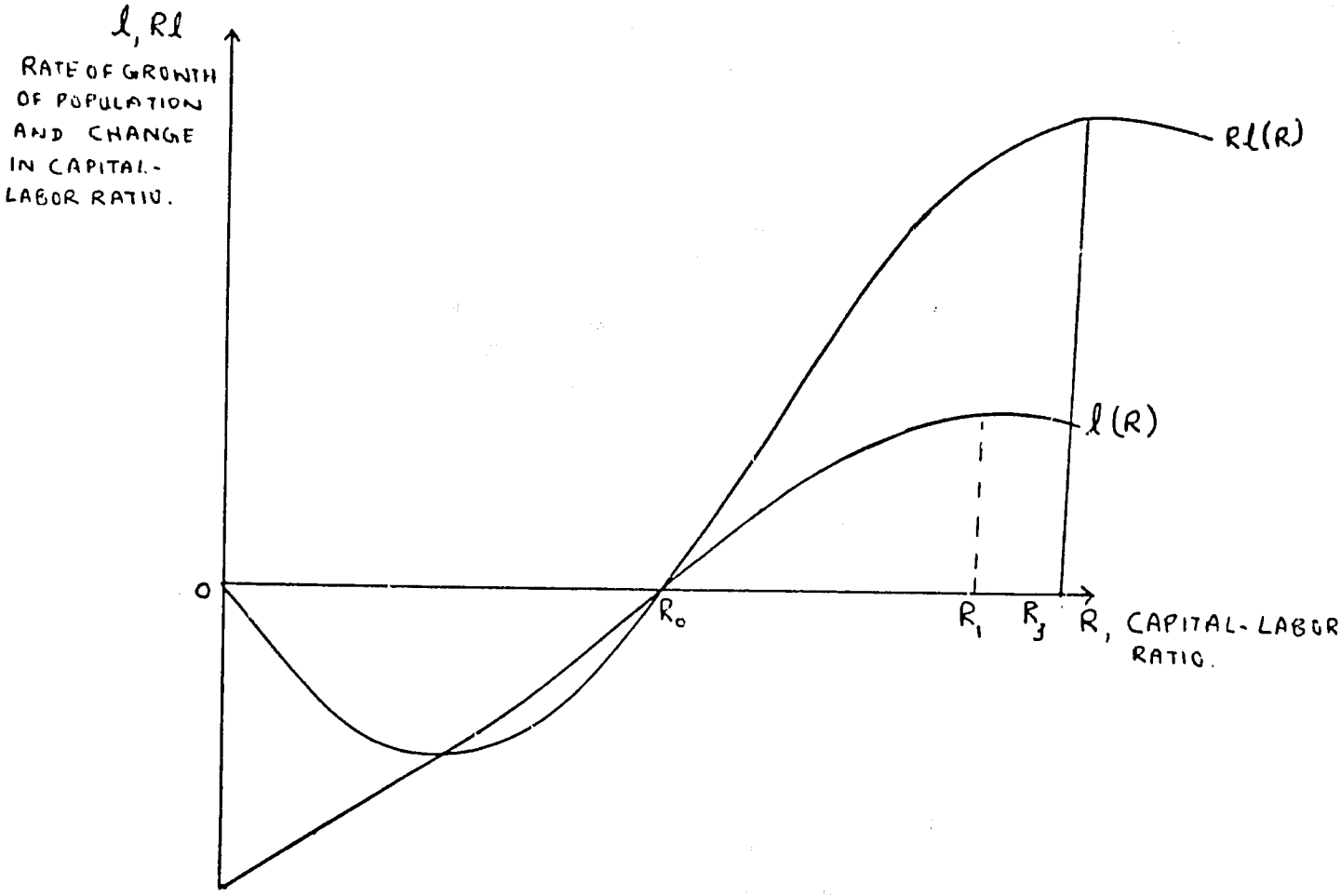

FIG. I. RELATION BETWEEN POPULATION GROWTH AND CAPITAL-LABOR RATIO.

returns to scale. As labor force participation is assumed constant, capital and income per capita are proportional to capital and income per worker. Hence income and capital per capita move together.

Tsiang argues that in many countries the growth rate of population, ℓ, is sensitive to income through the death rate and the birth rate. It increases with prosperity as prosperity lowers death rates. Its rate of increase falls, however, beyond a certain level of income or capital per worker, as the birth rate decreases. Eventually, due to increasing awareness of family planning and its benefits, birth rates fall further and hence the rate of growth of population declines. This is depicted in Figure 1. For R less than R_o, since income is below subsistence levels, the growth rate of population is negative. For capital-labor ratios between R_o and R_1, the growth rate is increasing due to decreasing death rates. For capital-labor ratios in excess of R_1, large declines in birth rates lower the population growth rate. The curve, $\ell(R)$ describes the general relationship between the rate of growth of the labor force, or population, and capital per capita.

The amount of savings per capita required in order to maintain any given level of capital per worker is a product of two variables: a) the capital-labor ratio itself, R, and b) the rate of growth of labor (equal to the rate of growth of population), ℓ. As R increases from low levels, the first factor increases proportionally, while the second factor also increases but at a decreasing rate, given Tsiang's specification of the relationship between population growth rates and the capital-labor ratio. The relationship between $R\ell$ and R is therefore determined by the relationship between the rate of growth of population, and R. This is depicted by the curve $R\ell(R)$ in Fig. 1.

The curve shows that when the level of capital per worker is less than R_o, $R\ell(R)$ is negative because the rate of growth of labor remains negative

as long as income per capita is below the subsistence level. Beyond R_o further increases in R cause a positive population growth and hence the R curve is increasing with R until it reaches the level R_3, at which point ℓ stops increasing with R, and may even start to decrease, bringing $R\ell$ down. In essence, the curve $R\ell$ describes the extent to which a population change affects the capital to labor ratio, and hence the minimum saving per worker required to maintain the latter ratio constant.

Capital is generated through savings (all of which is assumed to be invested). Savings as a percent of income is assumed to increase with per-capita income, and thus with R, a relation which Solow, in his original model did not consider. At levels of income below subsistence, savings per capita S is negative but increases with R as the subsistence level of income is approached. Once income or the corresponding R increases beyond the subsistence level, savings per capita becomes positive as people save and invest positive fractions of their income. Since there is diminishing marginal product of capital, however, additions to capital generate decreasing amounts of additional income as the capital-labor ratio increases: once a large enough stock of capital relative to labor is built up, further additions to capital provide increasingly smaller increases in output. If the reward for saving and investing is the value of the marginal product of capital, saving reaches a maximum at R_4 and then becomes constant. After R_4 there are no incentives for increased savings since the returns to saving are constant. Hence the savings per capita reaches a maximum at R_4. (See figure 2)

Suppose that an economy initially has a low level of income, T_A, and a low rate of growth of income per capita, R_A. If R increases due to a new government policy or some external reason, there are two effects. On the one hand, population increases faster thereby reducing capital per capita, R. On the other hand, the rate of savings increases, resulting in an increase in

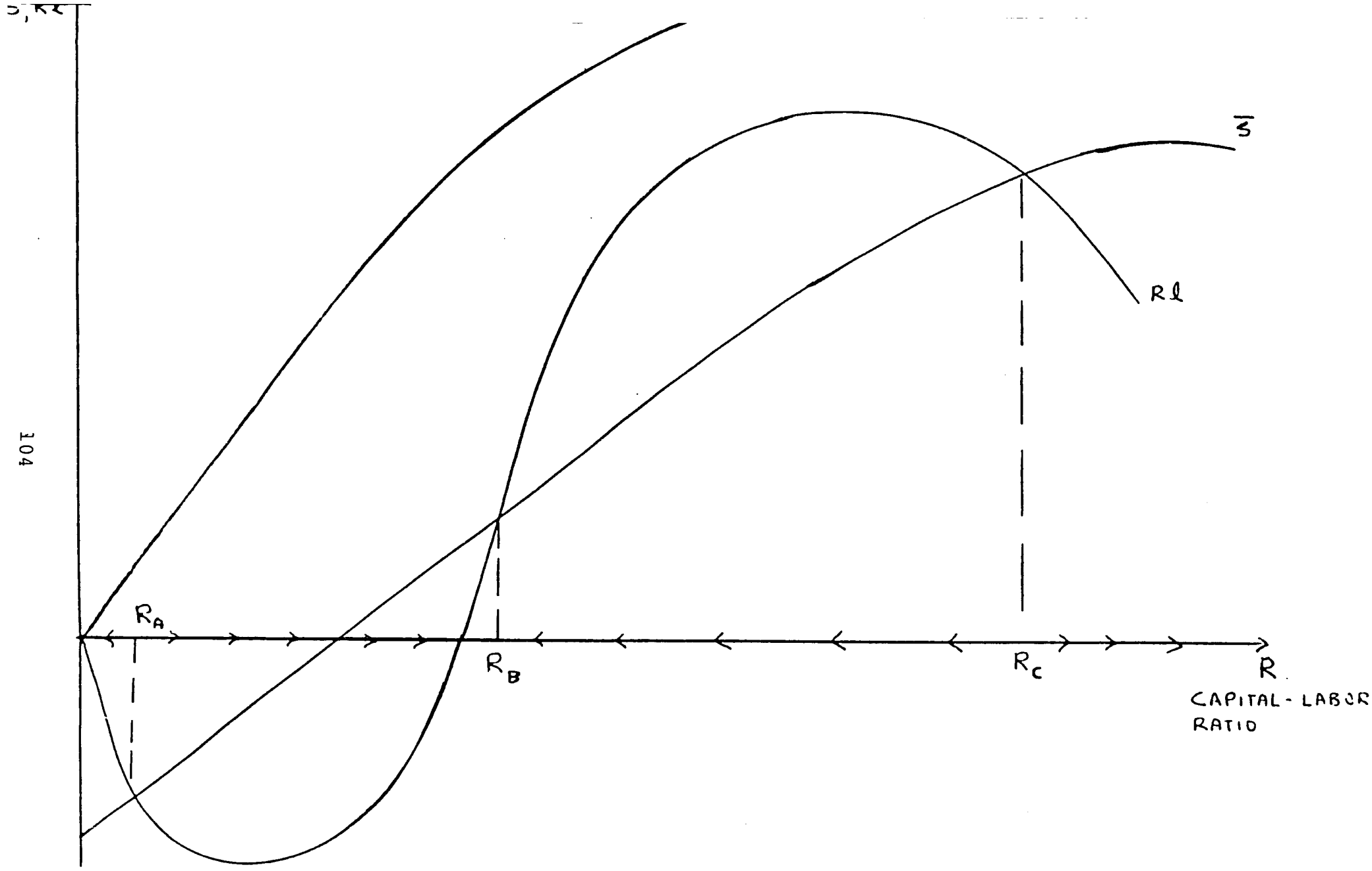

FIG. II. CHARACTERIZATION OF GROWTH PATHS

capital per capita, R. If the second effect dominates the first then the economy can grow continuously since R will keep increasing. If the first effect dominates, the economy will fall back to its old subsistence level of R_A and Y_A. Hence, if the increase in savings is sufficient to more than overcome the adverse effect of increased population, the economy will grow while otherwise it will remain at its low level equilibrium. This is illustrated in Fig. 2:

In this figure, the $R\ell(R)$ curve describes, as before, the amount by which increasing population decreases R, and hence the minimum savings necessary to maintain alternative levels of R. The S curve describes the corresponding actual savings per capita for these alternative levels of R. At a level of R given by R_B, any small increase (decrease) in R is temporary, since insufficient (more than sufficient) savings are generated. The reason is that at a level of R just greater than R_B, savings per capita is less than $R\ell$, the amount necessary to balance the additional population growth, therefore R falls. At a level of R just less than R_B, savings exceeds the amount necessary to balance population growth ($R\ell$), therefore R rises. This low level of income per capita or equivalently capital per capita, (R_B) corresponds to a stable equilibrium from which an economy cannot easily "take-off". At a third level of R, R_C, any small increase (decrease) in R will push the economy away from R_C since more than (less than) sufficient savings are generated to keep income and R from falling. An economy may achieve "take-off" into sustained growth only when it has reached a capital-labor ratio corresponding to R_C. In other words, sustained rapid growth occurs only if savings per capita, S, exceeds the capital-labor ratio R times population growth.

On the basis of this analysis Tsiang argues that the criterion by which

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one can determine whether a country is ready to "take-off" and and to achieve sustained growth is that savings per capita exceed the amount necessary to maintain the capital labor ratio. Tsiang then examines empirical data from various countries to verify whether this criterion for take-off is indeed compatable with the growth experience in these countries.

POLICY IMPLICATIONS

Tsiang argues that for an underdeveloped country to "take-off" into a sustained state of growth, it must undertake a policy aimed at enhancing savings sufficiently to reverse any deleterious effect of population growth on per-capita capital formation that may result from higher income levels.

Using Fig. 2, Tsiang argues that pro-growth policies are those which lower $R\ell$ and raise S, thus lowering the "hump" between R_B and R_C, and reducing the level of capital per worker required for the economy to reach take off. His pro-growth policies include:

A. Efforts through family planning, contraceptive education, and tax policies to reduce population growth.

B. Raising the savings rate by increasing the incentive to save through banking deregulation, monetary restraint, and other policies which increase the real after-tax return on financial assets.

C. Liberalizing foreign investment regulations to facilitate the borrowing of capital from abroad. However, mobilizing domestic savings still remains a necessary long-run goal.

D. Promoting technological improvements that raise income per capita and thus savings, for given R.

E. Liberalization of foreign trade, which has the same effect as improved technology, since the economy will now specialize in producing those commodities in which it has a relative advantage, and raise its real income through trade.

THE PERFORMANCE RECORD OF SOME COUNTRIES CONCERNING "TAKE-OFF" INTO SUSTAINED GROWTH

Tsiang's model implies that take-off growth requires the savings rate to

exceed the products of the capital to labor ratio and the rate of population growth. He investigates the validity of this proposition by considering data for 14 countries, only some of which are presented here. He further refines the basic proposition to be tested by measuring savings and capital as percentages of GNP, and not as rates per capita. Due to the lack of data on capital, however, Tsiang uses the marginal capital to output ratio that specifies the amount of investment necessary to bring about a given increase in output, which is an indication of the efficiency of investment Thus his basic prediction is that take-off growth requires savings as a percent of income to exceed the product of the ratio of investment to the change in income, and population growth. For economies where international trade is important, investment equals savings plus the current account (trade) deficit, therefore, these data are also considered.

TAIWAN

In the early 1950's Taiwan had a per capita real income close to 100 US dollars (current value). It had fewer natural resources and far greater population density than developing countries elsewhere. The marginal capital to output ratio was around 200 in the 1950's. With a fast population growth rate around 3.5%, its propensity to save of almost 5% was not sufficient for take-off. Saving was two to three percent less than the amount required for growth by 2% to 3%. Only with foreign aid from the US was Taiwan able to prevent declines in its capital-labor ratios.

By the 1960's the scenario changed rather dramatically. The propensity to save increased to 13.4%, the rate of growth of population dropped to 3.0%, while the incremental capital-output ratio declined to 190, indicating an improvement in the efficiency of investment. The condition for take-off was satisfied in 1962 and per capita growth in the subsequent years was between 6%

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and 10%. By the 1980's the propensity to save had increased to 36.1%, the rate of growth of population fell to 1.5% and the marginal capital to output ratio fell to 184. Taiwan certainly "took-off" into sustained growth by not only increasing savings generation but also lowering the required amount of savings for sustained growth. According to Tsiang, Taiwan achieved this by adopting:

A. Measures to encourage savings by deregulating bank interest rates.

B. A policy of export expansion accompanied by considerable import and exchange rate liberalization.

C. A sensible population policy that encouraged family planning and spread the knowledge and methods of birth control.

INDIA

In the early 1960's India, another important case that Tsiang considers, had a per capita income of only US $73.50, at the then-current prices. The savings rate was 10.82% which could certainly be considered respectable, while the rate of growth of population was 2.4%. By most estimates, India had achieved a modest "take-off" by the 1960's. However, despite a savings rate that increased to 17.21% and a slight decline in the rate of population growth by the early 1980's, the rate of growth of income still remained around the 1960's level of 3.8%. Some economists claim that India attempted to take off prematurely but this does not seem to have been the case. A tendency to resort to excessively capital-intensive methods of production and emphasis on the growth of sectors like heavy industries, which require a large input of capital, rendered even the high rate of savings that was achieved insufficient. The marginal capital to output ratio had values of 400 to 600, almost double those in Taiwan, indicating a considerably lower efficiency of investment in India. Although the condition for takeoff was satisfied, per capita growth was erratic and fluctuated between -2% and 7% during the 1960's and 1970's. Coupled with restrictions on trade that denied the country the advantages

stemming from specializing in the production of commodities it was most suited to produce, this emphasis on capital-intensity appears to have been the major cause of dismal performance. Tsiang concludes that improper government policies in India seem to have retarded the economic"take-off" of this country.

COLOMBIA

Starting with a per capita income of US $354 in the early 50's, Colombia appears to have been in a very respectable economic position, relative to other developing countries. With a savings rate of 7.8% and a population growth rate of 3.19%, Colombia achieved an economic take-off by the early 60's. However, this take-off had slowed soon afterwards. A strong bias in government policy towards protecting import-substituting industries that involved huge capital outlays, borrowing funds from abroad that were not utilized properly, and regulating the interest rate to keep it at low levels which discourage savings, all seem to have halted growth in this economy.

TANZANIA

Tanzania has failed to achieve economic growth although its income in 1960 was 85% that of India's. Population growth rose from 2.5% around 1960 to more than 3.5% in the late 1970's. Income per capita grew at 2% or 3% in the 1960's but fell at 2% or 3% after 1980. The condition for take-off was never satisfied because of the high population growth, moderate savings, and very high incremental capital-output ratio, indicative of unwise investment decisions.

CONCLUSION

The paper's main argument is that the "take-off" of an economy into sustained growth occurs when savings are sufficient to induce increments in per capita capital accumulations which propel the economy forward. The observed

divergence across counties in their levels of per-capita income is explained by the differences in their propensity to save out of income relative to the growth in their population. Government policies aimed at reducing the required amount of savings for growth to take place, e.g., liberalization of trade policies that reduce the growth of population or policies that encourage domestic savings, would all help to push an under-developed country towards a state of self-sustaining growth in per-capita income. By examining empirical evidence from many countries of comparable initial economic position, Tsai concludes that only those countries that followed these policies have in fact succeeded in achieving this objective.

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SUMMARY OF

ROBERT BARRO'S "GOVERNMENT SPENDING IN A SIMPLE MODEL OF ECONOMIC GROWTH"

Traditional analyses of economic development have generally recognized that certain "pre-conditions", such as the availability of basic economic infrastructures, must be satisfied before an economy can "take-off" and reach a self-sustaining level of economic growth. According to Barro, there has been little analysis of the productive role government plays in achieving this objective. He assumes that any increases in infrastructures such as roads, public utilities, law enforcement, and defense exert a continuously favorable effect on private production, and that the private sector is not able to provide such infrastructure on its own. A government dedicated to the provision of these services becomes, therefore, the necessary catalyst for, or "engine" of growth. The bulk of Barro's paper addresses the impact of various tax schemes for financing government services on the ensuing rate of growth of per-capita income and consumption.

THE ECONOMY

Barro's economy is represented by a single household (or unchanging population) that produces and consumes a composite commodity. He assumes that production requires combinations of governmental infrastructural services and private capital in a manner analogous to the combination of labor and private capital in the traditional production technology. Private capital is created by private savings and government services are created through the imposition of taxes. The production technology is of the Cobb-Douglas variety: it has constant returns to scale in both inputs, and decreasing returns to each input separately. Hence, higher private capital accumulation leads to a reduction in its marginal productivity if there is no change in the quantity of the

infrastructural services available. In addition, increases in any one input raise the marginal product of the other input.

In Barro's economy, parents are altruistic towards their future generations. Parents care about their children, their grand-children and so on, to the point where they consider offspring simply as extensions of themselves. Under such altruistic sentiments, the household can be depicted as "living forever", i.e, deriving utility from consuming the output produced over an infinite lifetime. The household does not have direct control over the level of the infrastructure made available to it and hence takes this as given. Part of the output produced is consumed by the household, another part is used to pay taxes, and the remainder is saved. All savings are invested and represent an addition to the stock of capital available as an input to production.

The government provides the infrastructural service and finances its expenditure by imposing a tax on the households. Barro assumes that the government budget is balanced at every point in time, and that each dollar of revenue is transformed into one dollar worth of government services. For any flat tax rate, the level of government services is proportional to the level of output and hence the ratio of government services to output will remain constant and equal to the tax rate. The role of the government is to provide these necessary products in sufficient quantities to enable the economy to "take-off" into self-sustaining growth in per-capita income. These pre-conditions include provision of basic infrastructural services such as highways and sewers that a private firm may not find feasible or profitable to provide. Even if private firms were to provide these goods and services, the incentive structure implies that the quantity supplied by the market would be sub-optimal.

GOVERNMENT EXPENDITURE FINANCED BY AN INCOME TAX

Barro first considers the implications of a constant tax rate on household's income, or output. Since the government is assumed to balance its budget, any increase in tax revenues collected must be spent on more services. The level of public services produced by the government is consequently a constant fraction of output, and given the constant returns to scale nature of the production technology, the level of production is a constant multiple of the stock of private capital available at any fixed tax rate. The marginal product of capital is therefore independent of the level of capital.

The household decides how much to save by comparing the costs and benefits from saving an additional dollar. The benefit is the additional output created by using the dollar saved to increase private capital. The cost of saving is the postponement of consumption. Since part of the savings-induced added output is taxed away by the government, however, the incentive to save is reduced by the tax. Although the tax is used to provide infrastructural services which increase the productivity of private capital, each household takes the volume of government services allocated to it as given and recognizes only the decline to the net benefits from savings due to the tax. The imposition of an income tax thus reduces private saving.

By this model the economy grows because households save and pay taxes, thereby increasing productive government services, the capital stock, and output. Efficient taxation makes the marginal product of capital independent of the amount of capital, so growth can continue indefinitely. The rate of growth of consumption and private capital is determined by the difference between the benefits from accumulating private capital, or the marginal product of capital that accrues to the household, and the cost of postponed consumption represented by the rate of time preference. Since the size of the benefits that accrue to the household from saving and investing in private capital

depends on the tax rate, the rate of growth of consumption also depends on the tax rate. However, Barro's specification of the technologies for producing output and government services is such that the marginal product of capital is independent of the level of capital and only depends on the tax rate. Since output is proportional to private capital, the output growth rate equals the capital growth rate, and with a constant tax rate, tax revenue or, equivalently, the volume of government services grow at the same rate as output. The constant tax rate means that the marginal product of capital after tax is constant and with a fixed rate of time preference and an isoelastic utility function, the growth rate of consumption will remain constant and equal to the growth rate of output.

When the tax rate is increased permanently, the household retains a smaller fraction of after tax-income. The benefit a household expects to receive from saving another dollar is smaller and therefore the level of savings falls. However, since the increase in the tax rate increases the rate at which the government service is provided, the actual benefit from saving and investing another dollar is increased. At low tax rates, Barro assumes that the second force dominates the first and thus an increase in the tax rate increases the rate of growth of consumption. At a high enough tax rate the beneficial effect of taxation is dominated by its deleterious effect, so that an increase in the tax rate results in a reduced rate of growth of consumption. There is, therefore, some level of taxation at which any change in the tax rate results in a reduced rate of growth of consumption and this tax can be considered optimal. If government services were sold in a competitive market, given the Cobb - Douglas technology assumed in the model, the share of the services in total output would be equal to the elasticity of output with respect to government services. i.e., to the percentage increase in output that

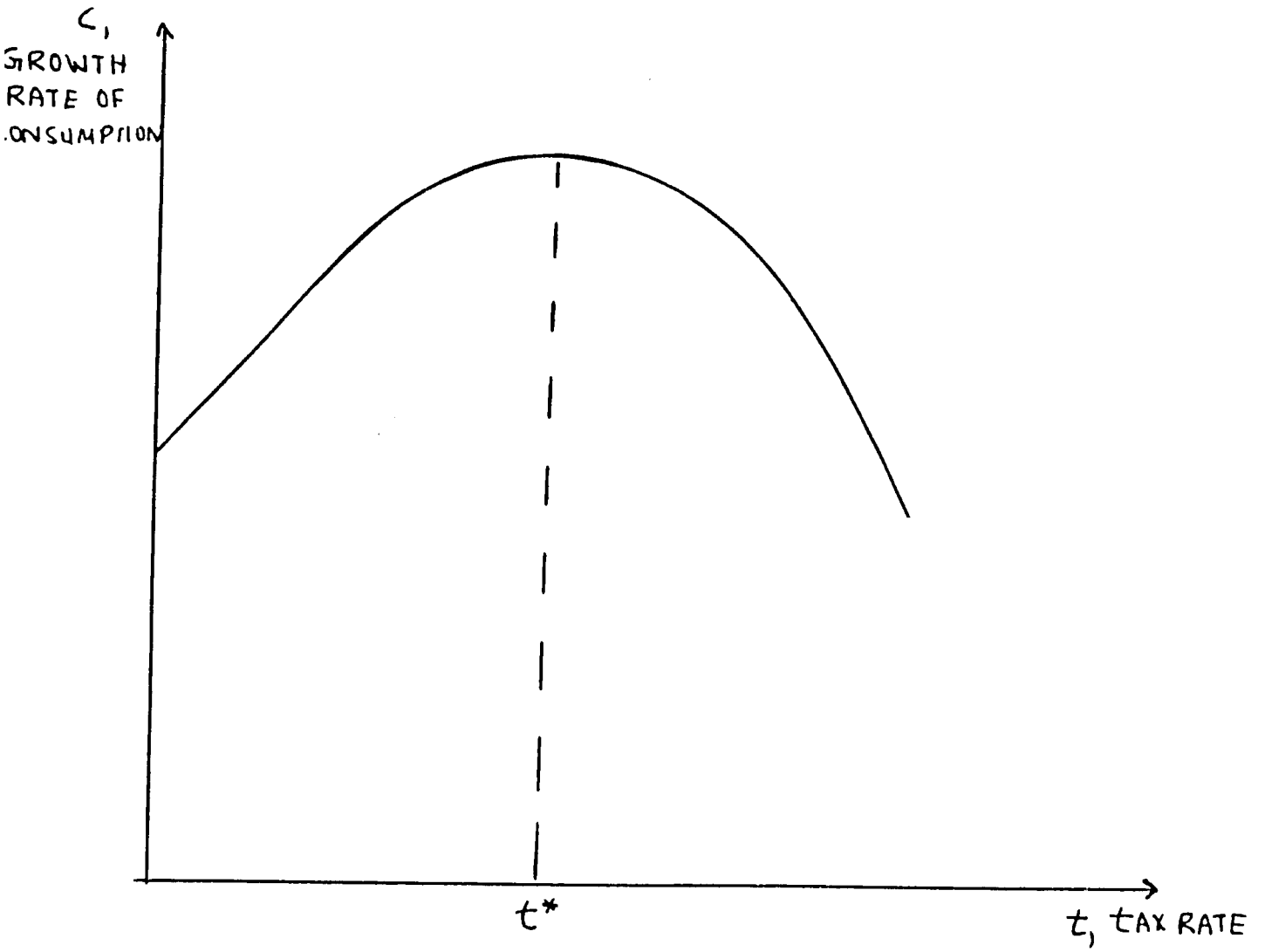

FIGURE I.

would result from a one-percent increase in government services, holding private capital constant (α). A competitive equilibrium is known to maximize output. If the government collects from households in taxes the fraction of their output they would have paid for government services had they been provided by a competitive market, the corresponding tax rate would be the optimal one in the sense that the rate of growth of income and consumption would then be the highest achievable. Since the government expenditure is financed by a flat income tax rate, this optimal tax rate is also the share of government expenditure in total output, or $t^* = \alpha$. The corresponding relationship between the tax rate, t, and the rate of growth of consumption, c, is depicted in Fig. 1. A tax rate of t^* is the rate that achieves the maximum growth rate in consumption.

A similar relationship could be depicted between the tax rate and the rate at which income is saved, or the investment rate. Consider a reduction in the tax rate from t^*. At the optimal tax rate t^*, an additional unit of savings results in an increase in output equivalent to the marginal product of capital. Part of this increase in output is taxed away by the government and used to provide a higher level of government services. The remainder accrues to the individual. A higher level of government services, in turn, increases the marginal product of capital and makes an additional savings more productive. However, individuals assume that their own decision to save and invest an additional dollar will not change the level of government services they receive. Hence they behave as as their return from savings is the after-tax marginal product of capital with a fixed level of government services. This results in a suboptimal level of savings at the tax rate t^*. If the tax rate were lowered, the individual would retain a larger portion of the returns to his investment, and would then have a higher incentive to save. Hence, the savings rate reaches a maximum at a tax rate t_1 that is lower than t^*.

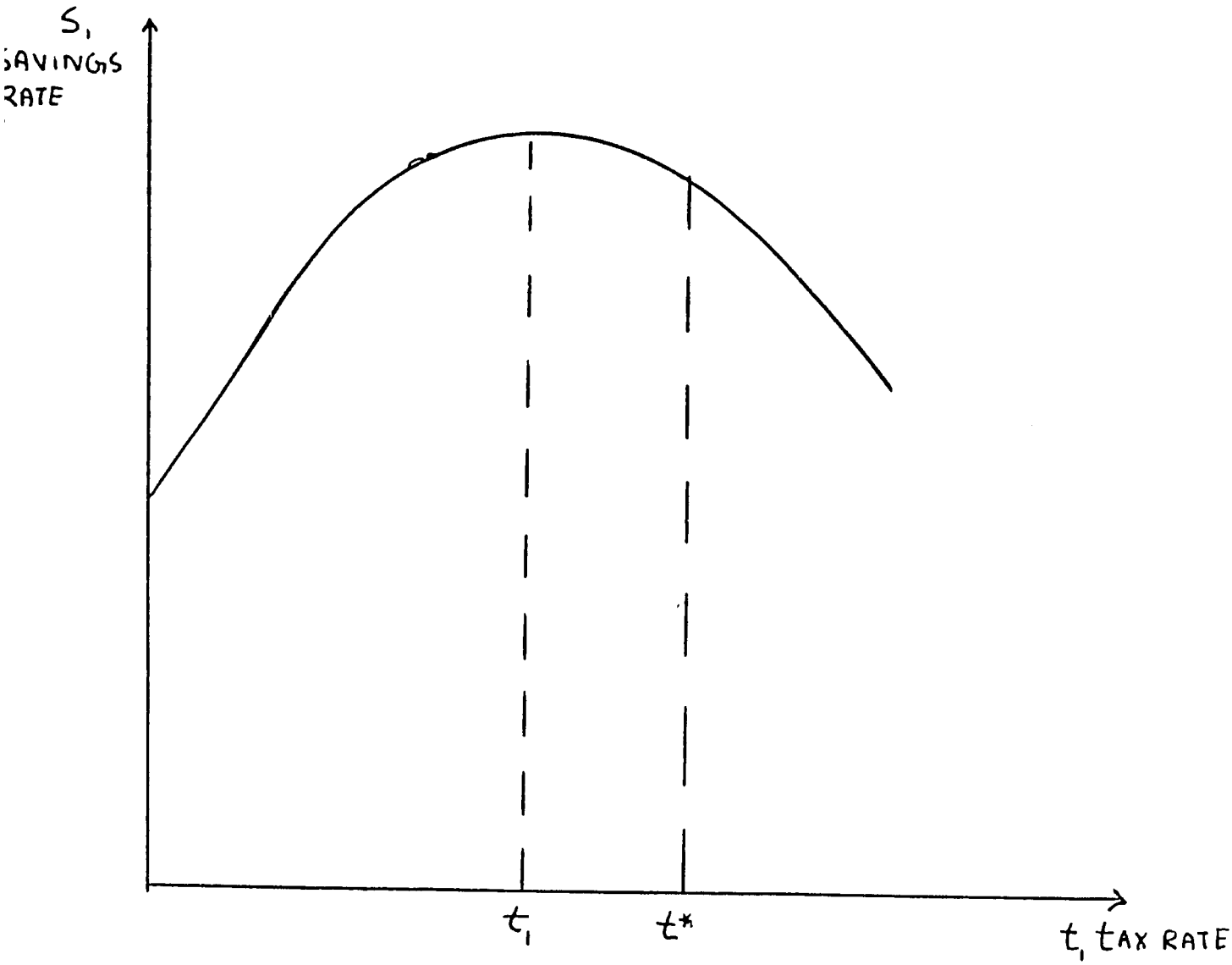

FIGURE II

Stated differently, in a decentralized economy, a tax rate t^* that achieves the maximum rate of growth in consumption does not achieve the maximum rate of savings. This relationship is depicted in Fig. 2.

A PLANNING PROBLEM FOR THE GOVERNMENT

As we saw in the earlier section, a government that must finance its expenditures with an income tax chooses the tax rate $t^* = \alpha$ if its objective is to maximize the rate of growth of consumption. However, such rate of taxation results in sub-optimal savings and capital accumulation. Consider, in contrast, a government that may choose not only the tax rate but also the rate at which households save. It would choose a higher rate of savings and hence be able to achieve a higher rate of growth in consumption than with the optimal income tax when savings decisions are made by households. This result follows from the gap between the social benefit and private benefit from an additional dollar of savings. Private individuals do not consider the benefit resulting from their paying more taxes since they consider the level of government services they receive to be independent of their own tax payments. However, when aggregate tax revenue increases, more services are provided and so long as government services are productive, the social benefit from an additional dollar of saving is higher than the private benefit. Thus the socially optimal savings rate is higher than the privately optimal savings rate when government services are financed by an income tax. Decentralized saving decisions in this case result in too low a saving rate and hence too low a growth rate even if the income tax is chosen optimally. The optimal tax rate remains the same but the growth rate is higher when the government can dictate the rate on individual savings.

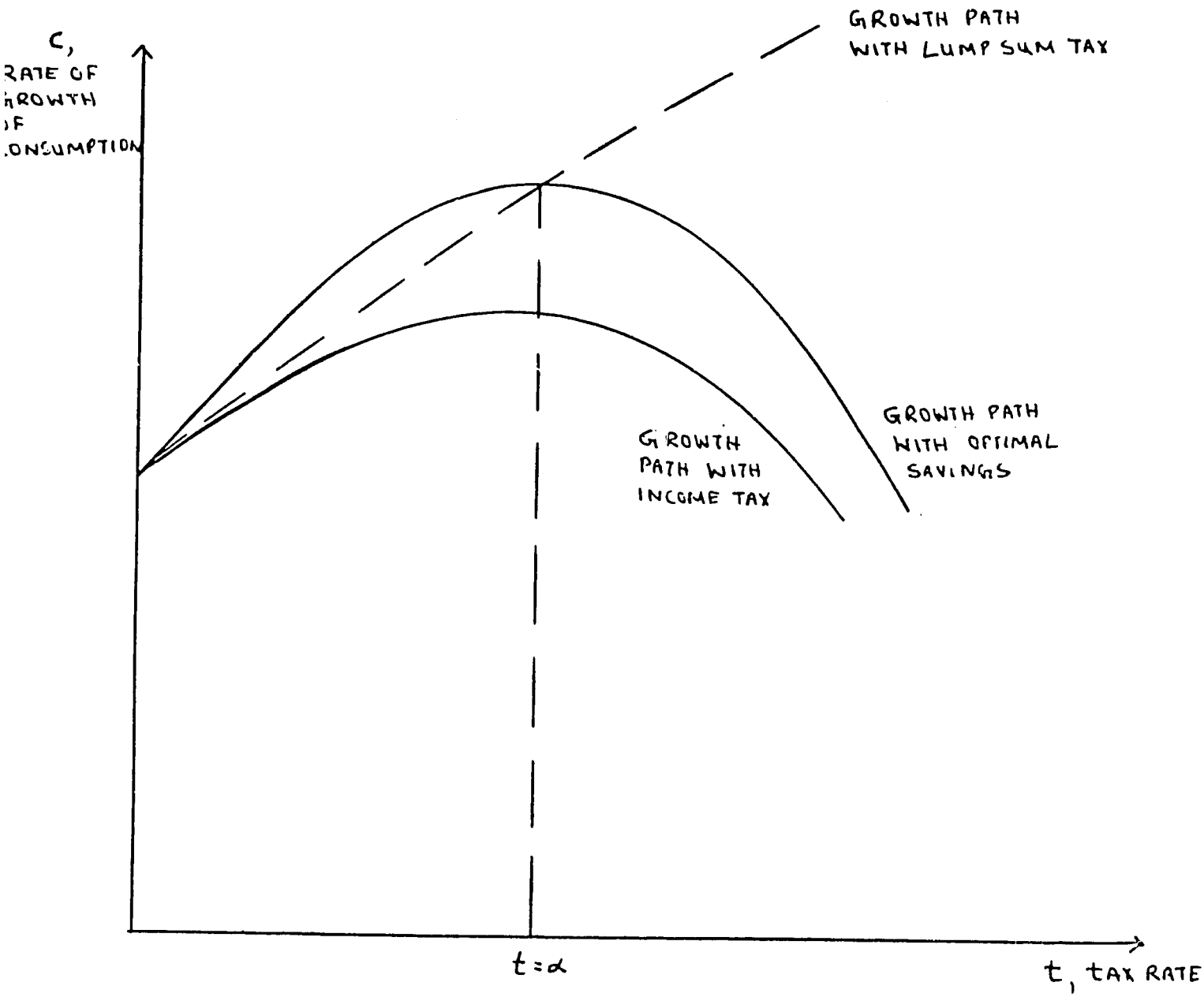
C,
RATE OF
GROWTH
OF
CONSUMPTION
GROWTH PATH
WITH LUMP SUM TAX
GROWTH PATH
WITH OPTIMAL
SAVINGS
GROWTH
PATH WITH
INCOME TAX
t = α
t, TAX RATE

FIGURE III

GOVERNMENT EXPENDITURE FINANCED BY A LUMP SUM TAX

Suppose that instead of levying an income tax to finance its expenditures, the government imposed a lump sum tax, which does not change with income. The disparity between private and social benefits from an additional dollar of saving that arises with an income tax now vanishes since provision of government services is not affected by different savings rates. Moreover, the benefits that households receive from an additional dollar of savings are now higher than with an income tax since no tax is imposed on the returns to savings. Hence the rate of savings as well as the rate of growth of consumption is higher with a lump-sum tax than with an income tax. Both the rate of savings and the rate of growth of consumption are also the same as that achieved when the government dictates the rate of savings, since the amount paid is not affected by the level of savings and hence there are no detrimental effects on the incentive to save. The maximum possible rate of savings is achieved here, however, only if the provision of government services corresponds to a tax payment per dollar of income that is equivalent to the rate the households would pay in a competitive market for the provision of such services. If the share of government expenditures in total output is set suboptimally, then a lump sum tax will not provide the optimal rate of growth in consumption. If the share of government is too high, each individual has an excessive incentive to save and expand output since the marginal product of private capital, which depends on the quantity of government services, is too high. Similarly if the tax rate or share of government in the economy is too low, there is an inadequate incentive to save and the growth rate of consumption is low. This is depicted in Fig. 3.

AN ALTERNATIVE SPECIFICATION

In the previous sections it was assumed that each household considers the

level of public services it receives to be independent of how much it saves. However, the provision of certain public services like police and fire protection are generally proportional to the amount of property that the household has to protect. In such cases, it might be more appropriate to assume that households choose their savings on the assumption that the ratio of the government services they receive to the output they produce, rather than the absolute amount of these services will be maintained at a constant level.

With such a specification, an optimal income tax rate achieves the maximum rate of growth in consumption, a rate otherwise possible only with government-dictated savings. An income tax now works like a user fee because when households save more to increase income, they receive more government services and pay an additional amount in taxes, which is proportional to the increase in government services they receive. A decision by households to save so as to raise output by one unit leads to an increase in government services and tax revenue by an amount equal to the tax rate. Since households are effectively paying for the services they receive, the optimal rate of growth is achieved.

An optimal lump-sum tax would now result in too much saving and growth since a household's decision to raise its savings, hence output, brings more services that the household does not have to pay for. If the household saves an additional unit it receives the entire return from it, but because the ratio of government services to output is constant, it receives more government services that do not require extra tax payment, which further increases the return it receives on savings. There is, therefore, too much savings at the expense of current consumption. The resulting growth rate is suboptimal since it does not maximize consumer welfare.

EXTENSIONS OF THE MODEL

Suppose that the government also provides some services that are consumed directly by households. The growth maximizing share of government expenditures designed to provide both inputs for production and consumer goods still remains $t^* = \alpha$ as in the case when the government provides only services that are crucial to the private production activity. However, the growth rates of consumption and of savings are now lower for all levels of the tax rate because part of the revenue collected from tax is spent on increasing present consumption rather than future consumption. The forced saving aspect of government taxes is now smaller in magnitude.

If the government is modeled as being run by an agent who seeks to maximize his own utility rather than that of the households (as assumed earlier) the results are similar to those in the previous paragraph. In essence, since the agent attempts to increase his own personal consumption, the tax rate that is optimal for the agent would be higher than the share of government-provided services in total output. The optimal expenditure share remains $t^*=\alpha$ but part of the forced savings is used to finance the present consumption of the government agent. The rate of growth of consumption is therefore consistently lower under a self-interested government relative to a benevolent government.

SOME EMPIRICAL IMPLICATIONS

Within the framework of optimizing governments, cross-sectional variations in the share of government services in total output arise only if the optimal tax rate or expenditure shares vary across countries. Since the optimal tax rate equals the percentage increase in output caused by a one- percent increase in government services, α, it can vary only when the latter varies across countries. This parameter, α, which is a measure of the productivity of

government services relative to private capital, could vary across countries for any number of reasons including geography, share of agricultural production, or urban density. The model predicts that an increase in this measure of the productivity of government services relative to private services will reduce the rate of growth of consumption and the rate of savings if taxation is via a proportional income tax. Since the optimal tax rate is higher the higher is α, it reduces the propensity to save, thus leading to a lower level of capital accumulation and economic growth. Under these assumptions, even if all governments operate to achieve maximum growth, there may be an inverse relation observed empirically between the size of government, or its share in the expenditures, and the rates of income growth and consumption, across different countries.

CONCLUSION

In this paper, Barro analyzes the role of government as an endogenous "engine of growth" using various specifications of this role. He shows that if the government share of expenditure to total output is chosen optimally a lump sum tax is superior to an income tax for types of public services where the level of service provided to households does not vary with their income. However, lump sum taxation becomes suboptimal if services were provided to each household in a manner proportional to their income. A flat income tax rate is optimal when government services are rendered proportionally to households' incomes since an income tax then operates as a user fee. The main behavioral proposition of Barro's analysis is that optimal growth necessitates a supportive level of government services, and that if governments were "benevolently" pursuing a maximization of growth rate, there would be little correlation between an economy's growth rate and the "size of its government" as measured by the share of government expenditures in national income. Since

each government chooses an expenditures share which maximizes growth, variations in growth rates and government sizes may be largely independent. However, with a fixed income tax rate there may also be an inverse correlation between the growth rate and the size of government if variations in the latter were proportional to differences in the productivity of government services relative to private capital services in producing output.

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THE PROBLEM OF DEVELOPMENT:

Exploring Economic Development
Through Free Enterprise

Proceedings of the Institute's First International Conference
May 27 - 29, 1988

PART II: Papers and Discussants' Comments

CONFERENCE AGENDA AND LIST OF CONFERENCE PARTICIPANTS

1. Author: Gary Becker and Kevin Murphy.
University of Chicago
Title: "Economic Growth, Human Capital and Population"

Discussions by:
Edward C. Prescott, University of Minnesota
Henry Wan Jr., Cornell University

2. Author: Mark Rosenzweig
University of Minnesota
"Population Growth and Human Capital Investments: Theory and Evidence"

Discussions by:
Sherwin Rosen, University of Chicago
Finis R. Welch, University of California, Los Angeles

3. Author: Paul Romer
University of Rochester
Title: "Endogenous Technological Change"

Discussions by:
Robert Vishny, University of Chicago
Lawrence Summers, Harvard University

4. Author: Paul Krugman
Massachusetts Institute of Technology
Title: "Endogenous Innovation, International Trade and Growth"

Discussions by:
Gene Grossman, Princeton University
Andrei Schleifer, University of Chicago

5. Author: Robert King and Sergio Rebelo
University of Rochester and Northwestern University
Title: Public Policy and Economic Growth: Developing Neoclassical Implications"

Discussions by:
Arnold C. Harberger, University of California, Los Angeles
Stanley Fischer, The World Bank

6. Author: Dale Jorgenson and Kun-Young Yun
Harvard University
Title: "Tax Policy and U.S. Economic Growth"

Discussions by:
Kenneth Judd, Northwestern University
Christophe Chamley, Boston University

7. Author: S. C. Tsiang
Chung-Hua Institution for Economic Research and Cornell University
Title: "Success or Failure in Economic Take-off"

Discussions by:
Gregory Chow, Princeton University
Ronald Findlay, Columbia University

8. Author: Robert Barro
Harvard University
Title: "Government Spending in a Simple Model of Endogenous Economic Growth"

Discussions by:
Robert Hall, Hoover Institution, Stanford University
Daniel Gros, International Monetary Fund

ECONOMIC GROWTH, HUMAN CAPITAL AND POPULATION GROWTH

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1. Introduction

In the Malthusian model, the typical person marries earlier and has more children when income is higher. Neoclassical growth models of the Solow-Cass variety neglect the demand for children and concentrate on the response of investments in physical capital to changes in rates of return due to autonomous technological change and to changes in the capital-labor ratio. The analysis of human capital developed partly in reaction to the neglect by both Malthusian and neoclassical models of investments in the quality of the labor force. The human capital approach did not produce a model of growth, but it stimulated empirical studies in many countries of the relation between economic growth and education and other training.

We believe that a promising model to explain both persistent growth and economic stagnation, as well as many other features of development, combines the neoclassicists' emphasis on rates of return on investments in capital, the human capitalists' emphasis on the special properties of education, on-the-job training, and other investments in knowledge and skills, and the Malthusian emphasis on the behavior of fertility. Although our paper is theoretical, we have been guided and motivated by several generally accepted empirical regularities associated with growth and development. A brief discussion of these regularities will provide a perspective on the theoretical analysis in this paper.

Expenditures on schooling and, presumably, also expenditures on on-the-job training and other types of human capital grow rapidly as countries develop even when measured relative to expenditures on physical capital. Fertility sharply declines with development, although the timing varies from country to country. We believe that the association between

growing human capital and declining fertility is not accidental: lower fertility induces greater investment in human capital by raising parental altruism toward each child, and higher human capital discourages fertility by raising the cost of children.

Children move out of the labor force into schools to invest in the human capital that becomes more important with development. Married women shift into the market sector when they have fewer children, and when the growth of their human capital greatly raises the earnings they forego by using time at household activities. Along with this shift between the household, market, and education sectors, specialization by occupation and education, trade between regions and countries, and other measures of the division of labor increase as countries grow.

Wage rates continue to rise as countries get richer. Much less is known about the path of real interest rates, although they do not appear to increase (or decrease) systematically with development. In our model, if tastes are stable, real interest rates first fall and then rise as countries pass from underdevelopment to development and growth.

Growth and development patterns vary enormously: countries in the West like Great Britain and the United States have grown for over 100 years without slowing down, newly industrialized countries of Asia are growing at unprecedented rates since the 1950s, and many African and some Asian countries remain poor. Although we do not pretend that our theory (or any other available theory) explains the rich variety of growth experiences among countries, our approach does throw light on some of these different experiences. It shows that whether countries stagnate at low incomes or take off with rapid rates of growth depends on temporary events, government

policies, and luck, as well as on permanent differences in preferences and productivity.

We make special assumptions about these preferences and technology. Parents are altruistic and care about the quantity and quality of children, where quality is measured by the utility of children generated by the human capital invested in children and the physical capital bequeathed to them. Physical capital and consumption are produced with the same technology. The accumulation of human capital is proportional to the effective human capital stock of parents and other teachers, where the factor of proportionality depends on the time devoted to teaching and to learning.

The next two sections set out a simple version of the model with endogenous fertility and a constant rate of return on investments in human capital. There are three steady states: one is locally stable with high fertility, no human capital, and low per capita income; one is unstable with some human capital; and one is locally stable with constant fertility and perpetual growth in per capita income through a perpetual accumulation of human capital per capita.

The intermediate steady state is unstable because a rise in income near this state raises the cost of children and reduces fertility. The number of children determines the degree of altruism per child, and hence the generational discount rate. Therefore, a decline in fertility as income grows raises the preference for future consumption, which increases the amount invested in each child. This pushes the economy toward higher incomes and further away from this development steady state. The results in these two sections are closely related to those in Tamura [1987].

Section 4 expands the model to distinguish more sharply between endowments of unskilled labor available to each person and accumulated human capital. The rate of return on human capital investments is greater when human capital is larger relative to the fixed amount of unskilled labor. The same three types of steady states appear as in sections 2 and 3, but the development steady state is now unstable because the rate of return increases when human capital becomes larger.

In either case, the economy takes off toward perpetual growth if its human capital exceeds the stock at the development steady state, and the economy declines toward the poor steady state if its human capital is less than this stock. If the rate of return rises sharply as human capital increases, or if fertility declines sharply as income increases, the take off toward perpetual growth is sufficiently rapid to create a discontinuity in the policy functions for both human capital and fertility.

Section 5 considers exogenous technical progress, augmentable physical capital, and fixed natural resources. Human capital grows relative to physical capital as an economy develops, and both increase at constant rates in the perpetual growth steady state. We show that the per capita rate of growth in income and consumption may increase when natural resources become more important because fertility is reduced.

A large destruction of physical capital, perhaps due to a war, induces greater investment in physical capital to replace the capital stock lost. We show that under reasonable assumptions, the destruction of physical capital may not reduce and may stimulate investment in human capital. The reason is that a decline in physical capital reduces foregone wages for individuals investing in human capital and encourages human

capital investment. As long as human capital investment does not fall, per capita income would eventually recover to and might even exceed its levels had physical capital not been destroyed.

This paper only considers models where all persons in the same generation have the same capital and allocate their time in the same way. However, some of the most surprising implications of the model relate to specialization in the acquisition of human capital between persons engaged in different tasks, especially between teachers and workers. A subsequent paper will consider this division of labor.

The analysis in this paper grew out of our work on addiction. While working out our analysis of addiction with multiple steady states (Becker and Murphy [1988]), we concluded that endogenous fertility combined with the complementarities of an "addictive" or learning-by-doing human capital technology produces a growth model with multiple steady states. Greater human capital raises the productivity of investments in human capital, just as greater past consumption of addictive goods raises the marginal utility of current consumption. We were making progress in working out the implications when we became aware of several papers on growth with similar technologies. Especially significant are the papers by Romer [1986] and Lucas [1988]; also see King and Rebelo [1986], and Prescott and Boyd [1987]).

Our contribution in this paper to the new literature on long-term economic growth lies in endogenizing fertility and population growth, in distinguishing between endowments of unskilled labor and skills, and in analyzing the interaction between human capital, physical capital, and fixed natural resources. These additions to the recent growth literature explain

our emphasis on steady states with low per capita income and little human capital, and on take-offs toward growth marked by declining fertility and rising investments in human capital.

To prevent the paper from becoming still longer, we excluded several related topics that are important to development. These include specialization in the accumulation of human capital, the effect of multiple consumer goods when some goods are less human capital intensive than others, trade in goods and people between countries at different stages of development, savings and growth when present consumption and past consumption are linked through habitual behavior, and the contribution of various public policies to the success of development programs. Subsequent work will consider these major topics.

2. The Model

We assume a simple overlapping generations model where each person lives for two periods, childhood and adulthood. A person has children at the beginning of the adult period -- we abstract from marriage and the spacing of children. The utility of parents depends on their own consumption (c) and separably on the number of children (n) and the utility of each child. In essence, we assume that parents have children and invest in their human capital because parents are altruistic toward children. If the utility of children enters linearly in the parental utility function, then

$$V_t = u(c_t) + a(n_t)n_tV_{t+1} \quad \text{where } u' > 0,\ u'' < 0, \text{ and } a' < 0, \qquad (2.1)$$

where $a(n_i)$ is the degree of altruism per child (for a full development of this utility function, see Becker and Barro [1988]).

Parents must allocate goods and time toward rearing and investing in children. Each child requires f units of consumption goods and v units of parental time where f can be negative if child labor contributes to family income. In addition, parents can spend time (h) to invest in the human capital of children. We assume that a parent invests equally in each child, so that the time budget equation is

$$(h+v)n + \ell = 1 \ . \tag{2.2}$$

where ℓ is working time and the given amount of leisure is ignored.

Each adult has a a fixed amount of unskilled labor ($\bar{H}$) that is produced by the fixed expenditure of time (v) and goods (f). Consumption is produced with constant returns to scale in the amount of effective working time, with unskilled labor and human capital (H) being perfect substitutes in producing effective time (we ignore physical capital until section 5). The budget equation for consumer goods is

$$c + fn = (d\bar{H}+H)\ell, \tag{2.3}$$

where d converts $\bar{H}$ into units of H. The wage rate is simply $w = d\bar{H} + H$.

We do not assume that human capital and consumption are necessarily produced with the same or similar technologies. The crucial assumption is that investments in the human capital of children or other students is more productive when the teacher's human capital is greater. -A

positive effect of the stock of human capital on the productivity of investments is commonly assumed in the human capital literature, whether the reference is to parents investing in children (see Becker and Tomes [1986]) or to persons investing in their own human capital (see, e.g., Ben Porath [1967]). The assumption is also part of the mastery learning concept in education, where learning of more complicated mathematics or other materials is more efficient when the building blocks of elementary concepts are mastered (see Bloom [1976]).

The human capital of a child is produced with his own time (assumed to be fixed) and the time his parents spend investing in him (h). In effect, h gives the ratio of teacher's time to student's time, and we assume in this paper that the production of human capital is proportional to the teacher-student ratio. Later work will modify this assumption to analyze specialization in the accumulation of human capital. The production of human capital is also proportional to the teacher's effective stock of human capital:

$$H_{t+1} = Ah_t(b\bar{H}+H_t) \ , \tag{2.4}$$

where b converts $\bar{H}$ into H units in the production of human capital. The term A measures the productivity of time and capital spent investing in children. This technology is similar to that in Uzawa [1965], Lucas [1988], King and Rebelo [1986], and Rosen [1976] except that they do not consider raw labor.

Human capital is knowledge embodied in individuals that is not freely available to others. The economics of embodied knowledge is very

different from that of disembodied knowledge -- exemplified by a simple blueprint easily understood by people with little human capital. The coefficient A in the production function for human capital includes the effect of disembodied knowledge on the productivity of investments in embodied knowledge. Although we analyze how investments in embodied knowledge respond to changes in A -- perhaps caused by changes in the amount of disembodied knowledge -- we do not endogenize the growth of disembodied knowledge (Romer's paper at this Conference [1988] models the accumulation of disembodied knowledge).

We first develop a simplified analysis with n exogeneous and $b = d = 1$, so that substitution between raw labor and human capital is unit for unit and is the same in the consumption and capital producing sectors. Parents maximize their utility in equation (2.1), subject to the time constraint in equation (2.2), the production function in equation (2.3), the investment equation (2.4), and the stock of initial human capital (H_t). The first order condition for human capital investment is

$$u_t'(\bar{H}+H_t) = a(n_t)A(\bar{H}+H_t)\,\frac{dV_{t+1}}{dH_{t+1}}\,, \tag{2.5}$$

This equation gives the utility-maximizing investment provided V_t is concave in H_t and $u'' < 0$, .

The left hand side of (2.5) gives the utility cost of spending an additional hour investing in each child rather than at work. The right hand side gives the marginal benefit from an additional hour spent investing discounted by the rate of preference for parents' consumption over

children's consumption -- we call this the rate of altruism-time preference

Equation (2.5) can be expressed as

$$\frac{u'_t}{a(n_t)V'_{t+1}} = A \text{ , where } V'_{t+1} = \frac{\partial V_{t+1}}{\partial H_{t+1}} \tag{2.6}$$

The marginal product of an additional hour spent on children is independent of h. With the assumption that b = d, the rate of return is also independent of the initial stock of human capital (H_t) because an increase in H_t raises foregone earnings from investments by the same percentage as it raises returns. The latter rises because of the positive effect of parents' knowledge on the productivity of investments in children. The constant rate of return to investments in human capital idstinguishes this model from those used in the neoclassical model.

An increase in H_{t+1} indirectly provides more resources for consumption in period t+1 by raising the productivity of investments in producing H_{t+2}. Therefore, the effect of H_{t+1} on the consumption and the utility of each child is, holding future human capital and consumption constant,

$$\begin{aligned} V'_{t+1} &= \frac{\partial V_{t+1}}{\partial c_{t+1}} \frac{dc_{t+1}}{dH_{t+1}} = u'_{t+1} \frac{d[\ell_{t+1} w_{t+1}]}{dH_{t+1}} \\ &= u'_{t+1}\left[\ell_{t+1} - w_{t+1} n \frac{dh_{t+1}}{dH_{t+1}}\right] , \end{aligned} \tag{2.7}$$

with $$w_t = \frac{dc_t}{d\ell_t} = \bar{H} + H_t. \tag{2.8}$$

Since we are holding H_{t+2} constant, we can find the saving in h_{t+1} from an increase in H_{t+1}:

$$\frac{dH_{t+2}}{dH_{t+1}} = 0 = A_{t+1}h_{t+1}\left[\frac{(\bar{H}+H_{t+1})}{h_{t+1}}\frac{dh_{t+1}}{dH_{t+1}} + 1\right] \tag{2.9}$$

Therefore,

$$V'_{t+1} = u'_{t+1}\ [\ell_{t+1} + nh_{t+1}] = u'_{t+1}(1-vn)\ , \tag{2.10}$$

where the right hand side follows from the time budget equation (2.2). Using (2.10), we can write the arbitrage condition in equation (2.6) as

$$\frac{u'_t}{a(n_t)\cdot u'_{t+1}} = R_t = 1 + r_t = (1-vn)A\ . \tag{2.11}$$

The rate of altruism-time preference ($1/a(n_t)$), adjusted for the change over time in the marginal utility of consumption (u'_t/u'_{t+1}), equals the marginal rate of return on capital.

The rate of return on investments in human capital is constant, and depends only on the productivity of investments (A), the fixed time cost of rearing children (v), and the level of fertility, and it is independent of the time allocated to investment. The rate of return is also independent of the initial stock of human capital because an increase in human capital

raises the productivity of investment and foregone consumption by the same percentage.

If $u(c) = c^{\sigma}/\sigma$, $(0 < \sigma < 1)$, the arbitrage condition becomes

$$(1+g) = (a(n)(1-vn)A)^{1/1-\sigma} , \tag{2.12}$$

where $1+g = c_{t+1}/c_t$. The rate of growth in per capita consumption is positive, zero, or negative as the rate of altruism-time preference is less than, equal to, or exceeds the rate of return on investments. The rate of growth in consumption is constant and is independent of initial conditions, as measured by the initial capital stock, because the rate of return on investments is constant. The economy moves immediately to the consumption growth path with no initial period of adjustment.

Consumption per capita would grow over time at a constant rate from any initial capital stock if the constant rate of return on investment exceeds the rate of altruism-time preference. Consumption would fall at a constant rate from any initial capital if the return is below adjusted time preference (see Figure 1). Note that per capita growth would continue indefinitely even without continuing advances in productivity (the same points are made by Lucas [1988] and by King and Rebelo [1986]).

The economy is underdeveloped when $H_t = 0$ because each person is unskilled and earns only the endowed wage rate, $\bar{H}$. Figure 1 shows that this underdevelopment position is not a steady state if the rate of return on investments exceeds altruism-time preference. For then, consumption and human capital per person rise over time, regardless of the initial capital stock. However, this underdevelopment position is a steady state if the

rate of return is less than altruism-time preference. Then consumption falls over time towards that position, regardless of the initial capital stock.

From the production function,

$$1+g = \frac{c_{t+1}}{c_t} = \frac{(\bar{H}+H_{t+1})}{(\bar{H}+H_t)} \frac{(1-vn-h_{t+1}n)}{1-vn-h_t n} \tag{2.13}$$

If H_t is large relative to $\bar{H}$, the first term on the right hand side is approximately Ah_t (see equation (2.4)). Then, the right hand side would be constant only if $h_t = h_{t+1} = h^*$. By equation (2.13),

$$h^* = \frac{1+g}{A} = A^{\sigma/1-\sigma}[a(n)(1-vn)]^{1/1-\sigma} \tag{2.14}$$

In the growth steady state, the fraction of time spent investing in human capital is higher when investments are more productive (A), fertility (n) is lower, the pure degree of altruism-time preference (defined by 1/a(1)) is larger, the fixed cost of children (v) is lower, and substitutability between the consumptions of different generations (σ) is larger.

Even when fertility is constant and exogenous, the fertility rate still significantly affects growth rates and the time spent investing in each child. Since the degree of altruism-time preference and the rate of return on investments are both negatively related to the number of children, an increase in fertility lowers investments per person and the growth rate in consumption per person.

For all $n < n'$, whre n' is defined by $a(n')(1-vn')A = 1$, the rate of return on investments exceeds the rate of altruism-time preference, and the the economy moves to the perpetual growth steady state from all initial values of human capital. However, the rate of return is below altruism-time preference when $n > n'$, and the perpetual growth steady state is then globally unstable. Instead, there is a globally stable steady state at underdevelopment with no human capital and with per capita income entirely determined by the endowment of unskilled labor ($\bar{H}$).

We have so far followed neoclassical and recent growth models in assuming that fertility and population growth are exogenous to utility maximization. But our assumption that families are major providers of capital to the young naturally leads to the incorporation of fertility into the network of utility-maximizing decisions. Parents choose both the number of children and the investments in each child. A larger number of children discourages investments in each one by raising the degree of altruism-time preference for the present and lowering the demand for future consumption. Similarly, a larger investment in each child discourages the demand for children since additional children are more expensive when investments are greater.

To simplify the analysis of this interaction between endogenous fertility and endogenous investments, we assume that the altruism function has a constant elasticity $a = \alpha n^{-\epsilon}$, where $\alpha < 1$ and $0 < \epsilon < 1$. Initially we assume that endowments and fixed goods costs are negligible ($\bar{H}=f=0$), so that the first order condition for n is

$$(1-\epsilon)\alpha n_t^{-\epsilon} V_{t+1} = u'(c_t)(v+h_t)w_t, \text{ where } w_t = H_t. \qquad (2.15)$$

The right hand side shows that the marginal cost of children depends positively on the time spent investing in each child. The marginal benefit of children (on the left hand side) is negatively related to the number of children and positively related to the utility level of each child.

The first order condition in equation (2.5) with respect to the investment rate h_t becomes

$$\alpha n_t^{-\epsilon} A V'_{t+1} = u'_t \quad . \tag{2.16}$$

Second order conditions for equations (2.15) and (2.16) are $u'' < 0$ and $\sigma + \epsilon < 1$. The second condition is required to insure positive values of n (see the appendix).

If the elasticity of u with respect to c is also constant, an economy described by the first order conditions (2.15) and (2.16) immediately goes to a steady state regardless of the initial capital stock. It is easy to show that the steady state values $h_t = h^*$, $n_t = n^*$ and $1 + g = c_{t+1}/c_t = H_{t+1}/H_t = Ah^*$ satisfy these equations for all t. Divide equation (2.15) by equation (2.16) to get

$$\frac{(1+g)(1-\epsilon)A^{-1}V_{t+1}}{V'_{t+1}H_{t+1}} = v + (1+g)A^{-1} \tag{2.17}$$

Along the steady state growth path,

$$\frac{V'_{t+1}H_{t+1}}{V_{t+1}} = \frac{d \log V_{t+1}}{d \log H_{t+1}} = \sigma = \frac{d \log u(c)}{d \log c} \tag{2.18}$$

since an increase in H_{t+1} by a given percentage increases all $c_{t+i}(i=1\ldots)$ by the same percentage. Then solving (2.17) for the growth rate gives

$$1 + g = \frac{c_{t+1}}{c_t} = \frac{H_{t+1}}{H_t} = \frac{v\sigma A}{1-\sigma-\epsilon} \tag{2.19}$$

that is independent of H_t. Similarly, by substituting for 1 + g into equation (2.11) we get the steady state fertility rate, n*, as the unique solution to:

$$\alpha n^{*-\epsilon}(1-vn^*) = \frac{(1+g_c)^{1-\sigma}}{A} = \left(\frac{\sigma}{1-\epsilon-\sigma}\right)^{1-\sigma} v^{1-\sigma}A^{-\sigma} \quad . \tag{2.20}$$

The growth rate and the fertility rate depend only on the parameters v, ϵ, σ, and A.

Comparing equation (2.19) to equation (2.14) shows that endogenizing fertility has an enormous effect on the determinants of per capita growth. More productive investments and easier substitutability of consumption over time still raise per capita growth. But an increase in the time cost of children (v) raises rather than lowers the per capita growth rate if fertility is endogenous rather than exogenous. The explanation is provided by equation (2.20). An increase in child costs reduces fertility, which raises the degree of preference for future consumption and hence raises the desired rate of growth in per capita human capital and consumption. An increase in the elasticity of per capita altruism with respect to the number of children raises the per capita growth rate for similar reasons.

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By differentiating equation (2.20), it is straightforward to show that

$$\frac{dn^*}{dv} < 0, \ \frac{dn^*}{d\alpha} > 0, \ \frac{dn^*}{dA} > 0, \text{ and } \frac{dn^*}{d\epsilon} < 0 \ . \tag{2.21}$$

An increase in the productivity of investment (A) raises both fertility and the growth rate of per capita income and consumption. Endogenizing fertility eliminates the positive effect of pure altruism-time preference (α) on per capita growth rates, but it does introduce a positive effect on fertility. Consequently, an increase in α raises the growth rate of aggregate income and consumption.

Since time preference and fertility are exogenous in the neoclassical model, a change in the degree of time preference does not affect steady state per capita and aggregate growth rates in this model because the interest rate simply changes by the same extent as time preference. That a change in pure altruism-time preference does not affect the per capita growth rate in our model is an artifact of the constant elasticity functional form ($\alpha n^{-\epsilon}$). The important general implication of this special result is that greater preference for the present generation could either lower or raise the per capita growth rate depending on how a change in n affects the elasticity of per capita altruism with respect to n.

Although a change in the cost of children (v) has opposite effects on fertility and per capita growth, the effect on fertility dominates, so that an increase in v necessarily lowers aggregate growth, as it does when fertility is exogenous. Equation (2.19) shows that 1 + g is proportional to

v. Equation (2.20) implies that the elasticity of n with respect to v exceeds 1:

$$-\frac{d \log n}{d \log v} = \frac{(1-\sigma)(1-vn)+vn}{\epsilon(1-vn)+vn} > 1 \text{ since } 1 - \sigma > \epsilon \ . \qquad (2.22)$$

3. Underdevelopment Traps and Growth Momentum

In the models considered so far, the rate of growth in per capita consumption and long term rates of growth in income and human capital depend only on permanent parameters of tastes and technology. These growth rates are independent of initial conditions, luck, temporary changes in technology, wartime and other shocks. Therefore, these models must rely on permanent changes over time and permanent differences across countries in tastes and productivity to explain the vastly different growth records of various countries and the take-off into development of particular countries.

Fortunately, it is possible to enrich these models to provide a major place for temporary events and initial conditions. In this section, we explore several simple models that incorporate endogenous fertility and human capital accumulation when each person is endowed with unskilled labor ($\bar{H}$).

The way endowments of unskilled labor enter the production functions for consumption and investment crucially determines the nature of steady states and dynamics. We first carry over the assumption from Section 2 that endowments have uniform effects on productivity in different sectors, and then in Section 4 explore the more relevant case where unskilled labor has a larger effect on the production of consumption goods than of human capital.

Endogenous fertility changes the first order conditions for investment in equation (2.12) to

$$(1+g_t)^{1-\sigma} = \left(\frac{c_{t+1}}{c_t}\right)^{1-\sigma} = \alpha n_t^{-\epsilon}(1-vn_{t+1})A = \alpha n_t^{-\epsilon}R_t \ . \tag{3.1}$$

The rate of return to investment in human capital at t (R_t) depends negatively on future fertility (n_{t+1}). The first order condition for fertility is

$$(1-\epsilon)\alpha n_t^{-\epsilon}V_{t+1} = u'(c_t)[(v+h_t)(\bar{H}+H_t) + f] \ , \tag{3.2}$$

where f is the fixed goods cost of each child.

The solutions to these equations clearly depend on the endowment of unskilled labor ($\bar{H}$) and on initial human capital (H_t). However, since both $\bar{H}$ and f become insignificant when H_t is large, the solution when H_t is large are the steady state levels of n, h, and 1+g that are given by equations (2.19) and (2.20), for the casewhere $\bar{H}$ and f were both zero. Unskilled labor and fixed goods costs are important only when human capital is not large.

We define an underdevelopment steady state by $H_t = h_t = 0$, and $n_t = n_{t+1} = n_p$, all t. Since at this steady state, the rate of return on investment must be less than or equal to the rate of altruism-time preference, equation (3.1) becomes the inequality

$$\alpha n_p^{-\epsilon}(1-vn_p)A \leq 1 \ . \tag{3.3}$$

Clearly, this inequality is satisfied if n_p is sufficiently large. With $h_t = H_t = 0$, the first order condition for n in (3.2) becomes

$$(1-\epsilon)\alpha n_p^{-\epsilon} V_p = u'(c_p)((v\bar{H}) + f) \quad . \tag{3.4}$$

By substituting for V_p and $u(c_p)$, equation (3.4) can be rewritten as

$$\frac{(1-vn_p)\bar{H}/f-n_p}{v\bar{H}/f+1} = \frac{\sigma[1-\alpha n_p^{1-\epsilon}]}{(1-\epsilon)\alpha n_p^{-\epsilon}} \quad . \tag{3.5}$$

The right hand side of equation (3.5) is increasing in n_p by the second order conditions for maximization (see the appendix). The left hand side gives the financial rate of return from an additional child: the ratio of adult consumption to the consumption foregone to produce a child. The rate of return from children is greater when endowments are larger and when time (v) and goods (f) used to produce children are smaller. Therefore, parents would have relatively many children with little human capital when they are cheap to produce and yet are reasonably productive ($\bar{H}$ is large). If the n_p determined from equation (3.5) is sufficiently large, it satisfies inequality (3.3), and an underdevelopment steady state exists (assuming that the first order conditions maximize utility; we discuss this issue later).

This steady state is stable for some initial values of H. Since the rate of return on investments is less than the degree of altruism-time preference for $H_t = 0$, it must also be less for some $H_t > 0$. The economy returns to the underdevelopment steady state in one generation from all H_t where the rate of return is below altruism-time preference. Clearly, the

underdevelopment steady state is also stable for some H_t where the return to $H = 0$ takes more than one generation.

If time spent on child rearing is not the dominant cost of children in underdeveloped economies, the relation between fertility and income would be positive in the interval where the economy returns to the underdevelopment steady state in one generation. In particular, if

$$\frac{v(\bar{H}+H_t)}{v(\bar{H}+H_t)+f} < 1 - \sigma \text{ , where } 1 - \sigma > \epsilon \text{ ,} \tag{3.6}$$

our model has the Malthusian property of a positive relation between income and fertility in an underdeveloped country with little human capital. A positive relation between fertility and income helps stabilize the underdevelopment steady state, for an increase in fertility lowers the degree of altruism, which discourages investment in children, and the rate of return on investment falls as n increases.

However, this Malthusian view of a positive relation between fertility and income is a myopic view of the effects of development on fertility that holds near the underdevelopment steady state, but does not hold when countries manage to reach a moderate stage of development. Even if parents do not invest in children ($h = 0$), time costs must continue to rise as H increases (see equation (3.6)). Eventually, therefore, the inequality in (3.6) is reversed and fertility falls as H increases further

This decline in fertility with increases in H means that the rate of return on investment in children will become as large as the degree of altruism-time preference -- the left hand side of (3.3) would increase until

it equals one. Then parents begin to invest in children ($h > 0$). At first, the amount invested is insufficient to maintain the parents' level of human capital, and the economy returns over time to the underdevelopment steady state (see point b in Figure 2). However, there might be a sufficiently high level of human capital where investments in children just maintain human capital (see point D in Figure 2). Fertility and investments per child then remain constant over time in a steady state.

This development steady state satisfies the following first order conditions for investments and fertility:

$$\alpha n_d^{-\epsilon}(1-vn_d)A = 1, \tag{3.7}$$

$$\frac{1-(v+h_d)n_d-fn_d(\bar{H}+H_d)^{-1}}{v+h_d+f(\bar{H}+H_d)^{-1}} = \frac{\sigma}{1-\epsilon}\left[\frac{1-\alpha n_d^{1-\epsilon}}{\alpha n_d^{-\epsilon}}\right], \tag{3.8}$$

where

$$H_d = \frac{A\bar{H}h_d}{1-Ah_d} \quad . \tag{3.9}$$

Equation (3.7) determines a unique development steady state fertility rate that is below the rate at the underdevelopment steady state ($n_d < n_p$) because the left hand side of (3.3) and (3.7) is negatively related to n. Even if fertility is positively related to income when a country is underdeveloped, higher income must drive fertility down prior to reaching development. Consequently, we can derive the strong negative relation

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between fertility and development found across countries and in the histories of developed countries. The Malthusian model went badly wrong because it took a myopic view of the effect of economic growth on fertility.

Equation (3.8) determines the steady state investment rate given that equation (3.7) determines fertility -- and (3.9) determines the steady state stock of human capital. If f is small relative to the wage rate $(\bar{H} + H_d)$ at the development steady state, the left hand side of equation (3.8) is negatively related to h_d. Then (3.8) determines a unique investment rate, h_d, that is negatively related to the value of n_d determined from equation (3.7).

The first order condition for investment in the development steady state is also expressable as

$$\alpha n_d^{-\epsilon} A V_d' = u_d' \ . \tag{3.10}$$

If we assume for the present that f = 0, and if this equation is divided by equation (3.2), the first order condition for fertility, then

$$h_d A = \frac{1-\epsilon}{\sigma} - vA \ . \tag{3.11}$$

where $\sigma = (V_d'/V_d)(\bar{H}+H_d)$ (see equation (2.18)).

Since h_d is feasible only if $h_d A < 1$, the steady state is feasible if, and only if,

$$\frac{vA\sigma}{1-\epsilon} < 1 \text{ and } \frac{vA\sigma}{1-\epsilon-\sigma} > 1 \ , \tag{3.12}$$

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The second inequality in (3.12) is the condition for perpetual growth (see equation (2.14)). Therefore, no development steady state exists when perpetual growth is not possible (remember we are assuming $f = 0$). The policy function that relates H_{t+1} to H_t then remains below the steady state line for all values of H_t (see US in Figure 2). The underdevelopment steady state would be stable for all H; no matter how rich the starting point, the economy eventually disinvests all its human capital and returns to a low income steady state with no human capital. The inequality in (3.12) implies that global stability of the underdevelopment steady state is likely when the fixed time cost of rearing children (v) is small, investments in human capital (A) are not productive, the elasticity of substitution in consumption (related to σ) is small, and the elasticity of the altruism function (ϵ) is small.

Since with $f = 0$, a development steady state exists only if perpetual growth is possible, the policy function for human capital investments must cut the steady state line (the 45° line) from below when it crosses at the development steady state (see the curve UP in Figure 2). Therefore, with $f = 0$, the development steady state <u>must be unstable</u>. Any deviations of H_t from H_d push the economy toward either the underdevelopment steady state or perpetual growth. The latter is stable for all $H_t > H_d$ and the underdevelopment steady state is stable for all $H_t < H_d$.

It is easy to show that H_d is positively related to $\bar{H}$ and negatively related to v and A. Consequently, the underdevelopment steady state is stable over a wider set of H_t when unskilled labor is more important, fixed time costs of rearing children are smaller, and investments are less productive.

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The first inequality in (3.12) shows that a development steady state does not exist when $(1-\epsilon)/\sigma > vA$, even if perpetual growth is possible. However, an underdevelopment steady state then does not exist either,[1] and the economy grows no matter how small the initial capital stock. In this case, perpetual growth is stable for all values of the initial capital stock (see curve GG in Figure 2).

Our model implies that when $f = 0$, there can be a stable steady state with only unskilled labor, and stable perpetual growth with steadily growing skills and knowledge, but not a stable steady state with a constant amount of per capita skills and knowledge. The steady state with a constant stock of human capital would not be unstable if fertility were not negatively related to income at that point. This negative relation means that the rate of return on investments increases and the rate of altruism-time preference declines when human capital grows near the development steady state.[2] These higher returns to investments and lower preference for present consumption are what destabilize the development steady state.

The negative relation between fertility and income near the development steady state is in contrast to the likely positive relation near the underdevelopment steady state. This positive relation helps stabilize the underdevelopment steady state, just as the negative relation near the development steady state destabilizes that steady state. Fertility tends to fall as income increases not only near the development steady state, but for all $H \geq H_s$ (see Figure 3). That $H_s < H_d$ comes from our proof earlier that even when $f > 0$, fertility is lower at the development steady state than at the underdevelopment steady state. Fertility also tends to continue to fall as H increases well beyond H_d. Since the right hand side of (3.1) is

negatively related to n, steady state fertility must be lower when $g > 0$ than when $g = 0$.

The relation between fertility and human capital in Figure 3 is positive when most workers are unskilled (in the region near $H = 0$). The myopia of the Malthusian view is seen from the fall in n after H becomes sufficiently large. Indeed, the relation between n and H is sharply negative near H_d, the unstable steady state human capital, and n is much lower when per capita income is growing steadily than at the other steady states.

We have been assuming a concave value function, so that the utility-maximizing choices are determined from the usual first order conditions. However, the value function may become convex as a result of the interaction through the altruism and cost functions between fertility and investments in each child. With a convex value function, the slope of the policy function that relates H_{t+1} to H_t would have a jump at some capital stock H^*. The lower leg of this discontinuous policy function lies below the steady state line (see Figure 4), with $H_{t+1} < H_t$ for all $H_t < H^*$. The upper leg lies above the steady state line with $H_{t+1} > H_t$ for all $H_t > H^*$. Although H^* is not the solution to the steady state first order conditions because the solution to these conditions would not maximize utility, H^* does have many of the properties of an unstable steady state.

If $Av < (1-\epsilon-\sigma)/\sigma$, a perpetual growth steady state does not exist. An underdeveloped steady state also would not exist if the goods costs of children are sufficiently large that parents with no human capital have only a small number of children. With few children, they might invest in each child because the degree of altruism would be below the rate of return on

investments in human capital. If underdevelopment and perpetual growth steady states do not exist, the policy function that relates H_{t+1} to H_t would cross the steady state line from above. Then the development steady state is unique and globally stable (see GL in Figure 2). Fertility is positively related to income near this development steady state, for otherwise it would not be stable. Again we see the important role of fertility in determining the dynamic path of income and investment in human capital.

It is also possible to have both stable and unstable steady states with positive human capital. This occurs when the fixed cost of children (f) is large enough. A large f makes fertility positively related to human capital at low income levels, and it also makes fertility sufficiently low when $H = 0$ so that investment is positive.

4. Higher Rates of Return When Human Capital Is Greater

Unskilled labor is less important in the production of human capital than consumption: many services and some consumer goods do closely depend on the input of unskilled labor, while teaching and other investments in knowledge are highly skill-intensive activities. This is captured in our model when the endowment ($\bar{H}$) of unskilled labor is less important in the production of human capital than of consumption, i.e., if $b < d$ in the production functions for H and c in equations (2.3) and (2.4). This assumption about the productivity of endowments reduces the need to rely on fertility to destabilize the development steady state and generate the dynamics of human capital accumulation. The decline in fertility with income is important to development, but it is far from the whole story.

Higher rates of return on investments when the stock of human capital is greater contribute greatly to the take off from unstable incomes levels into perpetual growth and human capital accumulation.

Since rates of return on investments increase with the human capital of the investor when $b < d$ and H is not large relative to $\bar{H}$, persons with relatively little human capital may specialize in producing consumer goods, while those with a lot of human capital would specialize in producing human capital for the next generation. However, this incentive to specialize would be weakened and possibly eliminated if the capital market, especially the market across generations, is not well developed. People may be unable to obtain loans to finance capital accumulation in order to specialize in teaching. They would have to rely on gifts from parents. But parents are only willing to give limited gifts, and they might not invest unequally in children if they are not confident that the children who receive more human capital would help out children who receive less.

The incentive to specialize is also weakened if there are diminishing returns to the time spent <u>by any person</u> in producing consumption, perhaps because of on-the-job training. For example, the incentive to specialize in producing c or H is reduced if hours worked in equation (2.3) is raised to a power $\delta < 1$. A sufficiently low δ can eliminate all specialization.

In this section and Section 5 we assume all persons in the same generation have equal human capital either because capital markets are highly imperfect or because of diminishing marginal products to working time. In subsequent work we will consider specialization and unequal investments in different members of the same generation when capital markets

are perfect and there is diminishing returns to the time spent investing in any person.

With diminishing returns to working time, the production of c is given by

$$c_t = (1-(v_t+h_t)n_t)^{\delta}(d\bar{H}+H_t) - fn \ . \tag{4.1}$$

The first order condition for optimal investment in human capital is

$$u_t' w_t = \alpha n_t^{-\epsilon} V_{t+1}'(b\bar{H}+H_t), \tag{4.2}$$

or

$$R_t = A\left(\frac{\ell_{t+1}}{\ell_t}\right)\left(\frac{b\bar{H}+H_t}{d\bar{H}+H_t}\right)\left\{\frac{\ell_{t+1}}{\delta} + n_{t+1}h_{t+1}\left(\frac{d\bar{H}+H_{t+1}}{b\bar{H}+H_{t+1}}\right)\right\} = \frac{u_t'}{\alpha n_t^{-\epsilon} u_{t+1}'} \ , \tag{4.3}$$

where $\ell = 1 - (v+h)n$ is the time spent at work. This equation reduces to equation (2.11) when $\delta = 1$ and $b = d$.

With $b < d$, the rate of return is higher not only when future fertility (n_{t+1}) is lower, but also when current and future human capital (H_t, H_{t+1}) are larger. As H increases, the weights given to the endowment become less important, until R_t becomes independent of b, d, and $\bar{H}$ for very large H. Unskilled labor is of no consequence when H is large, and the analysis with $b \neq d$ is then the same as the analysis when $b = d$. In particular, equation (2.19) still gives the determinants of the steady state rates of growth in per capita human capital and consumption when fertility

is endogenous. The basic parameters are still v, A, σ, and ϵ, while δ, b, and d have no effect on the steady state rates of per capita growth.

The parameters b and d do have very big effects when $\bar{H}$ is large relative to H. To isolate these effects from those of endogenous fertility, we assume that fertility is constant and given (= to n). The conditions for an underdevelopment steady state with h = 0 are then

$$\frac{b}{d\delta}\,(1-vnA) < \alpha^{-1}n^{\epsilon}\ . \tag{4.4}$$

Even if n is small, the inequality in (4.4) holds when $b/d\delta$ is small enough. The greater importance of unskilled labor in producing consumers goods than in producing human capital (b/d<1) can produce a stable steady state with no investment in human capital because the rate of return on investments is low when H is small.

If the value function is concave, a utility-maximizing steady state with h > 0 must satisfy the steady state first order conditions for h:

$$\frac{1}{\alpha n^{-\epsilon}} = \frac{A(b\bar{H}+H_d)}{(d\bar{H}+H_d)\delta}\left\{1 - vn - h_d n\left[1 - \frac{\delta(d\bar{H}+H_d)}{b\bar{H}+H_d}\right]\right\} \tag{4.5}$$

where

$$H_d = \frac{bA\bar{H}h_d}{1-Ah_d}\ . \tag{4.6}$$

The solutions to equations (4.5)-(4.6) for h and H are unique. If perpetual growth and underdevelopment steady states exist, these unique

values of h and H define a development steady state that is unstable. Higher rates of return on investments when the stock of human capital increases destabilize the steady state even with fertility constant. These higher rates of return can even make the value function convex rather than concave. Then the policy function would have a jump at a capital stock H* that replaces the steady state stock H_d. The capital stock falls over time toward underdevelopment if $H_t < H^*$, and it rises over time toward perpetual growth if $H_t > H^*$ (see Figure 4).

If fertility is endogenous, it would decline as income and human capital increase near the development steady state because greater investments raise the cost of children. Such a decline in fertility also destabilizes the development steady state (see Section 3), and raises investments even further through the interaction between fertility and investment. Indeed, rising rates of return and declining fertility together usually make the value function convex rather than concave. This is clear from the simulations reported in the appendix, where the policy functions are discontinuous for "reasonable" values of σ and other parameters (with b less than d). The investment rate jumps upward and fertility falls discontinuously when H increases slightly beyond a critical value of H. Per capita consumption either falls or rises discontinuously at that value depending on whether h changes discontinuously by more or less than n (assuming f is small).

In both the neoclassical and Malthusian growth models, temporary changes in technology and preferences leave no lasting imprint on the economy. In effect, these models have no room for history or state dependence. Although certain kinds of temporary changes presumably have

only a short lived impact, many others leave a permanent mark, and still others crucially influence the future course of an economy. Fortunately, in our model, an economy's past may have enormous effects on its subsequent income and growth.

To illustrate, consider an economy at the underdevelopment steady state with no human capital that experiences a temporary increase in the productivity of investments in human capital (A). This temporarily raises the policy function from UP in Figure 2 to say GG; when productivity returns to its normal level, the policy function returns to UP. Human capital grows while A is high because GG is above the steady state line. Suppose that productivity returns to its normal level and the policy function returns to UP when H_g units of H are accumulated. Since $H_g > H_d$, the unstable steady state stock, the economy continues to accumulate human capital along UP even after the temporary boom in productivity ends.

In this example, a temporary increase in productivity has an enormous impact on future income and growth. However, if less than H_d of human capital is accumulated while productivity booms, the economy eventually returns to the underdevelopment that it started from. Therefore, temporary changes in the productivity of investments have permanent effects on the economy only when they are sufficiently strong and long-lasting.

Investments in human capital may increase temporarily because public policies subsidize for a while investments in R & D, schooling, and other types of knowledge and skill, or because of a temporary tax on children that reduces fertility and raises investment per child. Rates of return may increase temporarily also because a sequence of new products and methods of production become available -- such as steelmaking, railroads, or

computers -- that raise returns to the endogenous accumulation of knowledge. If these innovations are sufficiently important and/or arrive rather close together, the endogenous accumulation of knowledge would push the economy into the region of eventual steady state growth, even if further exogenous improvements in products and costs are negligible. This is how our model integrates exogenously developed innovations and technologies (as stressed, e.g., in Rosenberg and Birdzell [1986]) with the endogenous accumulation of knowledge and skills. It also shows how leading sectors can induce a take off into growth (see Rostow [1963]).

Human capital is knowledge that is embodied in individuals. Technological progress in the form of new products and cost reductions sometimes raises the productivity of investments in human capital by creating common, not private, knowledge that is freely available to everyone. Our model considers the response of privately accumulated knowledge to spurts or sporadic changes in the creation of common knowledge, but does not endogenize the growth of common knowledge.

Other types of shocks and events can also push a stagnating economy into the region of perpetual growth, or a progressing economy into economic stagnation. For example, a rise in population due to a decline in mortality or immigration may lead to perpetual growth by raising rates of return on investments in human capital. Or the destruction of human capital due to war or other disasters can change a prospering economy into an impoverished one by lowering rates of return on investments in knowledge (see Section 5).

Therefore, economies will end up with very different levels of real income and rates of growth even though they have the same production

functions and tastes. Economies that receive the most favorable sequence of temporary improvements in productivity, public policies, population, and other variables will have the highest incomes and most favorable growth rates. This suggests that sheer luck must be an important contributor to the explanation of why, for example, the industrial revolution began in England rather than China or elsewhere. We are not suggesting that unwise bureaucracies and permanent differences among countries in tastes and productivity are unimportant, but only that the search for such differences may be excessive.

Joseph Needham [1969] has a famous discussion of why the industrial revolution did not occur in medieval China even though it was much more advanced technologically than medieval Europe. He emphasizes the policies of the Mandarin bureaucrats (a view criticized by Chao [1987]), but he also recognizes the delicacy and instability of the prior European equilibrium: "These many diverse discoveries and inventions had earthshaking effects in Europe, but in China the social order of bureaucratic feudalism was very little disturbed by them. The <u>built-in instability</u> of European society must therefore be contrasted with a homeostatic equilibrium in China, the product I believe of a society fundamentally more rational." ([1969, page 214], our italics)

We do not pretend that our simple model captures the rich historical experiences of different countries, or that it explains why Europe largely stagnated for a thousand years prior to the fifteenth century and China stagnated after that century. We do believe, however, that a relevant model must have multiple steady states, and that countries take off toward greater prosperity or fall back toward more poverty when in the

vicinity of unstable steady states. Luck might be a major factor determining whether they take off or retreat. Our model incorporates rudimentary versions of these properties.

5. Physical Capital

This section brings accumulated physical capital, fixed natural resources (such as land), and technological progress into the analysis of growth and development. These variables affect fertility and the rate of population growth, the relative productivities of unskilled labor and human capital, and the accumulation path of human capital. We use a simple model to describe optimal human capital investment in the presence of these variables.

The per capita output of consumer goods (Q) is Cobb-Douglas in working time, human capital, and a variable k that represents autonomous technological advance, a fixed amount of land or other natural resources, or optimally accumulated consumer goods:

$$Q_t = (d\bar{H}+H_t)^{\beta}\ell_t^{\delta}k_t^{s} \ . \tag{5.1}$$

The exponents β, δ, and s attached to each variable may differ. We assume that k as well as $\bar{H}$ has a greater effect on the production of c than of H, and only consider the simple case where k has no direct effect on the production of H.

The first order condition for h is the same, regardless of what k represents

$$u_t' w_t = \alpha n_t^{-\epsilon} A(b\bar{H}+H_t)\frac{\partial V_{t+1}}{\partial H_{t+1}} , \tag{5.2}$$

where $w_t = \partial Q_t/\partial \ell_t$. The first order condition for n depends on the assumption about k. If k represents exogenous technological progress that advances at the rate g_k, the first order condition for n is

$$u_t'[(v+h_t)w_t+f] = (1-\epsilon)\alpha n_t^{-\epsilon} V_{t+1} \tag{5.3}$$

If consumption and human capital grow over time, then eventually f and $\bar{H}$ will be negligible, and H and c will grow at constant rates. By dividing equation (5.3) by (5.2) and simplifying, we obtain in the growth steady state:

$$\frac{H_{t+1}}{H_t} = 1 + g_h = \frac{v\sigma^* A}{1-\epsilon-\sigma^*} , \tag{5.4}$$

where

$$\sigma^* = \beta\sigma = \frac{d \log V}{d \log H} \tag{5.5}$$

along the steady state path. Human capital grows more slowly in the steady state when β is smaller -- when the returns to H in the production of consumer goods diminish more rapidly -- because $\beta < 1$ reduces the rate of return to human capital investment.

Equation (5.4) has the surprising property that the steady state rate of growth in per capita human capital (g_h) is independent of the rate

of progress (g_k) in the production of consumer goods. Since the rate of return on h is positively related to g_k, one might expect g_h also to be positively related to g_k. However, even with fixed fertility, the effect of a higher rate of technical advance would be ambiguous since the rate of return to human capital investments would rise but the marginal rate of substitution in consumption would fall. With log utility, these effects cancel and human capital growth is independent of the rate of technological advance. With endogenous fertility, we have the additional effect that the utility of children, and hence fertility, increases when g_k increases. The greater rate of progress in the production of consumer goods does not affect investments in human capital because the decline in the degree of altruism-time preference due to the rise in fertility cancels the higher rate of return to investments in human capital. Note, however, that this neutrality result depends on the constant elasticity functional forms assumed for the altruism and production functions, and g_h can be either positively or negatively related to g_k with other functional forms.

Since $c_t = Q_t$ when k_t represents exogenous technology, then

$$\log (1+g_c) = \beta \log (1+g_h) + s \log (1+g_k). \tag{5.6}$$

The steady state rate of growth in per capita consumption depends positively on the rate of technological advance: g_c is a weighted su of the rates of growth in per capita human capital and technology. The rate of growth in c depends on the diminishing returns to H in the production of c both directly (β) and indirectly through its effect on g_h.

If instead of technical progress, k represents per capita endowments of a fixed amount of land, oil, or other natural resources (K_0), per capita resources are

$$k_t = K_0 N_t^{-1} , \tag{5.7}$$

where N_t is population at t. Since an increase in population lowers future per capita natural resources, the existence of limited resources raises the cost of children and thereby lowers fertility. Natural resources raise the cost of children by, in effect, raising the elasticity of the altruism function from ϵ to $\epsilon^* = \epsilon + s\sigma$.[4] With nothing else changed, the steady state rate of growth in H is obtained in the same way as equation (5.4) was obtained by dividing equation (5.3) by (5.2):

$$\frac{H_{t+1}}{H_t} = 1+g_h = \frac{v\sigma^* A}{1-\epsilon^*-\sigma^*} , \text{ with } \sigma^* = \beta\sigma \text{ and } \epsilon^* = \epsilon + s\sigma . \tag{5.8}$$

The rate of growth in human capital is larger when natural resources are more important in the production of consumption goods (s is bigger) because the decline in fertility when s increases lowers the degree of altruism-time preference.

The steady state rate of growth in per capita consumption is now

$$\log (1+g_c) = \beta \log (1+g_h) - s \log (1+g_N), \tag{5.9}$$

where g_N is the steady state rate of population growth. Greater importance of natural resources in the production of consumer goods directly lowers g_c

when $g_N > 0$. But an increase in s indirectly raises g_c by lowering g_N and raising g_h; the net effect of s on g_c is ambiguous when population is growing. However, if population is declining, $g_N < 0$, then both the direct and indirect effects of an increase in s lead to greater growth in per capita consumption.

If k is augmentable physical capital -- say accumulated consumer goods -- the first order condition for optimal capital accumulation is

$$u_t' = \alpha n_t^{-\epsilon} \frac{\partial V_{t+1}}{\partial k_{t+1}} . \tag{5.10}$$

The first order condition for n changes to

$$u_t'[(v+h_t)w_t+f+k_{t+1}] = (1-\epsilon)\alpha n_t^{-\epsilon} V_{t+1} : \tag{5.11}$$

the cost of an additional child is greater when k_{t+1} is larger (but so are the benefits). By substituting (5.10) into (5.11) and rewriting, we get

$$u_t'[(v+h_t)w_t+f] = (1-\epsilon^*)\alpha n_t^{-\epsilon} V_{t+1} : \tag{5.12}$$

with $\epsilon^* = \epsilon + s\sigma$, and $s\sigma = (d \log V_t)/(d \log k_t)$ with steady state growth. Then dividing (5.12) by equation (5.2) and simplifying, we get equation (5.8) once again.

The rate of growth in H is greater when physical capital is more important in the production of consumption goods. This is mainly because an increase in s raises the cost of children and reduces fertility, which lowers the degree of altruism-time preference. It is rather surprising that

the steady state rate of growth in H is the same whether k refers to fixed natural resources or to physical capital chosen optimally to maximize utility.

Equations (5.2) and (5.11) imply that the marginal rate of return on physical capital equals the rate of return on human capital. With the rate of return on H being constant in the steady state, the rate of return on k must also be constant. The latter is given by

$$1 + r_k = \frac{\partial Q_t}{\partial k_t} = s\ell^{\delta} H_t^{\beta} k_t^{s-1} \quad . \tag{5.13}$$

Therefore, a constant r_k requires that

$$\log\,(1+g_k) = \frac{\beta\,\log(1+g_h)}{1-s} \quad . \tag{5.14}$$

H and k grow at the same rate in the steady state only if output has constant returns to scale in H and k (β=1-s). The optimal ratio of k to H would then be determined from $r_k = r_h$, the fixed rate of return on human capital. If returns to scale increase in H and k (β>1-s), k would grow faster than H, and conversely if returns decrease in H and k. Regardless of the relation between β and s, per capita consumption and output grow at the same rate as per capita physical capital since from (5.14):
$\log\,(g_Q) = \beta\,\log\,(1+g_h) + s\,\log\,(1+g_k) = \log\,(1+g_k)$.

The responses of human capital and consumption growth rates to technological advance, fixed resources, or accumulated capital are driven by interactions with population growth. Technological advance has an ambiguous

effect on human capital accumulation since it increases fertility as well as the return to investing in human capital. Increased importance of fixed resources will stimulate investment in human capital, and perhaps also the growth rate of consumption, partly because it reduces fertility by raising the cost of having an additional child. Optimally accumulated physical capital also affects the growth rates of human capital and consumption by changing fertility.

By changing the relative productivities of labor ($\bar{H}$) and human capital (H) in the production of consumption goods and human capital (though unskilled b and d), and by changing the productivity of investments in human capital (A)), fixed resources, technical change, and accumulated physical capital also affect whether a country achieves perpetual growth or remains underdeveloped. To keep matters simple, we only consider the effects of exogenous technology differences and fixed endowments of resources, and we ignore the population effects that drove the earlier results in this section by assuming exogenous fertility (n=1).

If greater technological progress or natural resources raised d, the productivity of unskilled labor in the consumption sector, the rate of return on investments in human capital would decline and the development steady state would require a larger stock of human capital (see equations (4.5)-(4.6)). The economy is then less able to sustain investments in human capital, and it is more likely to converge to the underdevelopment steady state. By contrast, if technological progress or natural resources increased A, the productivity of time and other inputs in the investment sector, then the prospects for growth increase. An increase in A not only

lowers the development-steady-state human capital stock, but also raises the steady state growth rate (see equations (2.19) and (4.6)).

These examples illustrate that improvements in technology or greater endowments of natural resources have very different effects on growth depending on how they affect the productivity of the human capital sector, and the productivities of human capital and unskilled labor in the consumption and investment sectors. Much of this analysis carries over to the effects of optimally accumulated physical capital, which we take up next. We consider the dynamic paths followed by human capital and by physical capital that is accumulated consumption goods. To simplify the dynamics, we continue to assume that fertility is constant and given; we expect to include endogenous fertility in subsequent work.

The dynamics of a system with endogenous human and physical capital are functions of the state variables k and H. The isoclines $\dot{k} = 0$ and $\dot{H} = 0$ are of particular interest since they determine the steady states. The isocline $\dot{k} = 0$ in Figure 5 has a positive slope because an increase in k lowers and an increase in H raises the rate of return on k. Net investment in k is negative when k is large (at all points above $\dot{k} = 0$), and net investment is positive when k is small (at all points below $\dot{k} = 0$).

The sign of the slope of $\dot{H} = 0$ is less readily apparent, but for present purposes it does not greatly matter whether its slope is positive or negative. The important point is that the higher returns to large H implies that investment in H is positive at all points to the right of $\dot{H} = 0$, and investment is negative to the left of $\dot{H} = 0$.

Two steady states are shown in this figure: an underdevelopment steady state at U where $H = 0$ and $k > 0$, and a development steady state at D

where both H and $k > 0$. The economy might converge to a perpetual growth steady state, where the ratio of k to H given by the slope of the line Og. We assume that $\beta = 1-s$, so that k and H grow at the same rate in the growth steady state (see equation (5.14)).

The stable manifold for the steady state at D is given by MM. All points to the left of MM converge over time to U (see points a and b), while all points to the right of MM converge to the growth path along Og (see point c). The steady state at D is unstable because of increasing returns to H: $\dot{H} > 0$ for all points to the right of $\dot{H} = 0$, and $\dot{H} < 0$ for all points to the left. The stable manifold MM acts like the development steady state stock of human capital (H_d) in the one dimensional problem without k since MM is the dividing line between growth and convergence to underdevelopment.

Increasing returns to H implies that the ratio of H to k increases as the economy moves to perpetual growth from D since the rate of return to physical capital must rise to match the higher rate of return on human capital. If the economy starts off near D, H would grow faster than k to raise H/k to the level given by the slope of Og. Human capital in the United States apparently did grow faster than physical capital since the turn of the century (Schultz [1960]), and human capital now accounts for a large fraction of all U. S. capital (see the estimates in Jorgenson and Fraumeni [1987]).

The slope of the $\dot{H} = 0$ isocline is determined by the strength of conflicting effects of k on investments in H. On the one hand, a decline in k_t increases $\dot{k}$, which lowers the incentive to invest in H by raising c_{t+1} relative to c_t (i.e., increasing the interest rate). On the other hand, the

increase in $\dot{k}$ also encourages investment in H by lowering the cost of investment (w_t) relative to returns ($\partial c_{t+1}/\partial H_{t+1}$).

If u = log c (σ=0), and if the production function for c is Cobb-Douglas (see equation (5.1), the effect of a change in k_t on u'_{t+1}/u'_t exactly offsets the effect on the rate of return. In this case, a change in k does not change the rate of investment in human capital if H grows at a constant rate along the steady state growth path (including $\dot{H}$=0).[5] The isocline for H would be vertical, as is $\dot{H}$* = 0 in Figure 5. If either the elasticity of substitution in production of c is less than unity or the elasticity of substitution in consumption exceeds unity (σ=0), then a fall in k actually stimulates investment in H, and the isocline for H is positively sloped. The effect on u_{t+1}/u_t is then less than the effect on the rate of return. Similarly, $\dot{H}$ = 0 is negatively sloped if the elasticity in production exceeds unity or the elasticity in consumption is below unity.

When the $\dot{H}$ = 0 isocline is positively sloped, the stable manifold will also be positively sloped, so that economies with higher initial amounts of physical capital require higher initial amounts of human capital in order to take off toward the perpetual growth steady state. Note that an economy that starts with given levels of physical and human capital eventually will be overtaken in both consumption and human capital by economies that start with the same or even a slightly lower level of human capital, but with much less initial physical capital. The reason is that lower levels of physical capital stimulate investments in human capital when $\dot{H}$ = 0 is positively sloped.

The sign of the slope of the $\dot{H}$ = 0 isocline also has significant effects on the response of human capital investments to wars and other

shocks that destroy capital. Recovery from wars and other disasters has often been remarkably rapid (see the excellent discussion by Hirshleifer [1987]). John Stuart Mill remarked on ". . . what has so often excited wonder, the great rapidity with which countries recover from a state of devastation, the disappearance in a short time, of all traces of the mischiefs done by earthquakes, floods, hurricanes, and the ravages of war." ([1848], page 74). Mill argues that recovery is rapid when the most of the population and knowledge remain intact. He alleges that the physical capital destroyed is restored quickly because it would be replaced in a short time even under normal circumstances.

Consider a war that destroys much of a durable physical capital stock that would not have been replaced quickly. Rates of return and investments in this capital increase. If investments in human capital do not change when physical capital is destroyed ($\dot{H} = 0$ is vertical), the country will recover over time to the income it would have had were physical capital not destroyed. The faster growth in income would narrow the gap with the incomes of similar countries that were not involved in the war. This essentially is the implication of the neoclassical growth model with exogenous technological change. According to this model, the incomes of countries devastated by war converge toward the incomes of countries that avoided devastation (see, e.g., Baumol [1986]).

Although our model has endogenous investments in human capital, it has the same implication as the neoclassical model if the elasticities of substitution in both consumption and production are unity. However, the destruction of physical capital stimulates greater investment in human capital in our model if the elasticity of substitution in production between

human capital and physical capital is less than unity, or the elasticity of substitution in consumption over time exceeds unity. Then a country does not eventually merely recover from a war to what it would have had in the absence of the war; incomes eventually surpass what they would have been! Wartime destruction still lowers the present value of utility, but in this case it raises future utilities. Higher investments in human capital and knowledge induced by the enormous destruction during World War II may help explain the economic booms in Japan, Germany, and the Soviet Union during the 1950's and 1960's.

Therefore, in our model, the long-run decline in income due to a fall in physical capital is much smaller than the short-run decline -- income may even rise in the long-run. The consequences of a fall in human capital are very different, for the long-run income decline exceeds the short-run decline, possibly by a huge amount. If the rate of investment in human capital were independent of the stock of physical capital, human capital would continue to grow at its steady state rate after a fall in human capital that kept it near the steady state. However, a fall in human capital reduces the rate of growth of physical capital until the ratio of physical capital to human capital is restored to its steady state value. The ultimate decline in income clearly now exceeds the initial decline because the fall in human capital induces a decline in physical capital as well.

The long-run decline in income is much bigger if human capital falls below the isocline $\dot{H} = 0$(say below $\dot{H}^*$ in Figure 5). The economy then does not return to its steady state growth path, but instead it plunges

toward the underdevelopment equilibrium, where H = 0 and per capita income is low.

Our discussion of the effects of a fall in human capital explains Mill's proviso that recovery from wartime damage is rapid only if the population is left "with the same skill and knowledge which they had before . . . ." [1848, page 75]. One way to reduce knowledge is to kill much of the adult population that passes knowledge on to the next generation. Some cities and regions never recovered from major disasters that destroyed much of their populations (see Hirshleifer [1987, page 78]).

The seemingly perverse effects of wars and other disasters on growth rates and income levels illustrate the importance of making growth endogenous. Even though our steady states are similar to the steady states in exogenous growth models with labor augmenting technical progress that cause output, wages and physical capital to grow at the same rate, endogenous growth models allow one to analyze how growth rates respond to exogenous forces. Investments in human capital in our model respond to changes in wages and interest rates. Therefore, long run output and consumption are affected (among other things) by transitory changes in policies and shocks to physical capital. We have not presented systematic empirical evidence that supports the predictions of our model concerning the response of growth rates and income levels to changes in the environment. However, we have presented a few historical and other examples that appear consistent with our approach to endogenous growth.

Appendix: Simulations

All the simulations in this appendix are for the full model from section 4 with both endogenous fertility and different values on raw labor in the consumption and investment sectors. The base line simulation sets

σ = utility function curvature paramter = .45

ϵ = altruism curvature parameter = .25

α = rate of altruism time preference = .3

v = fixed time cost of children = .25

A = investment productivity = 5

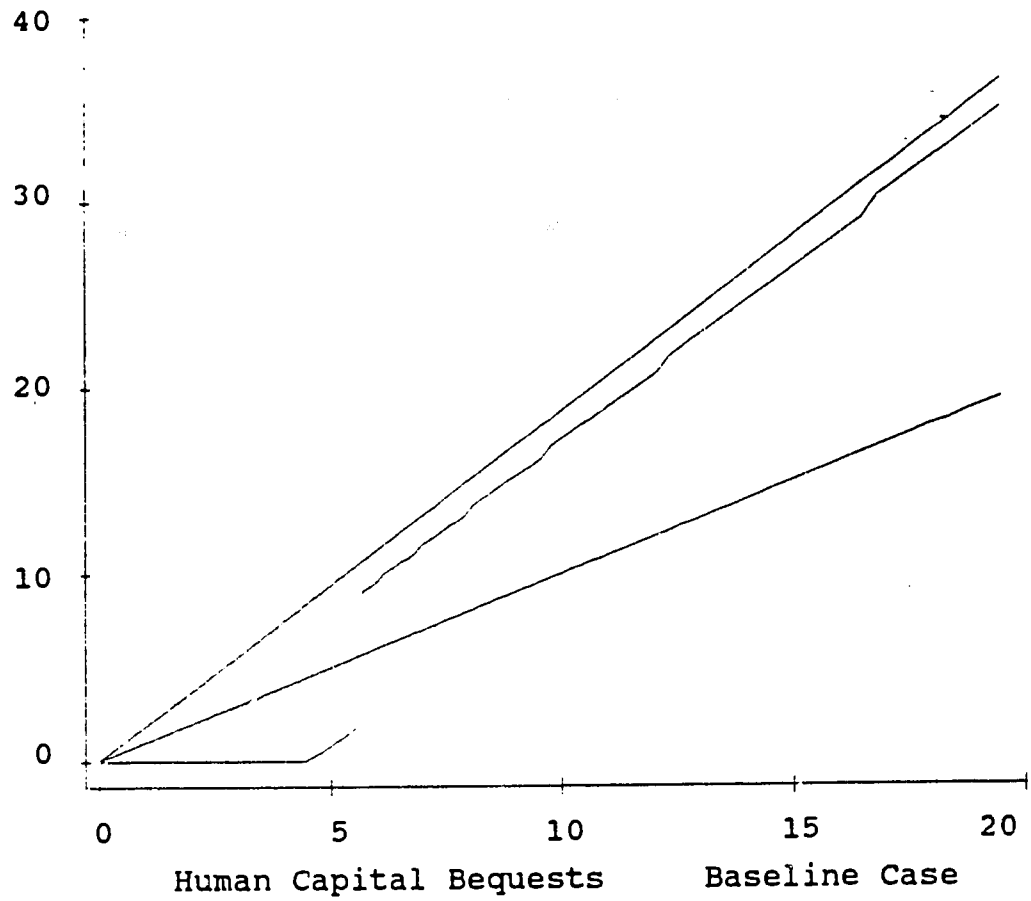
b = relative value on raw labor in the investment sector = .5

d = relative value on raw labor in the consumption sector = 1

$\bar{H}$ = units of raw labor per person = 1

f = fixed goods cost of children = 0 .

The remaining simulations begin with the baseline parameters and change one of the parameters to examine the effects on the optimal investment and fertility policies.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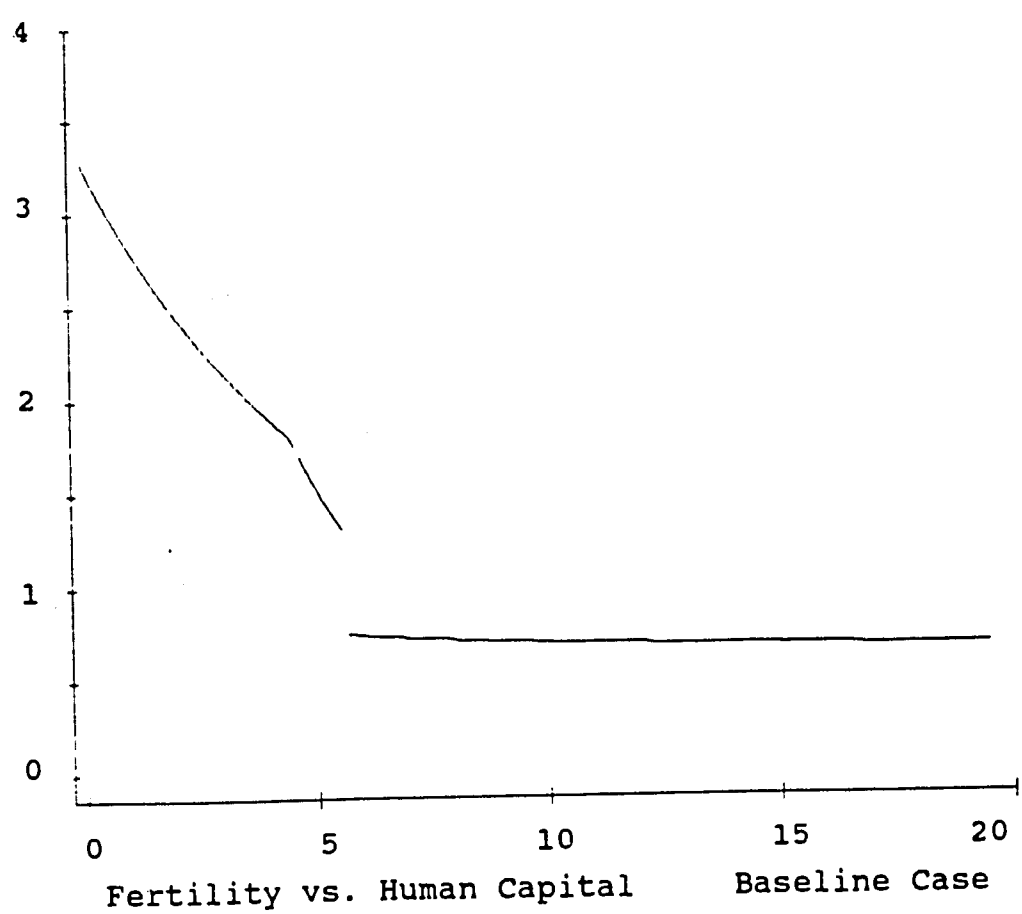
Human Capital Bequests
Baseline Case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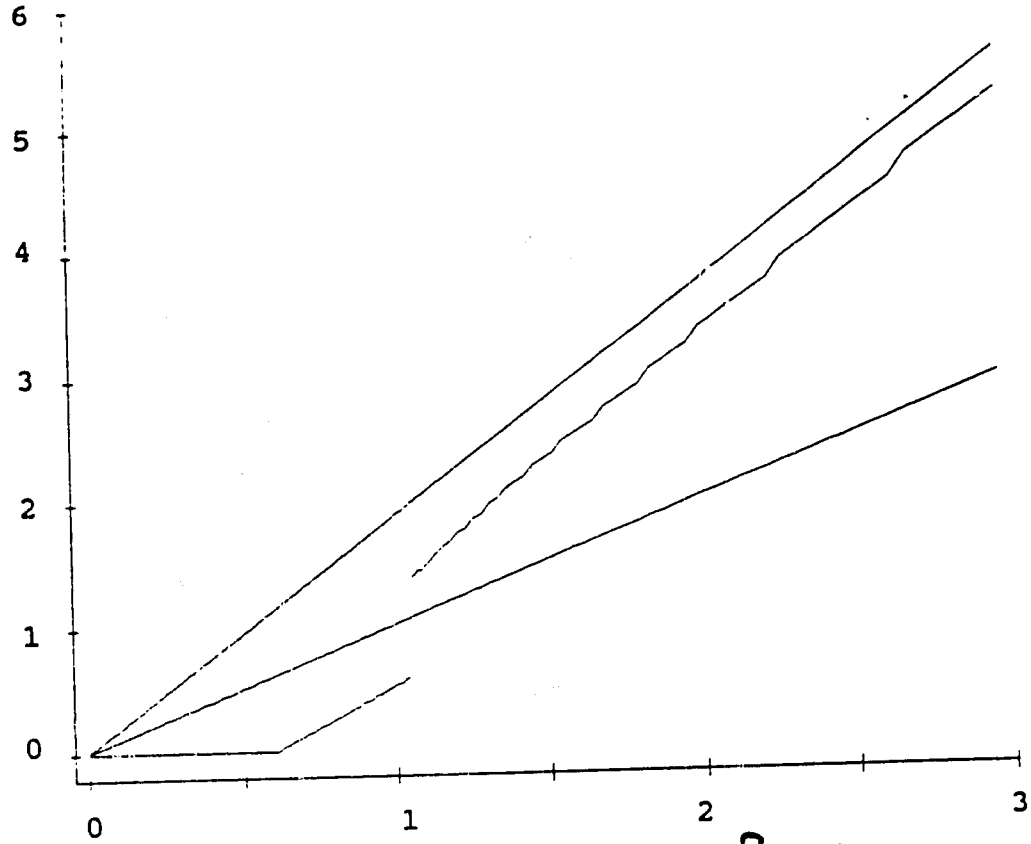
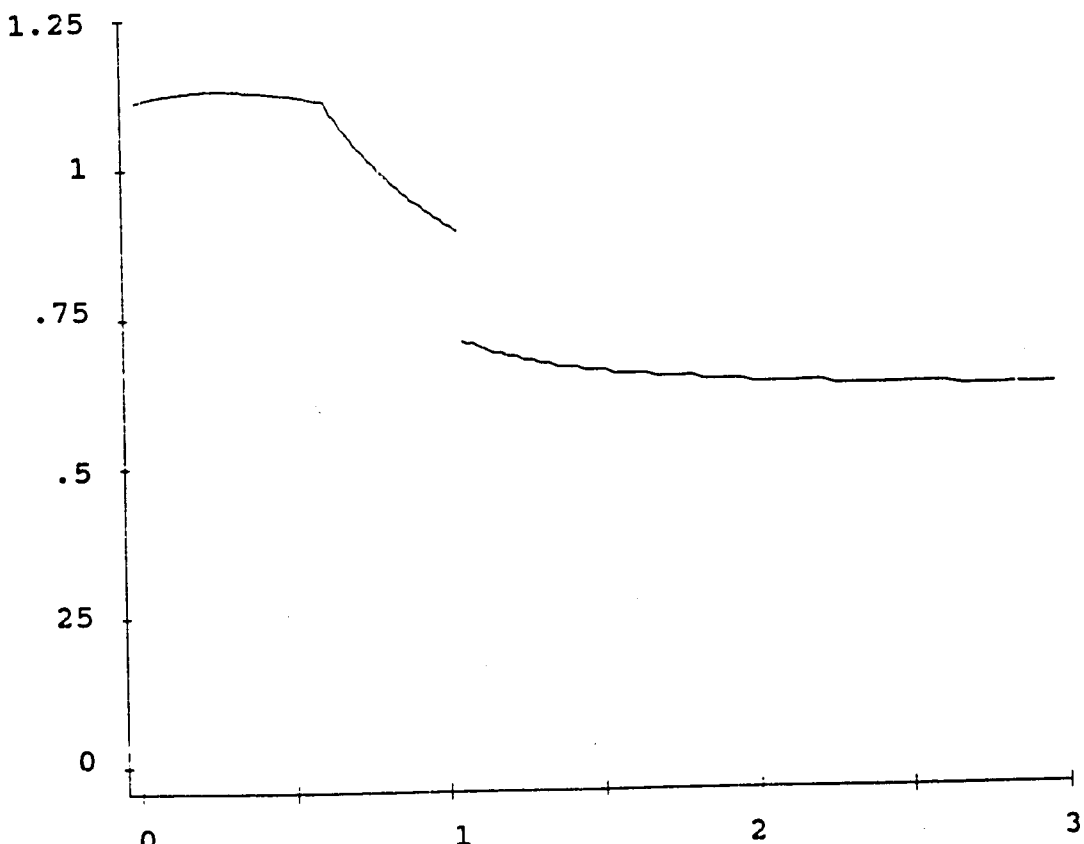
Fertility vs. Human Capital
Baseline Case

182



Human Capital Bequests (f=.15)



Fertility vs. Human Capital (f=.15)

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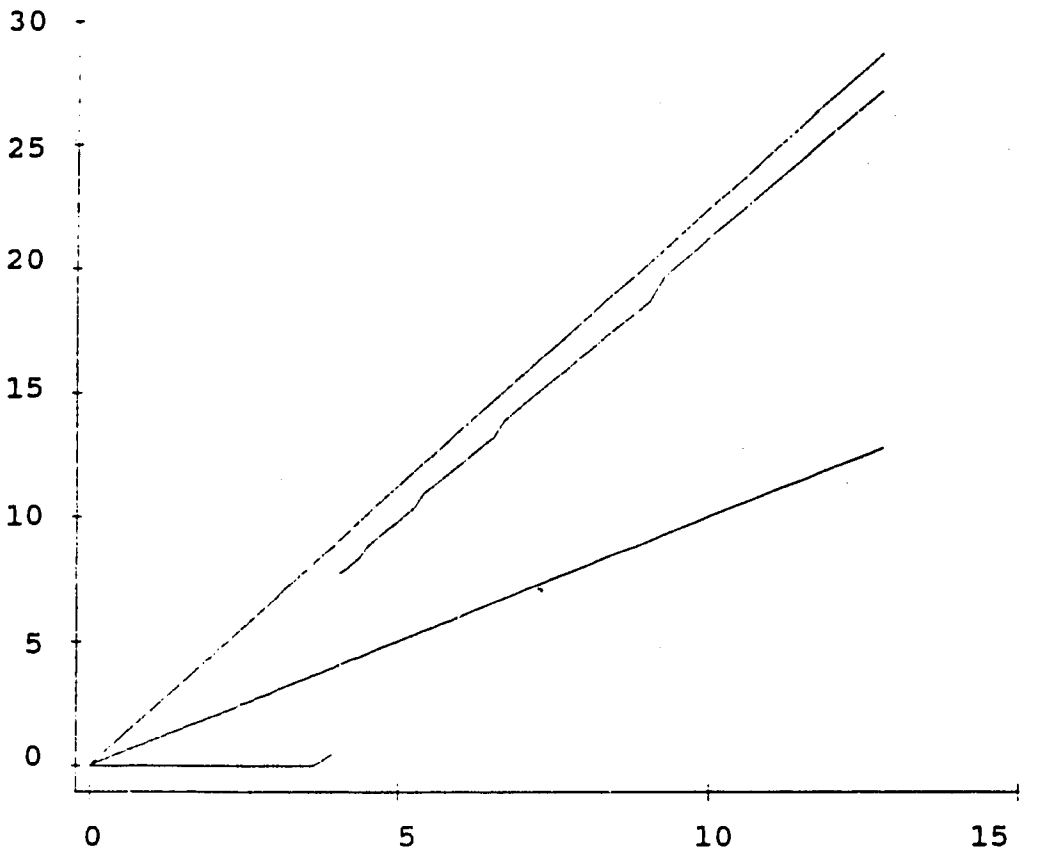
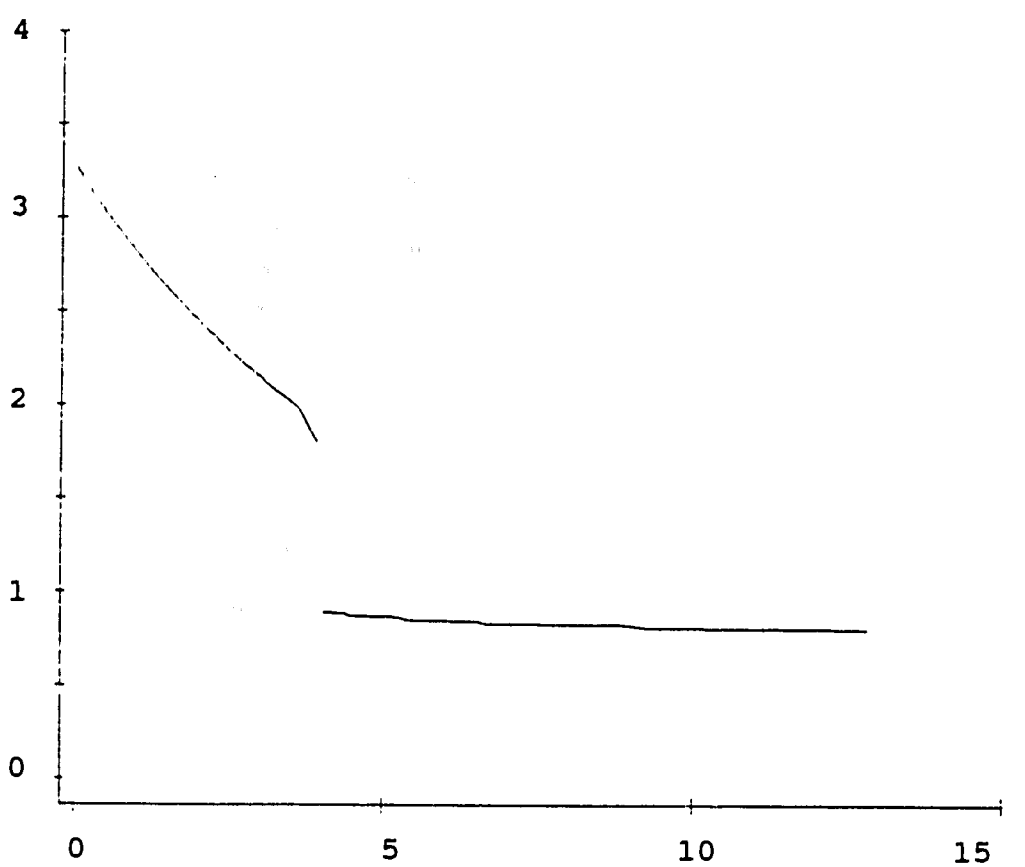


Human Capital Bequests (A=6)



Fertility vs. Human Capital (A=6)

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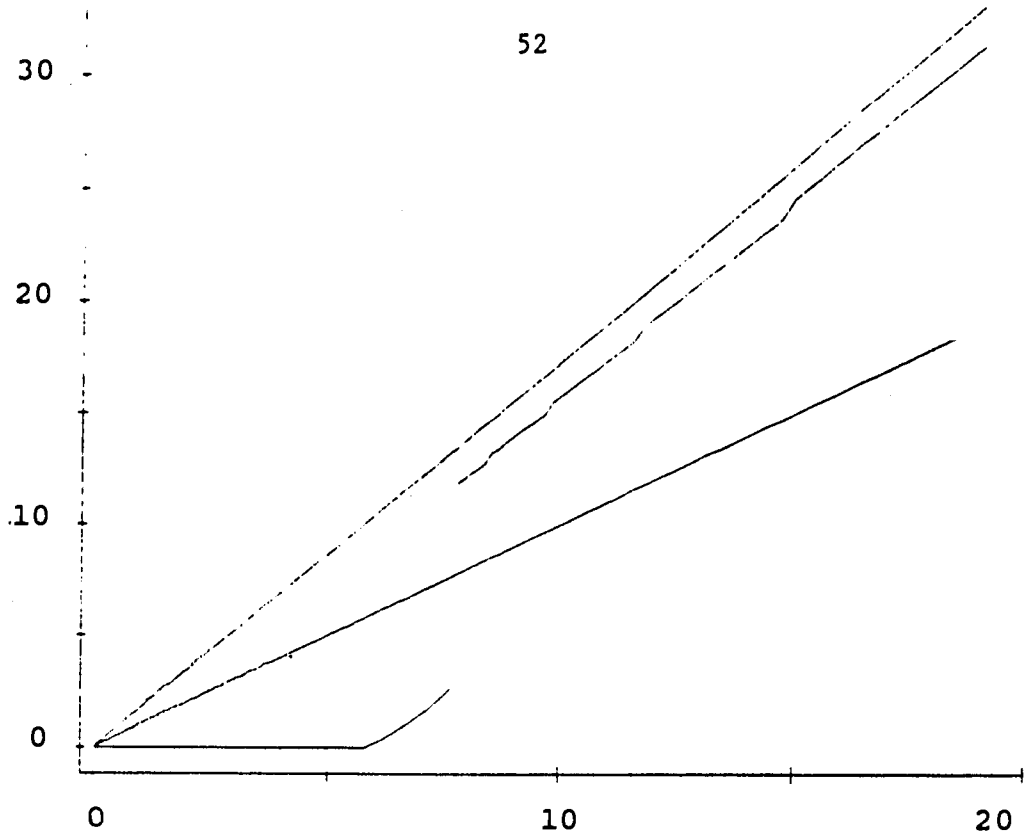
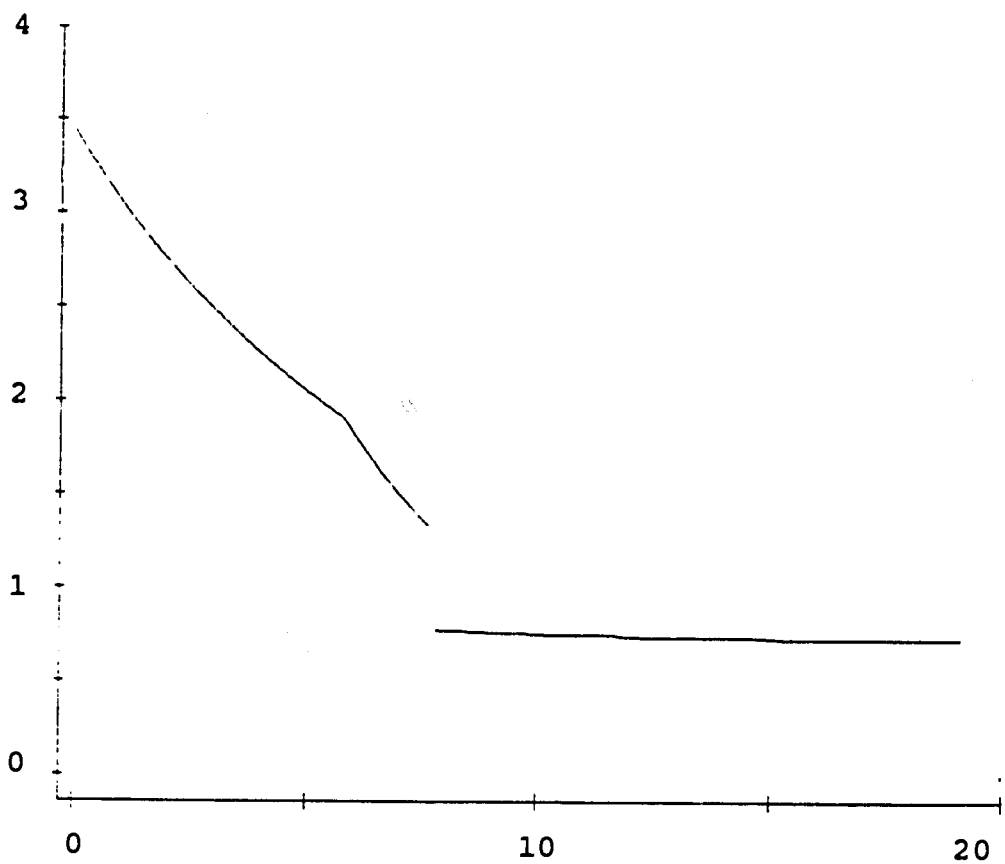


Human Capital Bequests (epsilon=.225)



Fertility vs Human Capital (epsilon=.225)

FOOTNOTES

[1]If $f = 0$, an underdevelopment steady state exists if

$$u'(c_p) > a(n_p)AV_p'$$

where n_p and c_p solve

$$u'(c_p)v\bar{H} = (1-\epsilon)a(n_p)V_p$$

By dividing one equation by the other and using $\sigma = V_p' \bar{H}/V_p$, we get

$$vA < \frac{1-\epsilon}{\sigma} \quad .$$

[2]The arbitrage condition at a point H' is

$$\alpha n'^{-\epsilon} A(1-vn_{t+1}) \frac{u'(c_{t+1})}{u'(c')} = 1$$

If $H' > H_d$ is sufficiently close to H_d, $n' \simeq n_d$ and $c' \simeq c_d$. The left hand side equals 1 when $n_{t+1} = n' = n_d$ and $c_{t+1} = c' = c_d$. If $c_{t+1} > c'$ when H_d is unstable and $H_{t+1} > H'$, then the left hand side equals 1 only if $n_{t+1} < n' = n_d$.

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[4]The utility function in the tth period is

$$\alpha N_t^{-\epsilon} c_t^{\sigma} = \alpha N_t^{-\epsilon} \ell_t^{\delta\sigma} H_t^{\beta\sigma} K_0^{s\sigma} N_t^{-s\sigma}$$

$$= \alpha N_t^{-\epsilon^*} \ell_t^{\delta\sigma} H_t^{\beta\sigma} K_0^{s\sigma}$$

[5]Letting α be the discount factor, w_t the wage in period t and c_t the corresponding level of consumption the first order conditions for human capital with log utility is simply

$$\frac{w_t}{c_t} = A\alpha \frac{w_{t+1}}{c_{t+1}}$$

and the first order condition for physical capital is simply

$$\frac{1}{c_t} = \alpha \frac{R_{t+1}}{c_{t+1}} ,$$

where R_{t+1} is the marginal product of capital in period t+1.

Rewriting these equations as

$$\left(\frac{H_{t+1}}{H_t}\right)\left(\frac{w_t H_t}{c_t}\right) = A\alpha\left(\frac{w_{t+1} H_{t+1}}{c_{t+1}}\right)$$

and

$$\frac{K_{t+1}}{c_t} = \alpha \frac{k_{t+1} R_{t+1}}{c_{t+1}}$$

shows that if human capital grows at the fixed rate $A\alpha$, the first equation will be satisfied since labor's share is fixed with Cobb-Douglas. If the savings rate is constant, the second equation will be satisfied since capital's share is also fixed.

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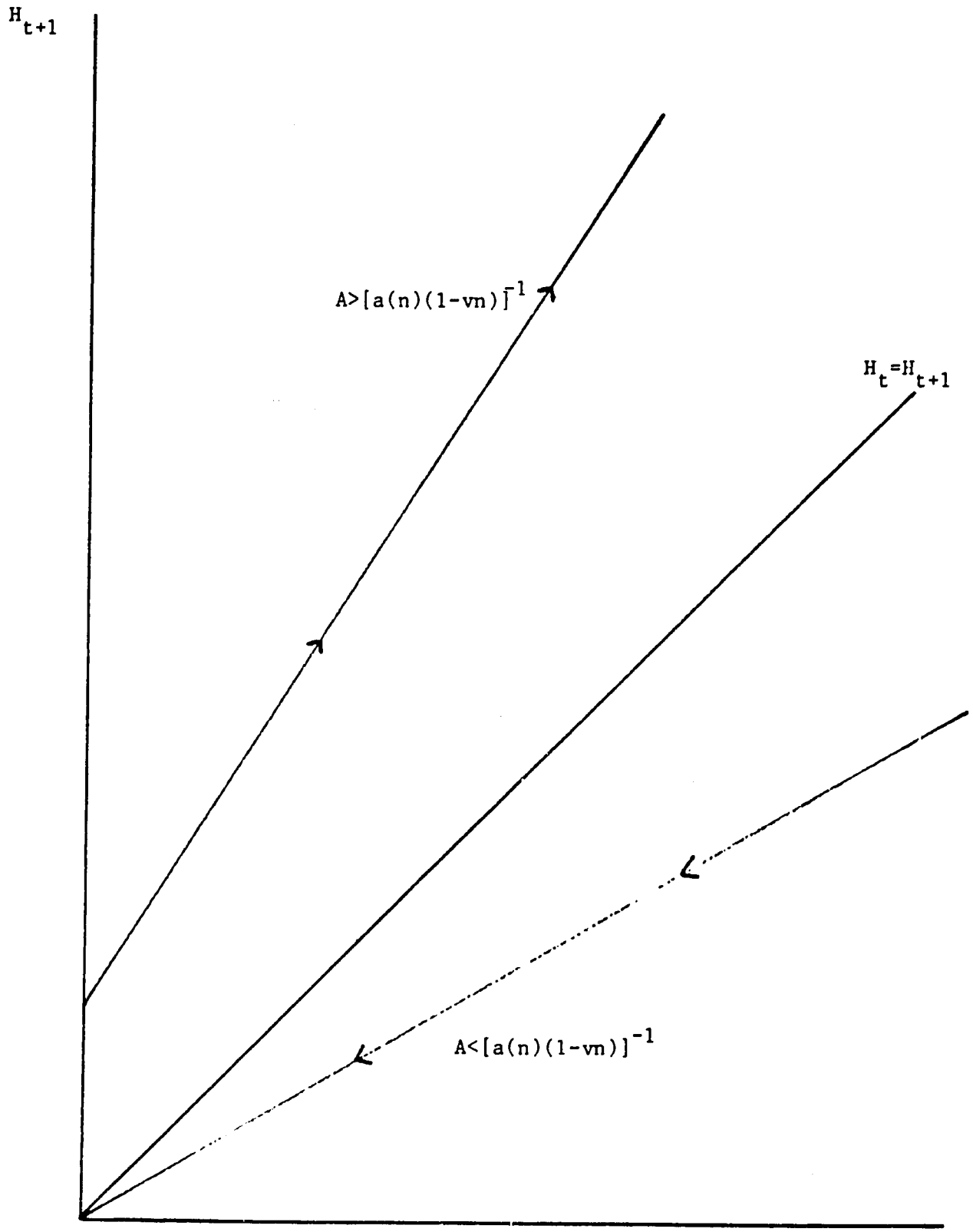

Figure 1

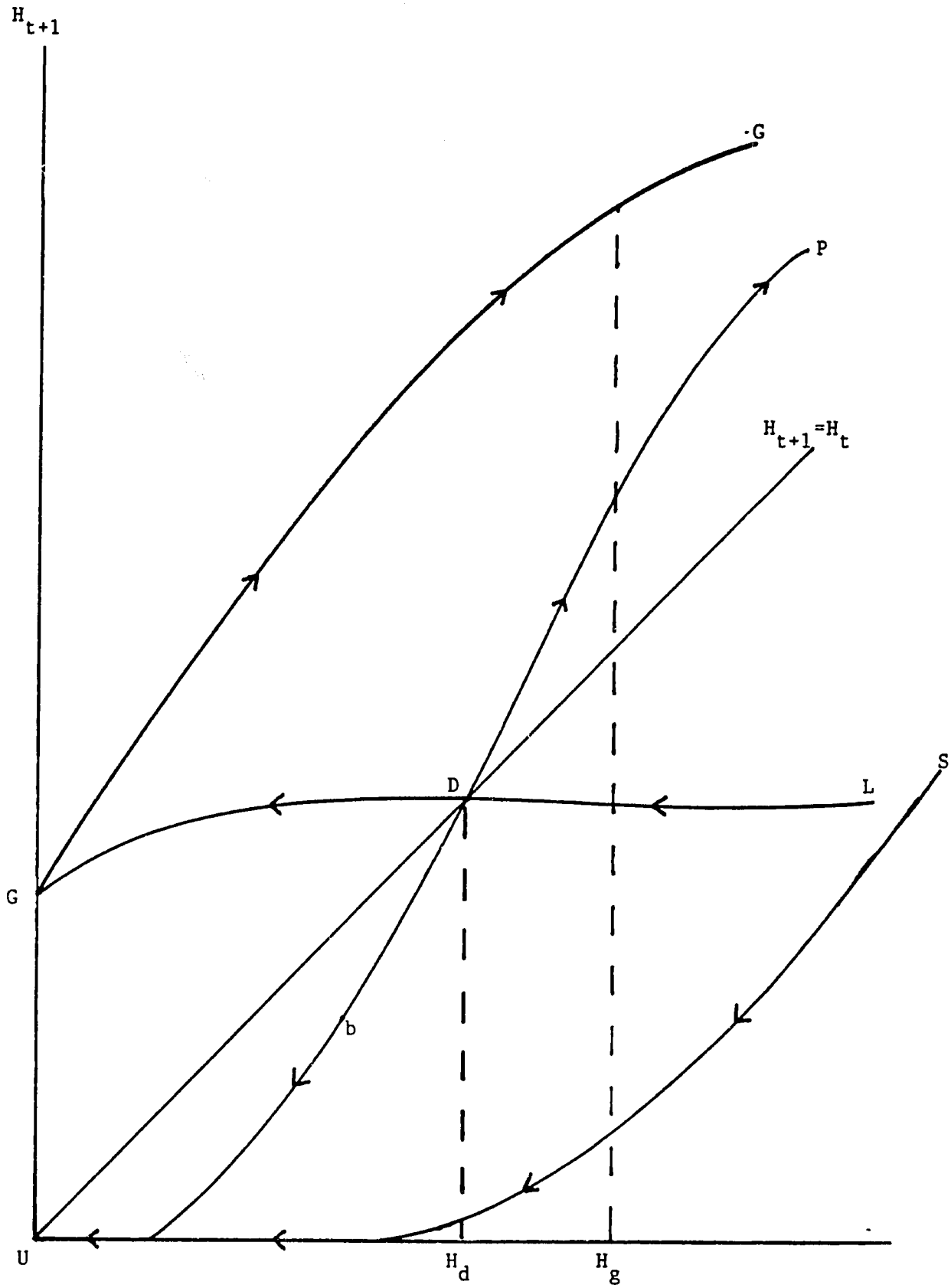

Figure 2

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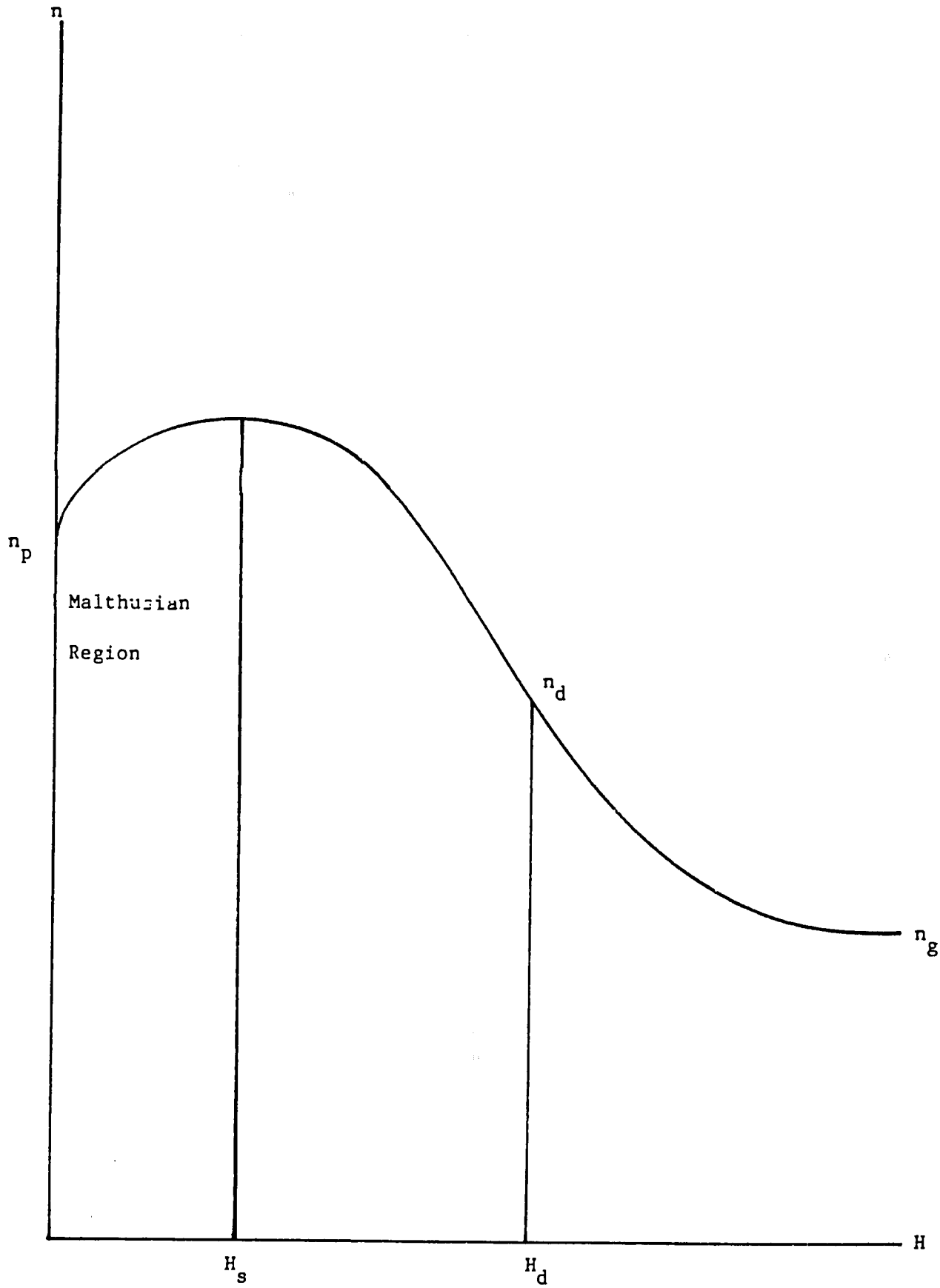

Figure 3

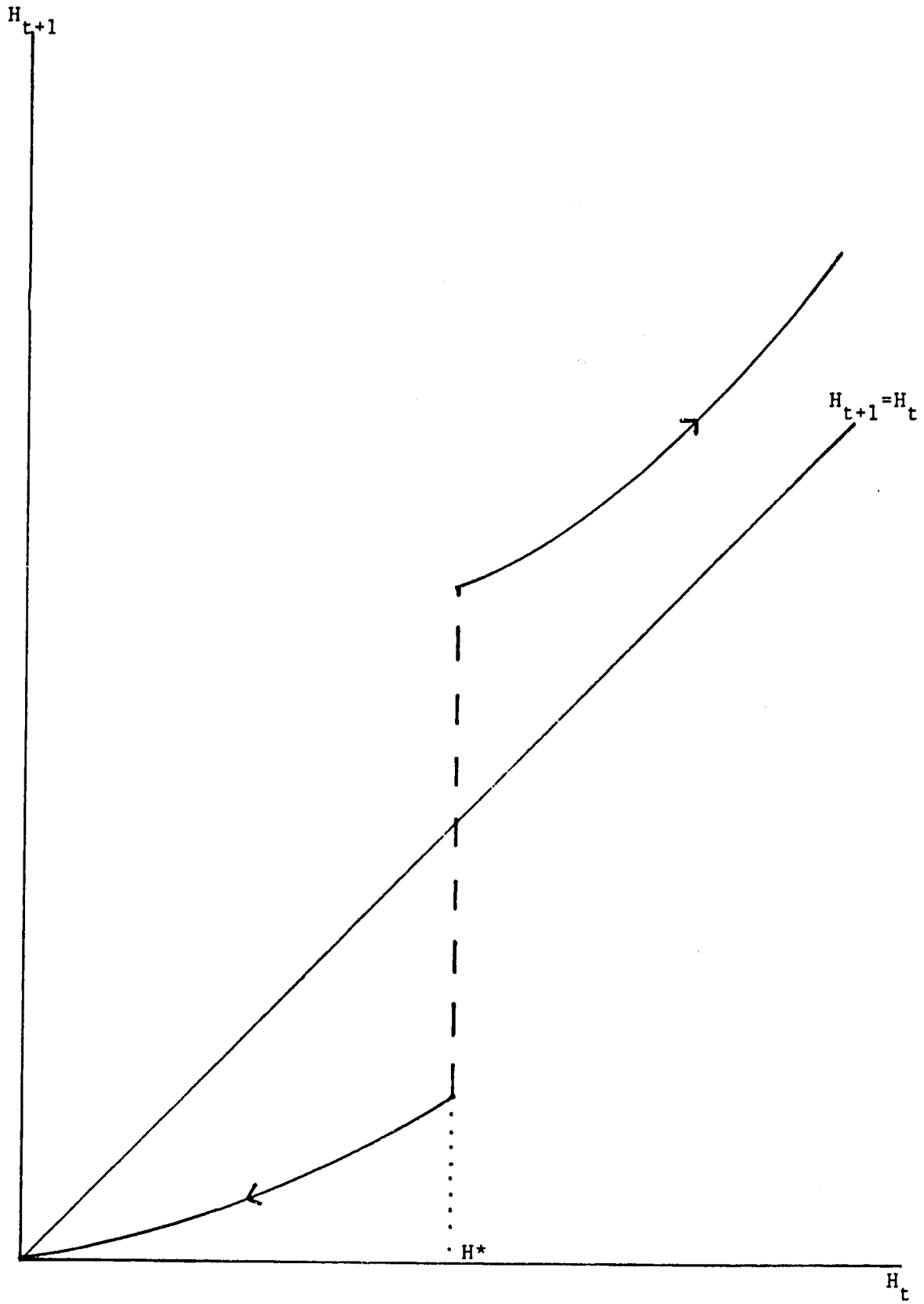

Figure 4

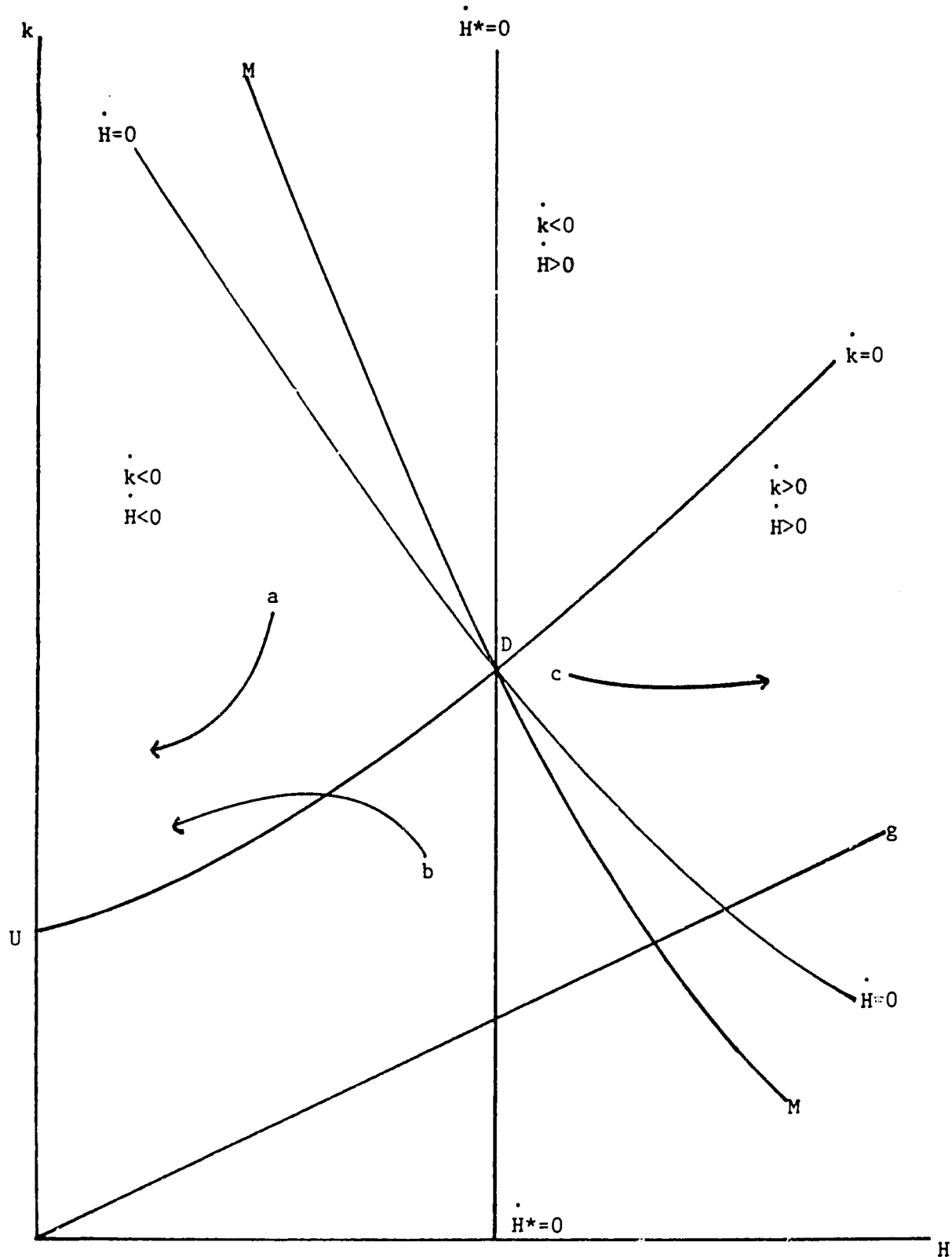
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Figure 5

Federal Reserve Bank of Minneapolis
Research Department

Comments

ECONOMIC GROWTH, HUMAN CAPITAL, AND POPULATION GROWTH

Edward C. Prescott

Revised August 1988

*Prepared for Institute for the Study of Free Enterprises Systems conference, "Exploring Economic Development Through Free Enterprise," May 27, 1988, University of New York at Buffalo.

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The central theme of the Becker-Murphy paper (1988) is that the growth rate of human capital investment per young person is the key determinent of growth in output per capita. The findings of Solow (1957) is that increases in tangible capital per person can only account for about a third of the growth in output per capita. If the other two-thirds can be accounted for by growth in the human capital input per worker, one need not rely on exogenous technological change.

A feature of tangible capital is that we can measure the quantities of various capital goods and aggregate using some set of market prices to obtain an aggregate stock of capital. This endeavor is not without its conceptual problems. Given the changing nature of capital goods, measuring the existing stock of say computers is difficult. And, of course, there is the famous Cambridge capital controversy of the sixties concerning aggregation problems. But, forming these aggregate input series along with aggregate output services was a success. They revealed the growth facts, which gave rise to the neoclassical growth model--a corner stone of modern public finance.

The position of Becker and Murphy is that changes in the quality of the human capital input can plausibly account for most of the growth in output not accounted for by growth in the tangible capital input. In other words the more or less steady growth in output per hour is the result of roughly proportional increases in both tangible capital and the quality adjusted labor input. In these remarks I will question whether there would be sustained growth absent exogenous technology change. In particular I shall argue that even if the human capital did increase as hypothesized it does not imply that exogenous technological change is not crucial for economic growth.

It is important to recognize that exogenous means exogenous to the profit center whether the center be the legal entity called a corporation or an individual or a family. There is considerable evidence that exogenous factors are an important determinent of the return on investment in human capital. Today the books in a public library contain information which can enhance an individual's productivity in market production and which was not in books at the turn of this century. This suggest the absolute returns to allocating time to acquiring knowledge is greater today because the stock of knowledge is larger--that is there has been exogenous technological change.

Becker and Murphy point out that a key input to education is teachers and that the quality of the teachers has surely increased over time. Chari and Hopenhayn (1988) have a growth model with vintage human capital and with experienced people training the inexperienced people in the use of various vintage technologies. In their framework, the arrival of new technologies is exogenous in the strong sense of being independent of the decisions of the economic agents. In equilibrium all of a given generation realize the same lifetime utility though they make different decisions as to which technology specific human capital to acquire. The data generated by their economy would be pretty much identical to that generated by the Becker-Murphy economy. Both would display sustained asymptotic growth. If one did Solow growth accounting with human capital measured the way labor economists say it should be, for both economies there would be no measured technological change.

The two economies have very different policy implications. In the Becker-Murphy world if society subsidizes the accumulation of human capital or simply compels families to send their children to school for more

years then they would otherwise choose, growth on average would be more rapid. In the Chari-Hopenhayn economy it would not be. Is there any careful empirical investigation that documents that average growth rates over extended periods are higher for countries whose young receive more years of schooling? I know of none.

I am a strong supporter of formal education and think a liberal education has public value. A knowledgable citizenry is needed for the effective working of a democracy society. Only if the people understand something about the operations of alternative arrangements and institutions will good ones be selected. I suspect good arrangements in this sense will result in an economy characterized by rapid growth.

When countries separate themselves from the rest of the world their growth slows. Recent examples of this include Franco's Spain prior to that countries policy shift in the fifties. Other examples include Albania and Burma in the postwar period and Japan in earlier eras. These observations suggest that there are factors affecting growth which are even exogenous to the national state. Becker and Murphy model assumes all external effects can be internalized within the family.

Some further evidence for external effect is that virtually all factors of production have smaller rental prices in India then they do in the United States. This includes the ones that are relatively scarce in India. If a random worker in India were selected, taught English and moved to the United States, except in very special cases the worker's wage soon would be higher than it was in India. This does not match well with competitive theory with no external effects. Of course a given factor though scarce can have a lower competitive wage if there is a sufficient amount of complimentarity and the complimentary factors are scarce as well. But, if

there are many goods and each does not have a close substitute the price taking assumption is suspect. As shown by Chari and Jones (1988), introducing property rights appropriately can eliminate external effects, but then market arrangements fail because of monopoly power rather than unpriced external effects. This, I think, is a problem for the Becker-Murphy theory, which has neither monopoly power nor external effects.

The Solow neoclassical growth model has proven useful in organizing and interpreting aggregate data that Kuznets and others collected. Solow's neoclassical growth model accounted for the growth facts. Cass endogenized the savings decision by introducing an infinitely lived family. But where does the family utility function come from? One approach is the overlapping generation with each generation having preferences on its own consumption only. Another is that of Barro (1974) who assumes agents care about their own consumption and the utility of their offspring. Insofar as this is an empirically valid abstract, it nicely rationalize the infinitely lived family construct. Barro and Becker (1988) go one step further. They endogenized the number of kids.

One weakness of the Barro-Becker approach is that family formation is not considered. A feature of this paradigm that does not match observations is that human reproduction is not a sexual. The typical pattern is that a male and female from different coalitions form a new children production coalition. This feature, I think, is important for developing a theory of household choice of number of children and the allocation decision made within the dynamic coalition. Developing a theory of the household seems every bit as challenging as developing a theory of the firm which like a family is an ongoing organization.

Is it any more appropriate to hypothesize a utility function for a family then for a firm or a labor union or a government or for that matter any organization? I think not. The general equilibrium approach is to hypothesize preferences orderings for individuals that are defined over their consumption stream, and if there are consumption externalities, those of other agents as well. This defines preferences over allocations. Following Arrow (1969) the commodity point can be expanded in such a way that there are no externalities. When people care about the consumption of their clones, that of the clones of their clones, etc., the reasonableness of the price taking assumption is suspect and some allocation mechanism other than the competitive must be assumed. One cannot define a dynamic coalitions utility function if one adopts the general equilibrium paradigm without some auxiliary assumptions concerning the mechanisms being used. And then, the function is a value function--not a utility function. Implicit in the Barro-Becker framework the mechanism used are ones with the property that each clone chooses from some choice set and the equilibrium is a Markovian perfect Nash equilibrium of the dynamic game.

In their paper Barro and Becker present one underlying set of preferences for which each clone's value function depends only of their own consumption and upon the utility of their immediate clones. What empirical evidence is their for this underlying preference orderings? As Becker and Murphy point out there are sometimes conflicts between generations and parents constrain human capital investment decisions of their children. This is inconsistent with the assumed structure.

There are other preference orderings, which given the class of mechanisms considered, yield observationally equivalent behavior but which have very different welfare implications. Suppose children care about the

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consumption of their parents and grandparents. Or suppose that agents have the Phelps-Pollak (1968) type utility. How does one econometrically distinguish between the alternative structures? For one, outcomes are efficient in a sense and for the other they are not.

To summarize, the Becker-Murphy paper is rich in ideas. A weakness of the theory is that it is too flexible and not sufficiently restricted by measurement. Theories too divorced from measurement often turn out to be sterile. I would have trouble using the structure Becker-Murphy in an applied general equilibrium analysis of alternative policies designed to foster growth.

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Comments on Becker and Murphy

-- by Henry Wan, Jr.

Overview

I was summoned via satellite, from *de hart van Noord Brabant*, with the Becker-Murphy paper waiting at state-side. With no time to learn how the first discussant will stage an act-hard-to-follow, I have to minimize my comparative disadvantage. In any case, stepping into the shoes of a development expert from the Yale Growth Center, I now act as an *ersatz* development economist and an observer of the (east) Asian Drama.

This paper of Becker and Murphy is timely, ambitious, and technically marvelous: timely, since growth and development are presently the pre-occupations of Gorbachev, Gandhi, Mitterrand, etc.; ambitious, because both fertility and economic growth are controversy-prone topics; technically marvelous, because so much theory has been compressed into so compact a nutshell. To illustrate how complex are the matters, note that demographic transition is viewed as an issue defying simplification by demography authorities [see Ansley Coale (1987)], and whether factors like Confucian ethos are crucial for development remains an unsettled issue [For example, Morishima (1982), Wan (1988)].

Overall, I consider this paper as highly successful, offering an approach ready to be applied and adapted. For illustration, I suggest two instances where such adaptation may yield intereting results.

A real-life example

First, this paper focuses on the long run, by then -- as Keynes noted -- we are all dead. As I am eager to sort matters out slightly earlier than that, I shall try my own hands to experiment with a 'short run Becker-Murphy analysis' before the authors.

This paper rightly concludes that, by and large, the Malthusian view of positive association between income and fertility is falsified by data. Yet this conventional wisdom of a negative association seems to be belied by exceptions like the comparison between Kuwait and Sri Lanka, below. I believe, however, this model by Becker and Murphy provides the clue to explain such paradoxes. Although I do not have the time for details, I shall include below a partially worked out schema to resolve the paradox.

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Paradox and Resolution

Paradox	Kuwait	Sri Lanka
GNP per capital (1985)	$14,460	$ 360
TFR	6.2 (1980-5)	2.8 (1986)

Resolution (a la Becker Murphy)	Kuwait	Sri Lanka
opportunity cost of the time for child care $(u')(\partial c/\partial h)$	low	high
physical capital (k)	rich	poor
human capital (H)	negligible	considerable
Proxy for the scarcity of H: % of no-schooling for age 25+	44.4% (1985)	15.5 (1981)

I have noted above that the authors are successful in packing much of their decades' insight into a model depictable in a two dimensional diagram. Still it leaves out such topics like the Beckerian analysis of marriage or envy, the contributions of other human capital school, like the tournament analysis by Lazear and Rosen (1981), or such studies of technology diffusion [for a survey, one may consult Lutter (1986)].

Some suggested adaptations

As my second illustration for the adaptation of the Becker-Murphy study, I shall consider the rapid growth in East Asia (namely, Japan and the four Asian NICs). The contrast of such performances with the modest record of some other LDCs is partly responsible to the rise of the *new* growth theory, as spearheaded by Lucas (1988). Moreover, human resource is almost the only thing these economies have to offer, at the outset of their industrialization. Their records form the natural benchmark to measure against for any human capital theory of development and growth. The analysis of such growth episodes seems to call for the inclusion of several new elements into of the Becker-Murphy approach.

Specifically, the two aspects requiring adaptation concern both the disaggregation of the labor supply and the interaction among the national economies, as tabulated below.

	Labor force	Different Ecomonmies
Becker-Murphy Theme	Homogeneous	Independent Growth
Suggested Variation	Heterogeneous	Interdependent Growth

Such an adaptation helps to determine the replicability of the East-Asian development. The East Asian Five differ in size (e.g., Japan: 120 million; Singapore: 2.5 million), government form (e.g., Hongkong: *laissez faire*; Singapore: authoritarian), and ethnicity, yet their development processes share the following six stylized facts --

(1) Export-led Development

The city states of Singapore and Hongkong trade very heavily. The Taiwanese ratio of export (or import) to GDP is comparable to those of the Benelux, which are among the highest in the world. Even Korea and Japan rely much more heavily on foreign markets than other economies of similar population size, like The Philippines and Indonesia, respectively.

(2) Manufacture-based Export

Apparently, inputs in manufacturing industries (say, radio production and T. V, production) are less industry-specific than resource-based industries (say, extracting oil and harvesting oil palm): an advantage for economies undergoing structural change.

(3) Female-staffed Manufacture

In East Asia, the *foot-loose* industries which powered the initial export drive, like textile, apparels and electronics, happen to employ a large proportion of female workers. At the dawn of industrialization, many Taiwanese female workers would work for their dowry before their marriage. Some would continue to live with parents, incurring rather negligible opportunity cost. They often receive wages lower than the unskilled (e.g., housemaid, or assistant bricklayers), due to substantial compensating wage differentials (higher status, and hence more eligibility for better marriages).

Such community-assisted input market distortions would guarantee both a high labor force participation for females, and a high rate of growth for such export industries. As it turned out, by backward linkage, such export industries contribute to the overall industrialization of these Asian NICs. This high rate of female participation in the labor market presumably also has effects on the lowering of the birth rates. See Wan (1978) for the following data.

a. Importance in major export sectors, 1973

Textile/apparel/leather	70 %
Communication Equipment	72 %
Electric generators	63 %

b. Monthly wage comparison (in U. S. $)[1]:

	Assembly workers (A)	Unskilled workers (U)	A/U
India	120	16	7.5
Taiwan	25♀	45	.55

Among the four categories, most Taiwanese assemblers are female. For comparison, it is reported that working in factories away from home may reduce the marriageability of teenage females in Bangla Desh (New York Times, April 17, 1988).

(4) Universally-educated Female Labor

The archetype is the system introduced to Meiji Japan by the Imperial Rescript on Education in 1890. It was imposed on Korea after the Annexation (by Japan), 1910, and emulated in various Chinese societies. This system imparts in the students a disciplined behavior and a functional literacy.

(5) Constantly-upgraded Structure

This is evidenced by profound and continuous changes in the export-mix, the output-mix and the employment-mix, in all the five East Asian economies we mentioned. See Lau (1986) for detailed evidence.

(6) Growth-by-Technology Diffusion

This follows the *parabolic* formula:

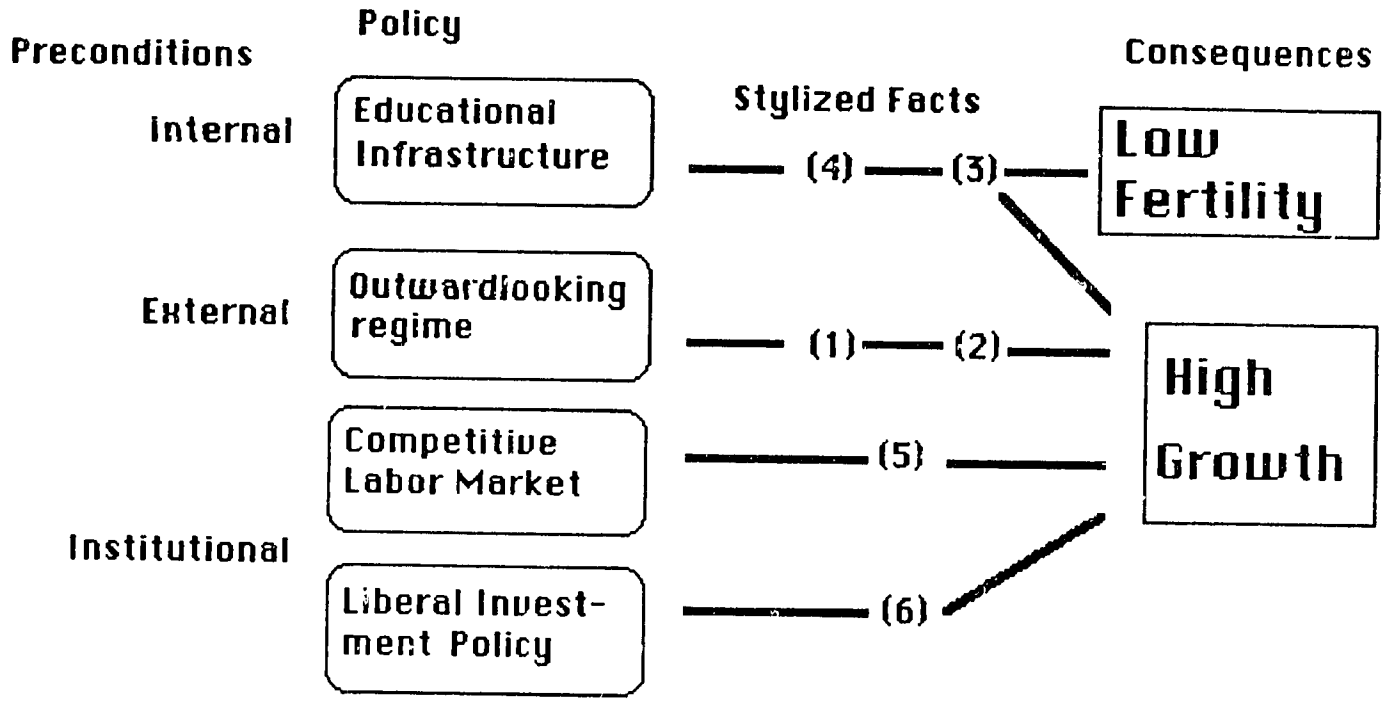
Rate of Imitation = (Scope for Imitation)(Capacity for Imitation),

where the scope represents the technology gap, and the capacity measures the current technical capability [see Lutter (1986)]. For East Asia, rapid growth apparently is driven by imitation. Specifically, when Japan begins to catch up with the West about 1970, her growth rate fell to about 5%: half of what it used to be (10% per annum), while the Asian NICs -- no more capable than the Japanese, by all counts -- continue to grow at the peak rate which Japan has ever achieved, even now. This is important since in most cross-country comparisons, causal explanations are sought after while different national economies (say, Korea and the U. S.) are treated as if they were developing in isolation, with no recognition given to the effect of international technology diffusion.

[1] Henry Wan, Jr.: Manpower, industrialization and export-led growth in Y. Wu and K. Yeh eds., Growth, Distribution, and Social Change: Essays on the economy of the Republic of China, Occasional Paper Series in Comparative Asian Studies, #3 -- 1978, no. 15, School of Law: University of Maryland.

A tentative theory

We believe that the above six facts are interrelated. They are conditioned by public policy and they have both theoretic and policy-relevant implications. This is summarized below.



Specifically, the policy of universal, compulsory education provides the female, semi-skilled labor force which fueled the East Asian type of export-led industrialization. The policy regimes permitting profitable exports (a realistic exchange rate, the absence of highly-subsidized import substitution sectors which would compete inputs away from the export sectors) tend to boost manufacturing exports for resource-poor economies in East Asia. In turn, a competitive domestic labor market, together with a willingness to phase out *sunset* industries offers the opportunity to continuously up-grade the value added margin within the manufacturing sector. Specialization in manufacturing helps, since by and large, the step from assembling radio to the production of personal computers seems to be shorter than from tending oil palms to tending oil rigs. Low adjustment cost forms the basis of the mechanism of *manufacturing up* [see Lau (1986)]. Again, in catering to foreign demands, it is advantageous for a newly industrializing economy to introduce foreign technology, as facilitated by a liberal policy for foreign direct investment and joint venture.

Together, these policies and those stylized facts which they produce lead to both low fertility and high growth. The Becker-Murphy model may be adapted to disaggregate the labor force both by gender and by skill grade, as well as to redefine the effect of human capital formation by recognizing that the *parabolic* nature of productivity gain (as reflected by the diffusion effect in stylized fact (6)

above). Such adaptations are certainly feasible for econometric simulation if not also tractable for qualitative analysis.

There are several implications along this line of reasoning. We shall introduce the following two for illustration:

I. Theoretical -- low fertility and high growth are both the consequences of high female labor participation; neither one need be the direct cause of the other.

II. Policy -- If foreign market is crucial for the East-Asian type of development and foreign technology is initially needed for such market entry, then for the sake of national advantage, conceivably the main thrust of education effort for development should be first directed to a broad-based education and not a narrowly-focused program of training an elite corps for domestic R. and D. The horror tales of an excess supply of over-qualified personnel in South Asia have been repeatedly discussed by Indian economists[1].

Remarks on human capital

The above discussions also lead to the following two observations about the notion of human capital. A digression is warranted since this concept is both the centerpiece of the Becker-Murphy approach and the chief ingredient which can make the *new* growth theory *new*. We focus here on the education component, which is crucial for East Asia during the emulative phase, rather than the R. and D. component which has already been addressed by Romer (1986).

(1) The formation of human capital yields pecuniary Pigovian externality. For example, real estates gain in value when foreign investment is attracted to the country, by the improvement in labor productivity. At the same time, when jobs are allocated through competitive examinations, education is encouraged society-wide by a process akin to the tournament model. Whether this implies over or under-accumulation of human capital is not obvious.

(2)In Japan, competition for the best job leads to the competition for the best college, and the competition for attending the best college leads all the way to competition among pre-schoolers for attending the best kindergarten [Morishima (1982)]. Such force-fed education often favors memorization over initiative. It may serve a society in transition, like Meiji Japan, but not the autarkic empires of ancient Sung China, or Ming China. It remains to be seen how efficacious is such

[1]The overqualification phenomenon is consistent with long run labor market equilibrium. For example, in Wan (1987) information asymmetry causes relative wage rigidity and job discrimination in a persistent equilibrium. Adding to this a Harris-Todaro rationing feature then agents would continue to elect for education, knowing fully well that in equilibrium, part of the educated is destined to be overqualified for the unskilled job they must take. The cost of education will be balanced by the expected incremental utility of having an education.

education for Japan (and the Asian NICs) as technology borrowing comes to its historic end. Thus, the value of a particular type of human capital may depend upon the stage of development of an economy. Moreover, human capital is just as heterogeneous as physical capital, a fact underlying much controversy for the *old* growth theory.

A concluding note

To set the matters in perspective, I would like to invoke the teachings of Milton Friedman (1953), where a theory is judged successful, not by its descriptive accuracy, but by its analytical relev e. Although various adaptaion may be needed to apply the Becker-Murphy theory to various occasions, the basic contribution is fruitful, beyond any doubt.

I would further take a leaf from the last page of The Growth Theory by my teacher, Solow (1970), where he proposed a dualistic approach: the coexistence of simple models to yield "usable insights" and "usable large-scale econometric models ... on the basis of ... insights from simple models". The Becker-Murphy model clearly fits well the first category.

Significantly, Rene Thom (1975) also favored a sequence of models for various applications rather than a single model for all occasions.

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Addendum

Circumstances prevented me from offering more complete comments at the conference than what appear above. With the revised paper on hand, I believe these comments remain relevant. In particular, there is much to be done to analyze the present, which is often regarded as short-run, and transient, thus left out of sight. Further, the performance of individual economies is sometimes inseparable from the interactions among them: the unprecedented growth of the Asian NICs after 1950 becomes possible only by tapping into the reservoir of American and European technology steadily cumulated over the last 100 years.

I do have several points to add, four methodological and the other more substantive in nature.

First, the Becker and Murphy paper is likely to be regarded one of the high point of the *recent* growth theory. The difference between the latter literature and the *neoclassic* growth theory is one of emphasis, and not analytic artillery, nor conceptual framework. The last (conceptual) point will be commented slightly later. We note that right in its very beginning, the *neoclassic* growth theory has considered various analytical features, from the unbounded paths to the steady states of both the stable and unstable types. Intertemporal optimization, two-state phase diagrams and overlapping generations were all studied within the next dozen years. Of the analytic features unexplored then, I can only cite the neutrally stable steady states of Lucas (1988). -- an attractive feature which may not survive structural perturbations -- and the strange attractors, with unproven applicability to growth and development.

The *recent* growth theory (like this paper) is designed to explain differential performances among various economies, by means of human capital. The importance of such a focus is well illustrated by the meteor-like rise of the Japanese economy, an economy without any significant resource base. The Japanese 'miracle' is not only the most significant single factor which has transformed the post-WWII world economy, but also the catalyst changing the developing course of the Asian NICs, and leading to the reappraisal of the private sector economy throughout the

less developed two-thirds of the human species. The key factor for the Japanese growth is doubtlessly the formation of human capital, the focus of the *recent* growth theory. The analysis of household decisions on fertility and education in this paper draws upon the insights accumulated by the authors over their decades of research.

Second, most economists would agree that both physical capital and human capital are important, they may also agree that different forms of human capital are accumulated by different means. Thus, education is obtained by schooling, experience can be secured by the processes of learning-by-doing, or learning-by-*others*-doing (imitation), and innovative knowledge is attained often by organized R. and D. Reasonable economists will agree further that all such forms of human capital as well as physical capital matter, if one is to explain the differential performance of various contemporary economies, and that tractable economic models should contain no more than two of these elements. The Becker-Murphy paper as well as the Romer studies [op. cit. and the one given in this same conference] are eminently successful tour-de-forces to capture two of these elements at one fell swoop. Thus, Becker and Murphy have focused upon both physical capital and education, while Romer considered R. and D. My previous comments suggest that the high growth of East Asian Five (Japan and the NICs) are due to learning-by-others-doing. Hence, some simple model should capture such an element, perhaps along the lines of Leonard Cheng. All these are 'partial' depictions offering qualitative insights and I suggested in my comments that a comprehensive quantitative simulation can further supplement our knowledge.

In a sense, this seems to be what all one can hope to do. After all, aggregative economic modeling is a challenging art, and as Andre Gide put it, art is created against a resistive medium. Inherently, aggregative modeling must be a compromise between analytic tractability and the goodness-of-fit for what is deemed essential. Conventional wisdom convinces much of us that tractability constrains us to use no more than two state variables and to limit the type of inter-acting individuals to three or less. One must be most selective in the choice of state (as well as control) variables and in characterizing the underlying functional relationships. Becker and Murphy (as well as the works of Lucas and Romer mentioned above), apparently have already made the most of a

'global' analysis, pressing hard against the bounds of tractability. Unless one suggests a shift of focus, bringing in new features at the expense of the old, not much more can be done on any isolated topic. By and large, I second this view (with a minor proviso below).

On the other hand, to understand the development process as a whole, perhaps one should take a three-pronged attack: (a) construct both a master model (with a high-dimension state space), itself intractable qualitatively, and an interlocking network of 'partial analysis' like the Becker and Murphy model, each as a specialization of the 'master' model. Each would treat no more than two or three of such variables as state variables, and relegate the rest as parameters. After all, one navigates on the spherical Earth with a network of interlocking two-dimensional maps, rather than an unwieldily large globe. (b) explore three-state analytic models by imposing simplifying special structure. Whenever possible, this may be done just to assure ourselves that some unexpected but important three-state interaction will not escape our notice. We live in three dimensions. Three-state phase diagram is not always unmanageable [see for example, Wan in Bhagwati et al eds. *Trade, Balance of Payments and Growth*, North-Holland, Amsterdam, 1971]. (c) conduct quantitative simulation as we have mentioned above.

The *recent* growth theory has made an impressive beginning. What I suggested above is that we already have the basis to launch a concerted attack against the *terra incognita*. The profession may gain more than having *all* efforts conducted as isolated projects.

Next, I would comment upon the conceptual underpinings of this paper. Fertility at present cannot be understood without reference to several factors such as (a) the lowering of the infant mortality, and the caring for the very old, both inherently related to the risk-taking attitude and (b) the changed decision process (including fertility decisions) inside the family, in societies with high rates of divorce and remarriage: game-theoretic elements are relevant here. At the present, overlapping generation models under uncertainty has become the foundation of macro-monetary models. Likewise, incomplete contract as well as bargaining theory have made much progress in labor economics. It seems apropos to ask whether the

studies of the household should be best/always patterned after the deterministic decision models for the individual. My guess is again that the Becker-Murphy paper has provided a much needed point of departure, for expeditions into the less charted waters. Focusing on steady state analysis, the more conventional approach in this paper has provided a highly useful benchmark. It may be a different story, however, if we aspire to develop policy guides closely supporting developing economies in transition.

A further analytic observation is that Becker and Murphy have included the effect of learning-by-doing without an additional state variable. It turns out that this is possible because that in their overlapping generations model, the working phase of each individual is lumped into a single period. If, along the pioneering version of Samuelson, there are two or more 'active' periods over the life of each individual, then the latter will surely consider the advantage of producing more in an earlier period, for experience. The more periods one subdivides the active life into, the more complex it would be without introducing a new state variable,

The final point concerns the example of ancient China as compared against Great Britain. This may illustrate an unstable intermediate steady state, from which *luck* may bring the system to either sustained growth or stagnation. However, in this particular case, not *luck*, but the opening to external trade seems to have made much difference. Since innovation is inherently lumpy, it may cause unbalanced growth and income redistribution which strains the socio-political fiber. Even with their export-led prosperity (and hence the relative ease for labor reallocation), the British industrialization has led to much suffering (e. g., during the Enclosure Movement). Ancient China was essentially autarkic on a per capital basis., major technical change might well create unacceptable socio-political upheavals. Hence, both crafts and commerce, the twin pillars supporting technological innovation, were traditionally accorded less importance than agriculture. As it was, several Chinese empires fell prey to insurrections arisen from economic stresses, like crop failure. If the above interpretation is true, this is one more instance where the evolution of an individual economy is inseparable from the international environment.

POPULATION GROWTH AND HUMAN CAPITAL INVESTMENTS: THEORY AND EVIDENCE

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Among the more striking regularities evident in aggregate cross-country data, whether examined cross-sectionally or over time, are the inverse associations between fertility rates and per-capita incomes and such indicators of human capital as schooling levels and survival rates. As a general rule, high-income countries have been and are characterized by low fertility and high levels of human capital; low income countries are characterized by high fertility and low levels of human capital. And those countries that have experienced high rates of per-capita income growth in the last 25 years have also experienced relatively rapid declines in fertility and increases in human capital levels.

There is little doubt that declines in fertility and increases in human capital levels accompany economic development. Such aggregate associations, however, by themselves do not reveal very much about the determinants of economic growth, human capital investments or fertility. While progress has been made in incorporating fertility, physical capital and/or human capital investment in models of economic growth (Ben-Zion and Razin, 1975; Eckstein and Wolpin, 1985, Becker and Murphy, 1988) that are capable of reproducing the actual intertemporal movements in these variables, such models do not appear to rule out many alternative intertemporal patterns. The success of these models in "explaining" actual events thus does not constitute evidence for or against the basic hypotheses embedded in them concerning, for example, the determinants or consequences of agent's fertility decisions. Moreover, the "stylized facts" of development are equally supportive of hypotheses, including those arising from early-generation growth models (Solow, 1956), that posit that reductions in fertility brough about presumably by non-economic factors have caused economic growth, perhaps via increased human capital investment, or that unmeasured forces influencing

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economic growth also jointly influence fertility and human capital accumulation.

Micro data, which more richly describe the individual agents making fertility and human capital investment decisions and the environment in which they take place, may appear to provide a superior basis for inferring the causal mechanisms that form the core of models of economic growth and that potentially underlie the observed aggregative associations between economic development, fertility and human capital levels. However, cross-sectional data from within a country may contain little true variation in variables that might plausibly be considered exogenous to agent's behavior. For example, when agents are mobile, wages are influenced by human capital investments, and such investments are made according to some (optimal) decision rules, the cross-sectional association between wage rates, family size and schooling would reveal little about the determinants of fertility or of its effects on human capital investments, particularly when the major source of cross-sectional heterogeneity is in preference orderings.

In this paper I review and present findings from empirical analyses that have attempted to estimate both the determinants and consequences of fertility and human capital investments based on the exploitation of "natural" experiments in micro data that plausibly simulate the theoretically-appropriate experiments designed to infer causal relations. In section one, I discuss evidence pertaining to the issue of whether fertility and human capital investments respond to economic development in ways consistent with economic theory. In particular I consider how exogenous changes in the rates of return to schooling which may arise from growth-inducing technical change jointly influence fertility and schooling investment decisions. A simple model is formulated to demonstrate how

information on the wage rates of children may be used to infer the effects of changes in the returns to schooling and to test the hypotheses that declines in fertility and increases in human capital in part result from economic growth propelled by (exogenous) technical change. Cross-sectional micro evidence from three countries on the fertility and schooling effects of variation in child wage rates are presented and aggregate time-series information describing the natural experiment provided by the geographically-selective profitability of high-yielding grain varieties introduced in India in the early 1960s are presented and used to assess the model. The ability of the estimates based on the cross-sectional data to account for the magnitudes of the actual intertemporal changes in fertility and schoooling evidently induced by the "green revolution" is also assessed.

In the second part of the paper, I discuss evidence pertaining to hypotheses concerning the effects of changes in fertility on human capital. Demographers have emphasized the importance of couples' inability to perfectly control fertility in influencing the resources allocated to children. Moreover, billions of dollars are expended annually by government agencies in support of programs that are aimed at lowering the costs of fertility control, predicated on the assumption that the consequent reductions in fertility have important and positive consequences for economic development, although the mechanisms are not spelled out. Here the issue is one of obtaining quantitative evidence on how exogenous shifts in the costs of fertility control affect, if at all, the human capital of children in the context of a model in which both fertility and human capital are the outcomes of optimally-made decisions. Biological attributes of reproduction and of human capital production are incorporated in the model formulated in part one and various methods that have been used to measure

those components of fertility that are exogenous and biological are discussed. Evidence obtained using these methods from a number of countries on the quantitative effects of exogenous changes in the costs of fertility control and of fertility itself on schooling, on birthweight and on the investments in the human capital of mothers are presented and discussed.

1. The Effects of Economic Growth on Fertility and School Investment

a. Technical Change, Rates of Return to Schooling and Fertility: A Model

Technical change is an important (if not the only) determinant of economic growth and development. If the influence of changes in the rate of technical progress on fertility and schooling decisions can be estimated, then an assessment can be made of models that posit that fertility and schooling respond (in a predictable way) to economic growth or its change. Changes in technology are notoriously difficult to measure, however, so that some indirect way of estimating their effects must be found. T. W. Schultz (1976) has hypothesized, and there is some evidence from the U.S. farm population (Welch, 1970), that changes in the pace of technological advances or the initiation of technical progress, raise the returns to schooling, as schooling enhances abilities to cope with and/or adopt new technologies. Estimates of how changes in the returns to schooling influence fertility thus can provide evidence on the responsiveness of family size decisions to at least one component of economic development. Because incomes are influenced by and schooling levels also respond to alterations in schooling returns, the associations between income, schooling and fertility are less informative about the consequences of economic growth than are direct estimates of the effects of changes in the costs or returns to human capital

investments.

In mobile populations, the rental rates on the services of human capital are unlikely to vary across space. However, in many low-income countries an important component of the cost of schooling, and thus of the net return to schooling, is the opportunity cost of child time. The major alternative to schooling among relatively young children, particularly boys, in such countries is labor market employment. In rural Peru in 1985-86, for example, boys (girls) aged 10-14 who were not in school (less than half) worked on average 32 (8.5) hours per week (Gertler and Glewwe, 1980); in India (1970-71), children 10-14 worked on average 150 days per year (Rosenzweig, 1981), contributing about 20 percent of total family income. Most importantly, the wage rates of younger children are unlikely to be influenced by (are exogenous to) human capital investments but are likely to vary in the cross-section, as families are unlikely to change locations in response to spatial differences in child wage rates. Thus, rental rates on human capital are likely to be spatially arbitraged but not opportunity costs of schooling. Cross-sectional information on the wage rates of children can thus be exploited to test whether and how family size and schooling decisions respond to alterations in the return to schooling that fuel the growth process.

To more rigorously establish the relationships among the costs and returns to schooling, fertility and school investments and to assess whether economic models of fertility behavior yield refutable predictions with respect to changes in schooling returns, I formulate a simple model of family size and schooling decisions designed to incorporate the major features of fertility models developed over the last 15 years.[1] To maintain simplicity, and to highlight the role of the own cost of schooling, I ignore

the contribution of parental time to human capital formation and its allocation across activities, although these features can be readily embodied in the model. The model incorporates a limited form of parental altruism, in that parents care about the incomes or earnings, and possibly also the schooling *per se*, of their children when they become adults, but I refrain from the dynastic model approach in which parent's utility depends on children's utility (Becker and Barro, 1988) to maintain the simplicity of a one-period model.

The family welfare function maximized by parents has the usual neoclassical properties and is given by

$$(1) \quad U = U(i, h, n, y),$$

where i = children's average income when adults, h = per-child human capital, n = number of children, y = composite consumption good. The human capital of a child is produced according to another neoclassical function:

$$(2) \quad h = h(t, x; v), \; h_j > 0, \; h_{jj} < 0, \; j = t, x,$$

where t = time each child spends in school, x = purchased schooling inputs, and v = exogenous endowment ("ability") of the child, which may influence the productivity of inputs.

I assume for the moment that parents can supplement or extract resources out of each child's adult earnings via transfers b, so that the income of an adult child i is given by:

$$(3) \quad i = \alpha h + b$$

where α = rental rate on human capital. The decision variable b may be positive or negative and may or may not be an *inter vivos* transfer.

Children when young are employed at a wage rate w per unit of time when not in school, so that the budget constraint is:

$$(4) \quad I + nw(T-t) = n(p_n + b + xp_x) + y,$$

where I = income of the parents, p_x = per-unit price of x, and p_n = direct costs of children. The labor market earnings of children when young (when schooling is acquired) is thus pooled with parental resources I.

The marginal rate of substitution between human capital and family size associated with the allocation of schooling time t in the household equilibrium described by the model is

$$(5) \quad mrs_{h,n} = \frac{n(w - \alpha h_1)}{h_1(p_n + b + p_x x - w(T-t)} .$$

The ratio of the shadow prices of human capital and family size, given by the rhs of (5), thus contain the child wage, the rental rate on human capital, the direct cost of children, the price of purchased human capital inputs and the level of parental transfers to or from children.

The compensated effects of a change in the child wage on the level of schooling t and on family size n are:

$$(6) \quad \frac{dt^c}{dw} = nS_{tt} + (T-t)S_{nt}$$

$$(7) \quad \frac{dn^c}{dw} = (T-t)S_{nn} + nS_{nt}$$

where the S_{kj} are Hicksian compensated substitution effects. Since the model implies that all $S_{jj} < 0$, then as long as schooling (human capital) and family size are Hicksian substitutes ($S_{nt} > 0$), the model yields the

result that compensated increases (decreases) in the opportunity costs of schooling, ceteris paribus, will raise (lower) fertility and lower (raise) schooling levels.

Thus, the empirical associations between child wage rates, schooling and fertility can be used to test the proposition that economic theories of fertility are capable of explaining why certain changes in the economic environment can result in opposite trends in fertility and human capital levels. None of the effects on either family size or schooling of the other exogenous variables in the model are unambiguous, with the exception of the effects of the direct costs of family size p_n.[2] Tests involving variants of p_n are discussed in section 2. The uniqueness of child wage rates in the model arises from the fact that variations in the wage rate of children simultaneously influence, in opposite ways, the marginal cost of having an additional child, given by the denominator of (5), and the marginal cost of an additional time unit of schooling, given by the numerator of (5).

How informative are the estimated quantitative effects of child wage rates on schooling and fertility for predicting the magnitude of the consequences of growth-enhancing technical change? The model accommodates a number of special cases depending on what is excluded from the family welfare function (1) and whether or not direct intertemporal transfers b are prohibited. While the qualitative predictions concerning the effects of alterations in child wage rates are robust to such respecifications of the model, the relationships between child wage rate effects and the effects of change in the returns to human capital as, say, induced by technical change, are not.

An interesting special case arises when parents do not care about the level of their children's per-capita human capital per se, but only about

their average incomes i. In that case, schooling and human capital inputs are allocated efficiently, since parents can directly transfer resources b from or to children in order to achieve the desired level of i for any given schooling level t (assuming interior solutions). Thus, barring corner solutions, the level of schooling always conforms to the allocation rule (8)

$$(8) \quad \alpha h_1 = w,$$

which is independent of parental preferences. It is obvious from (8) that the elasticity of schooling with respect to child wage rates is equal in absolute value to the elasticity of schooling with respect to a change in the rental rate on human capital α. In particular;

$$(9) \quad \eta_{t,\alpha} = -\eta_{t,w} = -h_1(th_{11})^{-1} > 0,$$
$$= -[t(\beta-1)]^{-1} \text{ when h is Cobb-Douglas,}$$

where η_{kj} = elasticity of k with respect to j and β is the schooling output elasticity in the Cobb-Douglas production function.

Knowledge of the child wage-schooling elasticity not only provides the magnitude of the schooling-human capital rental rate elasticity in this case, but provides the sign of the fertility-α elasticity without any additional information. It can be readily shown that if the human capital production function is crs,

$$(10) \quad \eta_{n,\alpha} = \frac{\alpha h}{p_n} [\eta_{t,w} + 1]\eta_{n,p_n},$$

so that $\eta_{n,\alpha} \gtrless 0$ as $|\eta_{t,w}| \gtrless 1$ or as $t(\beta-1) \gtrless -1$ in the Cobb-Douglas case. Relation (10) indicates that when schooling is wage elastic, increases in the rental rate on human capital will not only increase schooling levels but will lower equilibrium family size (assuming own price effects are

negative). This result can be more readily understood by substituting the rental rate-schooling elasticity in (10), using (9):

$$(11)\quad \eta_{n,\alpha} = \frac{\alpha h}{p_n}[\eta_{t,\alpha} - 1]\eta_{n,p_n}.$$

If schooling did not respond to, say, an increase in α, the earnings of children would still rise and parents would decrease (increase) transfers to (from) children; the benefits of the enhanced income prospects of the next generation is always shared among generations. The algebraic reduction in b, however, lowers the relative net cost of an additional child so that fertility could optimally increase. However, to the extent that schooling increases when α increases, the marginal net cost of children also rises, since time at work and thus the direct earnings contribution of children to the family declines. When $\eta_{t,\alpha} > 1$, the proportionate increase in schooling exceeds the proportionate increase in each child's earnings and thus also exceeds the proportionate reduction in per-child transfers b. The net cost of children thus increases and family size declines.

The critical assumption of the efficient schooling model is that parents provide to or can extract resources, via transfers, from their children in order to achieve an optimal (from their point of view) next-generation per-capita income level. Children thus bear the costs of their own schooling, which are financed by parents. Such a model may not be implausible for many low-income countries, where schooling levels and thus total school costs are low. Moreover, intergenerational transfers are often clearly visible in such environments. In India, for example, dowry payments which are provided to the household into which the daughter marries at the time of marriage are almost universal. To the extent that the income of the daughters' new household, the quality of her marital match, depends on both

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her schooling and on the dowry transfer, schooling will be efficiently provided. In farm households in India, bequests, principally of land, to sons are commonplace at the time of the death of the head. Suggestive evidence from Botswana (Lucas and Stark (1986)) moreover indicates that among non-resident children, those with higher levels of schooling remit larger amounts of resources to their parents, for given parental wealth levels.

The efficient schooling variant of the model is readily testable as it has additional strong implications. For example, because human capital inputs are allocated solely according to efficiency criteria, there are no effects of either changes in the costs of children (p_n) or of changes in parental income I on optimal human capital investments. Thus, attempts to change the cost of children (e.g. through family planning interventions) would not affect the level of human capital. However, because intertemporal transfers do respond to direct child-rearing costs (and to changes in I), if transfers are in the form of accumulated assets, savings levels would be responsive to alterations in the cost of children as well as to changes in returns to schooling.

If intergenerational transfers are ruled out (b=0), information on the effects of child wage rates on schooling and fertility is still informative with respect to both the magnitude and direction of the effects of changes in the returns to human capital on these variables. The relevant elasticities, when the human capital production function is, for example, Cobb-Douglas, are

$$(12)\quad \eta_{t,\alpha} = \beta^{-1}[\eta_{t,w} + 1 + \frac{wT}{p_n}\eta_{t,p_n}] \qquad \text{and}$$

$$(13)\quad \eta_{n,\alpha} = -\beta^{-1}[\eta_{n,w} + \frac{wT}{p_n}\eta_{n,p_n}] .$$

When direct transfers across generations are impossible, parents bear all of the costs of their children's schooling and thus can only extract some of the gains accruing to their children from the rise in schooling returns by compensatorily reducing investments in their schooling. As a consequence, in this model increases in the returns to human capital do not necessarily increase human capital investments. From (12), if the utility function is separable, or the ratio of the potential (full) earnings of children (when young) to their direct costs p_n is small, schooling levels will rise in response to an increase in human capital only if schooling is wage elastic. Similarly, the likelihood that a rise in α lowers fertility is higher the larger is the elasticity of family size with respect to child wages.

b. Estimates of Child Wage Effects

I have shown that if parental decisions about fertility and the schooling of their children respond to changes in the economic environment and if extensive and intensive investments in children are substitutes, then the variation in the wage rates of school-age children should be inversely associated with schooling levels and positively associated with family size. Table 1 reports estimates of child and adult male wage effects on fertility and schooling taken from two studies based on micro data sets from India and the Philippines and estimates based on micro data from Indonesia replicating the methodology of the prior studies. The specifications in each case included as regressors the mean wage rate of children based on the aggregation of child wage rates in the community of each household, the wage

Table 1

Estimates of Wage Elasticities for Measures of Child Schooling and Fertility: India, Indonesia and the Philippines

	Schooling						Children Ever Born		
	India: Enrollment Rate, Children 5-14[a,b]		Indonesia: Enrollment Rate, Children, 10-18[c]		Philippines: Schooling Attainment, Children 10-20[d]				
	Boys	Girls	Boys	Girls	Boys	Girls	India[b,e]	Indonesia[c]	Philippines[d]
Child wage elasticity	-.051 (1.84)[f]	-.066 (2.54)	-.030 (2.11)	-.020 (1.15)	-.021 (1.50)	-.021 (1.61)	.20 (1.71)	.010 (1.74)	.036 (2.05)
Father's wage elasticity	.98 (6.65)	.79 (5.64)	.24 (7.22)	.25 (6.21)	.066 (2.48)	.066 (2.76)	.68 (1.91)	.22 (16.6)	-.049 (1.48)

a. All schooling measures are standardized for the age of children using country-specific age-schedules.

b. Source: NCAER-ARIS Survey, rural households, from Table 15 in Rosenzweig (1981).

c. Source: 1980 SUSENAS.

d. Source: 1968 National Demographic Survey, from Table 3 in Rosenzweig (1978).

e. Based on age-standardized measures of marital fertility, from Table 5 in Rosenzweig (1982).

f. t-ratio in parentheses beneath elasticity estimates.

rate of the father in the household, and the schooling attainment of the mother, in addition to a number of community-level characteristics. The data set for each analysis is derived from a national probability sample containing a large number of communities (88 districts for India, 100 Provinces in The Philippines, 325 urban and rural kabupaten in Indonesia).

All three sets of child wage estimates conform to the pattern implied by the economic model of fertility and human capital--fertility is higher and the schooling enrollment or attainment of children lower where levels of child wage rates are higher. While the elasticity estimates are relatively imprecise, the probability of obtaining the correct pattern of coefficient signs across the three studies, if the signs were independent, random draws with equal probabilities, is less than two percent (of course, since the researcher is the same for all three studies, the independence assumption is dubious).

The point estimates of the child wage elasticities are relatively small for both fertility and schooling in all three populations--a halving of the child wage rate would reduce fertility by from one to 20 percent and would increase schooling by from 2.1 to 6.6 percent. These estimates thus suggest that increases in the gross returns to schooling would induce an increase in fertility if schooling investments are efficiently allocated. However, the adult male wage rate elasticity estimates indicate that schooling responds significantly (and positively) to variations in income. These estimates thus reject the efficient schooling model, at least for the average household in the three populations.

c. The Indian Green Revolution Experiment

The qualitative results with respect to the set of estimated child wage elasticities are consistent with the hypotheses that parents in low-income

countries are attentive to the costs of and returns to investing in children and that per-child levels of "quality" and family size are viewed by parents as substitutes. To assess whether the magnitudes of the child wage elasticity estimates are consistent with time-series evidence on the effects of technological change, via the augmentation of schooling returns, on schooling and fertility, I use information describing the "Green Revolution" in India over the 1961-71 period.

An important feature of the Indian experience with respect to the (exogenous) introduction of the newer higher yielding grain varieties in the early 1960s is the spatial variability in the degree to which the "revolution" took hold, chiefly due to location-specific heterogeneity in soil and weather conditions. In recognition of the selective potential for the success of the new technologies, the government of India in 1961 impplemented a program, the Intensive Agricultural District Program (IADP), in one district in each state in India (two in the state of Kerala) in which it was expected that the improved grain varieties were likely to be particularly productive. The program's objective was to facilitate the adoption of the new inputs and the implementation of any new agricultural practices associated with the new inputs.

To assess the income-distributional consequences of the availability of the new grain varieties, the National Council of Applied Economic Research (NCAER) undertook a national survey of rural households in 1968, the Additional Rural Income Survey (ARIS), based on a stratified random sample in which one of the sampling strata was defined by the presence of the IADP program in the district. One-third of the sample thus included households from each of the IADP districts (NCAER, 1975). Households were interviewed three times annually from the crop year 1968-69 through the crop year 1970-

71. Because of other sampling criteria, over two-thirds of the final sample, consisting of households interviewed in all three rounds, were land-owning (farm) households.

Wage growth in the IADP districts was substantially higher than that in the non-IADP districts over the 1961-71 period--the daily agricultural wage rates of males rose in real terms by 24 percent in IADP districts and by only 6.4 percent in non-IADP districts; the wage rates of adult female agricultural workers rose by 12.7 percent in IADP districts compared to 3.4 percent in non-IADP districts (Directorate of Economics and Statistics (1962, 1972). The 1970-71 round of the NCAER-ARIS data indicate, moreover, that farm households in the IADP districts were indeed substantially more likely to be using the newer high-yielding grain varieties (HYV). Moreover, within the IADP districts, farmers with higher levels of schooling, for given wealth levels and land size, were significantly more likely to have adopted the new seeds (Rosenzweig, 1982a), consistent with the Schultz hypothesis that schooling enhances efficiency in using new technologies.

As a direct way of assessing the influence of technical change on the returns to schooling, I regressed the log of the gross income of farmers residing in IADP and non-IADP districts in 1970-71 on their educational level, controlling for own landholdings, the value of their farm estate, electrification, and an indicator of weather conditions (whether or not crops in the village adversely affected crop yields). Table 2 reports the schooling estimates, which indicate that the contributions of schooling to gross income were indeed higher at each schooling level among farm households in IADP districts, but only significantly so for primary school education. Differences in the contributions of schooling the incomes of

Table 2

"Returns" to Schooling: Gross Income of Farmers in 1970-71 in IADP and non-IADP Districts[a]

Schooling Level	non-IADP	IADP	F-statistic Differential
Primary	.011	.160	4.1
	(0.37)	(2.06)	
Above primary, below matriculate	.266	.280	0.04
	(8.64)	(4.14)	
Matriculate	.509	.558	0.36
	(13.1)	(7.73)	
Above matriculate	.678	.840	1.78
	(9.52)	(8.47)	

a. From regression analysis. Left out schooling category = illiterate. Other regressors = own landholdings, value of farm assets, whether farm electrified, head's age, and indicator of weather. Number of observations = 3226.

b. t-ratios in parentheses.

farmers across the two regions for schooling levels above primary are not statistically significant.

It is, of course, not possible to know based on the NCAER-ARIS income data, collected ten years after the introduction of the HYV seeds, whether the returns to primary schooling were higher in IADP districts prior to the green revolution. However, in the last round of the survey a complete retrospective pregnancy history was obtained for each married woman in the sample households. It is thus possible to compare the pre- and post- Green Revolution cumulative fertility experiences of comparably-aged women across the IADP and non-IADP districts and to thus "control for" India-wide trends in fertility over the 1961-71 period. This is because the children born to women aged 25 to 34 in 1971 in IADP districts should almost wholly reflect the "Green Revolution" experience, while the cumulative fertility of women aged 25 to 34 residing in IADP districts in 1961 and that of women aged 25-34 residing in non-IADP districts in either 1961 or 1971 should not have been directly influenced by the new technologies.

A similar cohort comparison analysis can be performed with respect to primary schooling attendance based on the NCAER-ARIS data. Members of households aged 25 and above in 1971 would have completed their primary schooling, if they had attended primary school, prior to the introduction of the new grain varieties, while those persons aged 10-14 in 1971 would have completed their primary school education, if any, after 1961. Table 3 reports the changes in both the number of children ever born and the percentage of males with no primary schooling in farm households across the IADP and non-IADP districts along with the changes in real adult male and female wage rates. The figures suggest that there were important effects on fertility associated with the introduction of technical change. Although in

Table 3

Change in Fertility, Schooling and Wage Rates Associated with the "Green Revolution" in Indian Farm Households: 1961-1971

Variable	IADP			non-IADP		
	1961	1971	% Change	1961	1971	% Change
Children ever born, women 25-34[a]	3.44	3.04	-11.6	3.11	3.03	-2.6
Percent no primary schooling (males)[a,b]	25.8	11.3	-56.2	40.8	28.7	-30.0
Real agricultural wage, 1961 rupees per day[c]						
adult males	1.50	1.86	24.0	1.73	1.84	6.4
adult females	1.02	1.15	12.7	1.18	1.22	3.4

a. Source: NCAER-ARIS Survey.

b. For 1961, based on schooling of male heads aged 25-50 in 1971. For 1971, based on schooling for boys aged 10-14 in 1971.

c. Source: Agricultural Wages in India.

1961 the average number of children ever born to women aged 25-34 was about a third of a child higher in IADP districts, by 1971 the cumulative fertility of women in the 25-34 age group was almost equal across the two areas, due to a significantly larger decline in cohort fertility in the IADP districts. Schooling trends are less differentiated. The proportion of men with no schooling fell considerably over the period, but only slightly more in IADP areas--the proportion of males with no schooling in farm households increased by 14.5 percentage points in IADP districts and by 12.1 percentage points in non-IADP districts.

The figures in Table 3 thus indicate, consistent with the pattern of child wage elasticity estimates in Table 3, that increases in the pace of development, fueled by exogenous technical change, can lead to substantial reductions fertility and increases in human capital investment without direct family planning interventions. However, it is difficult to reconcile in the context of the model the quantitative magnitudes of the cross-sectional child wage elasticity estimates of Table 1 with the magnitudes of the changes occurring in the initial stages of the green revolution that could be attributable to the increase in the returns to schooling. The estimated adult male wage elasticities for India in Table 1 suggest that the 24 percent rise in wages between 1961 and 1971 in the IADP districts would have led to an <u>increase</u> in fertility by 16.3 percent (.68 x 24) in the absence of any rise in the returns to schooling or other changes. If male wages did not rise, fertility therefore would have fallen by almost 28 percent (16.3 + 11.6). Some part of this decline might be attributed to the 12.7 percent rise in female wage rates occurring over the period, but for all of the fertility reduction to be accounted for by the change in the wage rates of women, the female wage elasticity would have to be over 2 in absolute value

(27.9/12.7).[3] On the other hand, if the estimated difference in the rate of returns to primary schooling across the IADP and non-IADP districts in 1971 reported in Table 2 represents the (percentage) change in the gross returns to primary schooling (α) associated with the flow of new agricultural inputs begun in the 1960s, then the elasticity of fertility with respect to α would be -1.8 (27.9/15), also very high. The inelastic child wage rates estimates in Table 1, while consistent with the relatively small differential in the increase in schooling across the IADP and non-IADP districts, are not consistent with a high fertility-α elasticity.[4] Indeed, as noted, the efficient schooling model predicts a fertility increase when the response of schooling to child wages is not elastic.[5]

2. Consequences of Changes in the Cost of Fertility

a. Biological Aspects of Human Reproduction

The empirical results based on the cross-sectional variations in child wage rates and the time-series changes observed during the Indian "Green Revolution" quasi-experiment lend support to the hypothesis embodied in the economic model of fertility behavior that the human capital of children and family size are responsive to price changes and are viewed as substitutes by parents. An increase in the direct cost of fertility, p_n, should therefore also raise human capital investment levels. If fertility levels are too high and human capital levels too low, then one reason may be that the cost of increasing family size faced by households is in some sense too low.

For many family planning advocates and demographers imperfect information about the biological aspects of reproduction is the principal reason for high fertility levels. They suggest that in many low-income countries couples' information about methods of fertility control and about

the consequences of high fertility for their children, for given resources allocated to children, is deficient. The dissemination of information about improved methods of birth control and about the negative consequences of high fertility, in their view, will importantly increase human capital investments and thus lead to higher income levels.

To examine hypotheses concerned with fertility control efficiency and the biological consequences of fertility it is necessary to incorporate in the basic model of section one functional relationships reflecting the biological aspects of fertility. The simplest way to model the biological supply of births, following Easterlin et. al. (1980) and Rosenzweig and Schultz (1985), is to add a reproduction function of the following form:

(14) $n = \mu + n(z) \quad n' < 0, \; n'' > 0,$

where the z are resources used to control births (e.g. contraceptives) and μ is the exogenously determined number of births that would occur in the absence of fertility control ($z = 0$). The level of μ, fecundity, is biologically-determined, but parents choose the actual level of fertility n by allocating more or less of the fertility control input z; z not n is thus now the control variable. Note that since a couple's demand for z is derived from its demand for n, the observation that sophisticated methods of birth control are infrequently used in some environments says little about the cause of high fertility there.

The assertion that fertility has a direct, biological effect on the human capital of children can be expressed by including n as one of the inputs in the human capital production function (2); i.e.

(15) $h = h(t, x, n; v)$.

If $h_3 < 0$, then among parents allocating the same resources to each child, those with a higher family size will accumulate less human capital per-

child; lowering fertility directly benefits those children born when all other parental behaviors are the same.

The marginal rate of substitution between schooling time and family size in the modified model incorporating the biology of fertility becomes:

$$(16) \quad mrs_{h,n} = \frac{n(w - \alpha h)}{h_1[p_n + b + p_x x - w(T - t) - n(h_3/h_1)w + p_z n']},$$

where p_z = per-unit cost of z. The shadow price of family size n is now higher compared to the case, implicitly assumed in the model of part one, in which fertility control is costless (p_z=0). The higher is the per-unit cost of the fertility control input and the less efficient is z in reducing births (the lower is $|n'|$), the higher is fertility. Thus, if couples are ignorant of efficient methods of fertility control, so that their optimal $|n'|$ is too low, fertility will be too high and, if h and n are substitutes, human capital per-child will be too low. The shadow price of family size, on the other hand, is higher to the extent that higher fertility reduces human capital in (15), that is, the larger is $|h_3|$. If parents are unaware that $h_3 < 0$ or underestimate its magnitude, then they will have more children and children of lower "quality" than they would have preferred if fully informed.

b. Biological Consequences of Fertility for Human Capital: Evidence

Testing the proposition that fertility has a direct influence on human capital given other resources that directly influence h, that $h_3 < 0$, would appear straightforward, requiring the estimation of the human capital production function (15). However, it is obviously necessary that there be information on all of the relevant inputs contributing to the human capital of children that are potentially correlated with fertility. Lack of

controls for other h inputs that be correlated with fertility may lead to misleading inferences. For example, fertility and mortality may be positively correlated because parents living in unhealthy environments expect their children to die more frequently. They thus invest less in each child and bear more children.

Even if data are available describing all of the inputs in (15), when there is no information on the v term, reflecting, for example, the endowed intelligence or healthiness of the child or the healthiness of the environment, attempts to fit some parameterized form of the function with least squares or some other curve-fitting method will result in consistent and unbiased estimates only if the inputs, inclusive of the fertility variables, are not correlated with the unobserved v. If parents know v and v varies in the population, the human capital inputs will in general, however, vary with human capital endowments. For example, when v does not directly influence the productivity of any inputs (is an additive term in (15)) the relationship between fertility n and v derived from the model is given by:

$$(17) \quad \frac{dn}{dv} = \frac{w}{h_1}\left[-n\frac{h_{11}}{h_1} s_{nt} - s_{nn} + n\frac{dn}{dI} \right]$$

where dn/dI = income effect on n. Expression (17) indicates that parents with children who are endowed with more human capital (perhaps because they reside in healthier environments) bear more children when the number of children and schooling or human capital per child are Hicksian substitutes ($s_{nt} > 0$). Thus, higher fertility might appear in this case to be positively correlated with measures of human capital, controlling for all

inputs in (15), even if fertility actually has no direct influence on human capital (h_3=0). This result arises principally because an increase in the endowment induces parents to reduce their per-child investments x or t in human capital. With less resources invested per-child, the cost of adding an additional child is also reduced. In the general case in which the endowment influences the productivity of the inputs, the direction of the bias cannot be predicted.

Whether or not the existence of unobserved exogenous factors is accounted for in how (15) is estimated, it is still necessary to have information on all of the relevant inputs directly affecting human capital that are under the control of parents. This information is most likely to be complete for early indicators of child development, such as birthweight and infant morbidity and survival. The number and variety of "inputs" that could have directly affected an adult's accumulation of human capital, aside from his/her number of siblings and sibling intervals, is large indeed. It is not likely therefore that simple measures of the associations between fertility variables and adult levels of human capital provide good estimates of the marginal product of n in (15).

A number of recent studies have estimated the biological determinants of early human capital indicators employing econometric methods that take into account parental responsiveness to unobserved (by the researcher) human capital endowments. Rosenzweig and Schultz (1983) estimated the effects of birth order and maternal age at birth, but not intervals between births, on children's birthweight using instrumental variables, namely proxies for input prices and parental characteristics, based on a random sample of all legitimate births in the United States. They found that estimates of the effects of inputs on birthweight are sensitive to whether or not the

unobserved factors are taken into account. However, their two-stage procedure applied to cross-sectional data assumes that the characteristics of parents (schooling, earnings) and the community-level health infrastructure, the identifying instruments, are uncorrelated with the human capital endowment of the children. These assumptions are violated if there is some genetic transmission of human capital endowments, if persistent location-specific endowments have influenced the investments in parents' human capital, and/or if the location of programs is related to area-specific endowments associated with human capital (see below).

Olsen and Wolpin (1984) estimated the biological determinants of infant survival in the presence of unobservable endowments by estimating how differences across children <u>within</u> the same family in birth order, spacing, maternal age and other variables were associated with differences in infant mortality. This technique purges out the family human capital endowment, thus requiring no assumptions about the intergenerational transmission of endowments or of governmental program placement rules.

The <u>family</u> fixed effects procedure, however, assumes that parents do not respond to exogenous differences across individual children. That is, dynamic behavior is assumed away. It is a procedure faithful to the static model in which all children have the same (family) endowment v and there are no unanticipated events. However, if parent's fertility decisions respond to the individual characteristics of the heterogeneous children, the within-family estimators will also be biased and inconsistent. For example, if parents have an additional child more quickly because their last child dies (the so-called "replacement" effect),[6] it will appear that shorter post-birth intervals increase the risk of death even when in fact they do not. Similarly, the mother may less intensively breastfeed a child who is ill and

who is thus more at risk of death, leading to overestimates of the true, if any, mortality-reducing effects of breastfeeding.[7]

An estimation procedure that combines (i) the within-family estimator, to purge the family endowment, and (ii) instrumental variables, using as instruments variables plausibly uncorrelated with differences in child-specific endowments within a family, not only permits a larger set of instruments (parental characteristics and programs are unlikely to be correlated with differentials in endowments within a family) but provides consistant estimates of the human capital production function even when parents respond dynamically to child endowments. The first two columns of Table 4 report estimates of the effects of three fertility variables -- the age of the mother at the birth of the child (timing), the interval between births (spacing), and birth order (number) -- on birthweight from two studies, based on data from Malaysia and Colombia, obtained using this combined estimation procedure. In the third column of Table 4 I present additional estimates, using the same methodology and specification, based on data describing the children of U.S. mothers from the National Longitudinal Survey of Youth (NLSY).

Because the women in the NLSY sample were only aged 21-29 by 1986, the latest round of the longitudinal survey, there are few children of order greater than three in the U.S. sample (12 percent of the children). It is not likely therefore that these data will yield reliable estimates of birth order effects. The limited age range makes it also unlikely that maternal age effects will be measured precisely. However, there is considerable variability in the spacing of births, and this parameter is estimated with reasonable precision. Indeed, the most striking feature of Table 4 is the similarity of the estimated birth spacing elasticities, estimated from data

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Table 4

Estimates of Birth Spacing, Birth Order and Maternal Age Elasticities for Birthweight, from Within-Family, Instrumented Production Function Analyses: Malaysia, Colombia and United States

Variable	Malaysia[a] Elasticity	Mean	Colombia[b] Elasticity	Mean	United States[c] Elasticity	Mean
Birth order (after first birth)	-.16 (1.17)[d]	2.5	-.24 (2.08)	4.6	-.012 (0.31)	1.6
Prior birth interval (months, order>1)	.026 (1.62)	27.3	.056 (1.83)	27.6	.031 (1.65)	33.0
Maternal age at birth (years)	.63 (1.50)	22.5	.76 (1.35)	23.5	.17 (0.71)	21.2
Number of children	1458		238		1926	

a. From Rosenzweig and Schultz (1987), Table 7. Based on children of order two and three only.

b. From Rosenzweig and Wolpin (1987), Table 2.

c. Source: National Longitudinal Survey of Youth.

d. t-ratio in parentheses beneath the elasticity estimate.

sets describing behavior in three very different economic environments. Of course this result is to be expected if biological relationships are being identified, as is the goal. In contrast to the wage elasticity estimates in Table 1, the estimates of Table 4 are "structural" estimates that should be invariant to the economic environment.

Although all three sets of estimates indicate that the postponement of births, wider intervals between births, and fewer births increase biologically the weight of children at birth, an important determinant (or correlate) of infant mortality and subsequent child development among surviving children, the magnitude of these direct effects appears to be small -- a doubling of the intervals between births (2.5 years to 5.0 years) increases birthweight only by from 2.6 to 5.6 percent; the birthweight of a fifth child is from four to six percent lower than his/her immediately preceding child (Colombia, Malaysia), postponement of births by one year, for given spacing and birthorder, increases birthweight by from 1.4 to 3.2 percent (Colombia, Malaysia). Whether or not parents take into account these biological consequences of fertility in forming their family size goals is thus not likely to have important consequences for the level of human capital investments in an economy. The observed negative correlations between family size and per-child measures of human capital do not appear to have a strong biological component.

c. Imperfect Fertility Control and Fertility: Evidence

The assertions that the inability of couples to control fertility is a principal cause of low levels of investments in human capital in low-income settings and that the dissemination of birth control information would have a strong effect on economic growth require two kinds of evidence. First, there must be

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evidence that the costliness of controlling births is an important determinant of the actual number of births in low-income countries. Second, it must be demonstrated that parents or households respond to "excess" births by diverting resources from per-child human capital investments.

A seemingly-straightforward means of ascertaining both the prevalence and consequences of imperfect contraceptive control is to ask parents about the number of their births that they did not want. Attempts to relate parental reports of "unwanted" births or pregnancies to measures of their human capital investments, as in Rodgers (1984), are however, difficult to interpret. First, because information on "wantedness" is usually obtained after a child is born, the wantedness of a child may be related to factors other than to its parents' inability to control fertility perfectly. In particular, ex post (post-fertility) "unwantedness" may be a function of unrealized expectations, expectations formed when the fertility decisions were originally made, regarding economic circumstances or the "qualities" of the as yet unborn children. Rosenzweig and Wolpin (1988) find evidence that because young mothers in the United States evidently have unrealistically high expectations about the quality of their children and because of the ex post rationalization of observed birth outcomes in terms of wantedness, the proportion of births that are retrospectively reported as unwanted overstate the proportion that were truly "unwanted" prior to conception by 26 percent.

A second problem with using reports of excess births to measure the costliness of fertility control is that couples' willingness to bear "excess" children will clearly depend on the net cost of children (Michael, 1973). Both "excess" births--the number of additional births that would have been averted if fertility control were costless--and desired births

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are function of the costs of children. Thus, in societies where the shadow price of children is low, actual, desired (under costless control) and excess fertility will be high. In an environment having identical costs of fertility control, but in which the relative returns to (costs of) large families are low (high), however, excess births will be lower (as will as actual births and desired births).

Finally, if excess births as well as human capital investments are likely to be correlated with economic circumstances, it is necessary to look at the consequences of variations in "excess" births controlling for those circumstances. But why should observationally identical couples facing the same economic environment report different numbers of unwanted children? Unobservable differences in human capital endowments (v) and/or in preferences, in addition to variability in fecundity (μ) or in contraceptive costs p_z may influence excess births. For example, households in which smaller per-child human capital investments are preferred may be more willing to control fertility less perfectly.

The association between reports of unwanted births and human capital investments in children thus are not likely to provide evidence that can be unambiguously interpreted in terms of the effects of the costs of controlling fertility on levels of human capital. There are alternative methods that can by used to asses the consequences of the costliness of fertility control, however. One is to estimate the effects of variation in p_z, the cost of contraception, on human capital investments, i.e., estimate the cross price effect s_{nt} by estimating dt/dp_z. Studies of the "cross price" effects of family planning programs (which either reduce p_z or increase (in absolute value) n'), have typically employed cross-sectional data on community-level programs merged with either household or community-

level information on measures of human capital and parental characteristics. In Rosenzweig (1988) I discuss three such studies, all of which support the hypothesis that raising the net cost of children, through decreasing contraceptive costs, raises human capital levels. The estimated quantitative effects of the family planning programs are very small, however.

The principal difficulty with exploiting the cross-area variability in either program presence or intensity to estimate the effects of programs on the behavior of households is that the areal distribution of programs is unlikely to correspond to the randomized distribution required for the appropriate experiment. That is, program placement is not likely to be orthogonal to unmeasured variables influencing household behavior. For example, programs may be located where the demand for program services is high, or where the environment is least healthy, as found, for example by Rosenzweig and Wolpin (1986) for both family planning and health clinics in the Philipines.[8] Conversely, households may move to localities that provide services they prefer or can use most efficiently (Rosenzweig and Wolpin, 1987).

A third strategy for assessing the consequences of imperfect fertility control for human capital investments is to exploit the "natural" experiment associated with the variability in fecundity in the human population, μ in the model. Because fecundity is likely to be orthogonal to preferences and robust to at least small changes in the environment, this "variable" mimics the ideal randomized experimental intervention of varying births exogenously. Moreover, if and only if fertility control is costly can the variability in fecundity influence the variability in family size and, possibly, human capital investments. To see this, consider the effect of a

change in μ on fertility control resources z, allowing the household to adjust all of its resources optimally:

$$(18) \quad \frac{dz}{dn} = (n')^{-1}\left[\frac{n''}{n'} p_z s_{nn} - 1\right]$$

Because $dn/d\mu = 1 + n'(dz/d\mu)$,

$$(19) \quad \frac{dn}{d\mu} = \frac{n''}{n'} p_z s_{nn}$$

Expression (19) indicates that if either $p_z = 0$; i.e., fertility control is costless, or $n' = -\infty$, i.e., fertility control is perfectly effective, variations in fecundity will not affect actual family size. If fertility can be costlessly adjusted, there are no consequences. With $p_z > 0$, high fecundity will be associated with high fertility. Moreover, fecundity and schooling will be negatively related if family size and per-child human capital are substitutes, from (20):

$$(20) \quad \frac{dt}{d\mu} = -\frac{p_z}{n'}\left[\frac{n''}{n'} s_{nt} + \frac{dt}{dI}\right]$$

Two methods have been used to measure fecundity. Rosenzweig and Wolpin (1980 and 1980b) proposed that the behavior of couples experiencing a multiple birth could be compared to those couples not experiencing such births to obtain unbiased estimates of the effects of "excess" births.

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Such comparisons would not require any information on the economic circumstances of the couples, only information on birth histories and the behavioral outcomes of interest. Since the probability that a couple experiences a twin birth rises with the number of pregnancies, Rosenzweig and Wolpin (1980a) studied the consequences of imperfect fertility control for child schooling by using a measure of twins per pregnancy. A better method, implemented in Rosenzweig and Wolpin (1980b), in their study of the labor supply behavior of U.S. married women, compares couples with a twin on the first pregnancy to other couples. The "twins first" method is preferred since at which pregnancy the multiple birth occurs may matter. Indeed, in a regime of costless fertility control, and where couples desire at least two children, couples having a twin on the first birth should not behave very differently from other couples, unless the timing of births is important. Couples experiencing a twin on their last (planned) pregnancy, however, cannot adjust their family size no matter what the cost of contraception.

A major practical shortcoming of the twins first method is that less than one percent of all first pregnancies result in mutiple births. Thus very large sample sizes are needed to exploit the natural twins experiment. Rosenzweig and Schultz (1985) have proposed a method which also exploits the variability in fecundity but does not require unusually large sample sizes. In this approach μ is measured by estimating the reproduction function (14). If the parameters of (14) are known (i.e., the effects of different contraceptive methods on conceptions and birthsare estimated), then the difference between a couple's actual number of births and that predicted on the basis of their use of fertility control (and all other relevant) inputs in (14), the "residual," represents that part of fertility which, definitionally, is beyond the couple's control; i.e., for couple k,

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(21) $\mu^k = n^k - n(z^k)$.

The Rosenzweig-Schultz residual method requires detailed information on couples' contraceptive use and conceptions. Moreover, estimation of the reproduction function is not straightforward. Couples will adjust their contraceptive behavior to realized births, and thus to μ, as in (18) and as a consequence the unobserved μ will be correlated with Z in (14). The estimation procedure must take into account this correlation. Rosenzweig and Schultz (1985, 1987) used instrumental variables to estimate the reproduction function using data from the United States and Malaysia, respectively. Thus, another data requirement of their procedure is information on the (exogenous) determinants of contraceptive control z. In both countries, variation in fecundity was found to account for some portion of the variability in actual births, although the proportion was small - ten percent in the United States, three percent in Malaysia.

Table 5 reports estimates of the effects on children's schooling attainment due to an <u>exogenous</u> increase in fertility by one birth from three low-income countries, from the Rosenzweig and Wolpin (1980a) study applying the twins per pregnancy method to rural Indian data, from the Rosenzweig and Schultz (1987) study based on the residual method applied to Malaysian data, and from a study (Song, 1988) applying the "twins first" method to a large (57,000 household) Indonesian data set. Comparable quantitative effects across the residual and twins methods were obtained by converting the residual measure of fecundity estimated from the Malaysian data into excess births using the estimated effect of a change in μ on cumulative births in that study, i.e., an estimate of $dn/d\mu$, since $dt/dn = (dt/d\mu)(dn/d\mu)^{-1}$.

Table 5

Estimates of the Percentage Change in Children's Schooling Attainment due to One Unanticipated Birth Using Three Methods: India, Indonesia and Malaysia

Method	Age-Standardized Schooling Index[a]		Mean Years of Schooling[b]
	Non-Twin Children	Twin Children	All Children
Twins per pregnancy (India)[c]	-34.0 (3.22)[f]	-	-
Twins on first birth (Indonesia)[d]	-17.3 (1.48)	-20.0 (1.63)	
Residual fecundity (Malaysia)[e]	-	-	-8.3 (1.62)

a. Mean of actual schooling of children of age i in family divided by average schooling for all persons aged i in population.

b. Includes expected schooling attainment for households in which children are still attending school.

c. Estimate assumes 7 pregnancies for average family, from Table 2 in Rosenzweig and Wolpin (1980). Source: NCAER-ARIS.

d. From Table 5, rural households in Song (1988). Source: 1980 SUSENAS.

e. Fertility of couple net of age of mother, breastfeeding and use of contraceptive methods. From Tables 5 and 6 in Rosenzweig and Schult (1987). Source: Malaysian Family Life Survey.

f. t-ratio in parentheses beneath coefficient.

Each study confirms at the .10 significance level that contraceptive control is not perfect and that the inability to perfectly control fertility lowers, on average, the human capital of children.

The range of quantitative estimates, from an 8 to a 34 percent decrease in schooling due to an exogenously-induced extra child, arises in part from differences in the methods used. Because the twins-first method measures the effect of an exogenous extra birth early in the child-bearing life-cycle, its effect on the human capital of (non-twin) children should be smaller in absolute value than the effect of an extra child occuring, on average, halfway through the life-cycle, as measured by twins per pregnancy. This is because parents have a greater period of time to adjust their contraceptive strategies in the former case. The results are consistent with this; the schooling of non-twin children is reduced by 17 percent if the extra birth occurs at the first pregnancy (Indonesia) and by 34 percent on average if it occurs at the third or fourth pregnancy (India). The residual method applied to the Malaysian data provides the effect of an increase in fecundity that persists over the entire (child-bearing) life-cycle on the completed or expected shcooling of children, rather than the effect of a discrete but exogenous increase in the number of births in a particular life-cycle period. The smaller effect of an extra birth induced by an increase in fecundity on schooling estimated from the Malaysia data could, however, be due to cross-country differences in contraceptive efficiency or to differences in contraceptive costs or preferences.

The estimates obtained from the "natural" experiments associated with variability in human fecundity suggests that improvements in contraceptive technology that reduce completed fertility by one child would have non-trivial effects on human capital investments, although estimates are still

lacking on how changes in the cost or availability of contraceptives influence family size or excess births. The fecundity variation can also be exploited to examine the impact of variations in births on the mother's wage rate, to assess the effects of costly fertility control on the accumulation of skills by married women. Rosenzweig and Schultz (1985) and Rosenzweig (1988) estimated the effects of the residual measure of fecundity on the log of the weekly wage rate of married women in the United States and in Malaysia, respectively. Both sets of estimates indicate that the costliness of fertility control also results in lower wage rates for married women in these countries--one extra birth resulting from the inability to perfectly control fertility decreases the wage by 14 percent for U.S. married women and by 36 percent for married Malaysian women. These results indicate why information on the association between the wage rates of married women and fertility does not provide a good estimate of the effects of exogenous changes in the opportunity cost component of childbearing on family size, since the wage rates of women, unlike for children, appear to be themselves influenced by the costs of childrearing via job-related human capital accumulation.

3. Conclusion

Nature and happenstance provide few natural experiments that can effectively substitute for the experiments needed to perform tests of theories and models of human behavior. The recent aggregate development experiences of the few hundred countries of the world are no exception, and the possibility of learning from less recent historical events is almost irreversibly constrained by the absence of detailed information describing such events. In this paper I have presented evidence from empirical studies that have sought to approximate the appropriate experiments needed to test

hypotheses, derived from models of household behavior, about the interrelationships among population growth, human capital accumulation and economic development. Such studies have exploited the cross-area variability in the wage rates of children in a number of low-income countries, the inter-couple variability in the biological propensity to conceive, and time-series evidence provided by the geographically-selective introduction of new agricultural technologies in India over the period 1961-71.

The three types of evidence, some of which has been replicated across two or more countries, support the fundamental proposition, embodied in most economic models of household fertility behavior, that parents "trade-off" family size and per-child human capital levels in response to changes in the relative costs and returns to increasing human capital investments or to increasing fertility. In particular, the evidence suggests that (i) alterations in the returns to human capital associated with exogenous technological change lead simultaneously to increases in schooling investments and to significant reductions in fertility in the absence of family planning interventions and that (ii) the costliness of fertility control is a significant but modest contributing factor to inhibiting increased human capital investments. Evidence from a number of different coutries based on econometric studies informed by economic theory also suggest, however, that the biological component of the trade-off between fertility and the human capital of children is relatively trivial; reductions in fertility that increase by large amounts the spacing of births, for example, have only an insubstantial negative effect on early life-cycle indicators of child development. The evidence also appears to reject the hypothesis that schooling is provided efficiently to children, at

least in low-income countries.

The empirical foundation for understanding the role of fertility and population growth in economic development through understanding household behavior is still in a primitive state. For example, while the cross-sectional evidence based on child wage rates is qualitatively consistent with the time-series changes in fertility and schooling observed after the introduction of new grain varieties in India and supports the view that economic growth (of a particular kind) induces a slowdown in population growth, the cross-sectional quantitative estimates understate substantially the intertemporal changes. Which estimates are more reliable for predicting the consequences of growth induced by technical change? Moreover, while the evidence that the costliness of fertility control is a factor in maintaining low levels of human capital investment appears robust, there is a notable absence of studies providing information on the sensitivity of human capital investments to the costs of contraception. This in part results from a lack of attention in empirical studies to the processes generating spatial and intertemporal variability in governmental efforts to promote or subsidize contraceptives. Without such estimates, however, and without therefore an improved understanding of the interaction between household-level decisions, market structure, and governmental behavior, there is only a weak justification for particular levels of financial support for population programs.

Footnotes

1. The model embodies the interaction between child quantity and quality in the household budget constraint (Becker and Lewis, 1973), the economic value of children (Rosenzweig and Evenson, 1977), the production of human capital by heterogeneous households (Rosenzweig and Schultz, 1983), and intergenerational transfers (Becker and Tomes, 1979) that have been emphasized in prior work formulating models of household fertility behavior.

2. For example, a rise in p_x increases the cost of both increasing per-child human capital levels and adding to family size so that the decomposition of the reduction in the total human capital of children (nh) into changes in n or h cannot be predicted without imposing further structure on the model.

3. In Schultz (1985), one of the few studies to treat the (adult) female wage rate as an endogenously-determined variable, the elasticity of the total fertility rate with respect to the female wage is -.88. In that study, based on a time-series of cross-sectional district-level Swedish data, identification of female wage rate effects was achieved based on the strong assumptions that: 1) the aggregate prices of food (rye and butter) were exogenously determined in Sweden and 2) relative food prices, given wage rates, do not influence fertility decisions (i.e., the utility function is strongly separable in food and family size).

4. One reason that the child wage elasticity estimates may understate the true elasticities is that they may be influenced by the supply of child labor. In areas where schooling rates are low, so that relatively more children are working, wages may be bid down; similarly, where fertility is low, and thus the relative number of young people relatively low, child wage

rates may be high. The estimates reported in Table 1 assume that most of the variation is child wage rates is due to spatial differences in the demand for labor. In Rosenzweig and Evenson (1977), the possibility that higher fertility rates or lower school enrollment rates might lower area-specific child or adult wage rates was taken into account in a simultaneous equations analysis of Indian district-level data using such variables as rainfall and industrial infrastructure to identify wage effects. The elasticity of child wages for female school enrollment was -2.02, but that for boys could not be precisely estimated because of collinearity in that equation between the wage rates of children, adult females and adult males.

5. In Rosenzweig (1982b), cross-sectional differences in school enrollment and in fertility between IADP and non-IADP farm households in 1970-71, net of male, female and child wage effects, were shown to be statistically significant.

6. Wolpin (1983) formulates and estimates a dynamic stochastic model of fertility incorporating survival risk which calls into question the simple replacement hypothesis.

7. Evidence on responses by parents to the individual endowments of children is presented in Rosenzweig (1986) and Rosenzweig and Wolpin (forthcoming).

8. The Rosenzweig-Wolpin (1986a) study of the effects of family planning on child development in Laguna, Philippines that did attempt to take into account the endogeneity of program placement found that results were sensitive to whether or not placement was "controlled for." The "corrected" estimates indicated, however, that among children less than six years of age, those living in families fully exposed to a local family planning clinic were only 3.4 percent heavier than children residing in an area with

no family planning clinic.

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Population Growth and Human Capital Investments: Commentary

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I've noticed a tendency for demographers to rationalize their abysmal population predictions by stating that they do no worse than economists' macroeconomic forecasts. Economics is finally influencing demography! But economists are far more concerned with studying the determinants of behavior than with unconditional forecasts, and this too seems to be influencing demographic thought about the pros and cons of population size and growth. Rosenzweig presents a useful overview of economists' search for behavioral structure in fertility and human capital investment decisions. He asks whether this line of empirical work supports recent developments in neomalthusian growth theory. Though some systematic behavioral regularities are apparent in the work surveyed, he concludes that the observed effects are too small to have much bearing on these theories.

I accept this conclusion as a correct inference from his analysis, but hazard the opinion that the work reviewed here is somewhat narrowly focused by a highly structured theory and by placing heavy and to some extent questionable demands on the quality of available data in its econometric methods. Certain tests of the theory certainly withstand this kind of assault, but nonetheless both factors limit the applicability of these results to the broader macro time-series questions and observations from whence much of the interest in this area of social science is derived. Perhaps further progress will be made by paralleling our effort at micro-data structural modeling with a somewhat "lower road" approach that widens the empirical net of evidence to be considered and that is less constrained

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by a tightly specified structure. Surely there are many ways of gaining insight and improved understanding of empirical phenomena in this area. Rigorous structural model estimation on individual household data is only one among many ways of gaining improved understanding, and long experience shows that it is a road with some pitfalls. Judging from some of the tone and style of this paper, perhaps it would be well for economic demographers to consider wider varieties of evidence, however impure, and learn what they can from them. Both the available theory and data seem to me to point in these directions.

First consider the theory as laid out in section 1. Nonlinearities are essential to the problem, but raise many red flags in my mind for literal structural interpretation and estimation. Who would take the simpler static consumer theory as a literal description of individual behavior rather than of a kind of average behavior? More important, the time-frame of decisions in these problems run on the scale of generations, yet little attention seems to be paid to the intertemporal measurement of prices and constraints in the empirical work. This seems crucial to testing and estimating a decision structure where such long lags are involved: structural interpretation of the estimates is a bit shaky without close attention to these matters. In practice it means that the model must be tested in a relatively stationary environment (little intertemporal variation in relative prices) where most of the informative variation comes from cross-section differences in exogenous variables. Rosenzweig does not make the case that these conditions are met in the studies reviewed here. But even if it is, the differences between time-series and cross-section results in many other areas of applied economics gives one pause in applying these results to natural time-series experiments. The timing and occurence

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of the demographic transition are among the most interesting phenomena to be studied in the development context. That these transitions have occurred in many countries is beyond dispute, yet the results reported here are too small to be reconciled with those events (insofar as they bear on them at all). Presumably something could be learned by directly studying some of these episodes on a more macro (and if need be less structural) basis. The effect of the green revolution in the Punjab seems like a good case in point.

A similar point could be made about the estimated effects of child wage rates on fertility and human capital investments. Economic development is associated with decreases in fertility and in labor force participation rates of children, and with increases in school enrollment rates. If one didn't already know that, the evidence in table 2 would not exactly lead a person to think it might be so. Perhaps part of the difficulty with this evidence is that the wage rates of adults also vary in these data and the variation may not be sufficiently independent to provide sharp evidence on the partial effect that is being sought here (as is hinted in some of the footnotes).

It is not made so clear in the paper that the extensive investigations of the pure biological effects of fertility on children's human capital is a research problem defined by noneconomists, and presumably by hardhatted Malthusian population control proponents. Surely the most direct evidence on these matters would come from experiments on nonhuman populations and by general biological knowledge, where these effects are apparently so small at the frequency and birth intervals actually experienced by human beings as to be safely ignored. If the economists had found big effects here, who would believe the results other than those who

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are committed to a strong population control agenda? And who among those who are so committed will believe the findings of trivial effects?

The section devoted to the effects of unwanted births on resource allocation is much more interesting for Malthusian and economic theory. Yet here too the effects are difficult to find with these micro data sources. As Rosenzweig points out, the evidence in table 4 on the influence of state family planning expenditures may be affected by the political process whereby clinics and family planning centers are situated. And the results in table 5 using the twin method rest on a rather delicate statistical procedure and a small number of observations. It's not surprising that the effects are small and imprecisely estimated. The results in table 6 are somewhat better, but in large measure reflect the other side of female labor force participation and labor supply studies that have proliferated over the years. Still, the economic effects found seem very small. Readers would like to have more detail as to whether they are worth worrying about. Once again, however, we observe large scale macro events that would seem to be very informative about this kind of problem. The disturbing accounts of the "liberation" of millions of small children associated with large scale migrations of rural families to major urban centers in Brazil is a case in point, and if true, call for extensive study whatever the potential for testing theory.

Finally, the section on externalities and family planning subsidies seems limited by the presumption of an external effect whose empirical importance is not clear to uninitiated readers. Greater effort should be taken to spell out the precise content of the positive externality in equation (15). The residential and school segregation by wealth that is observed in so many Western societies does not seem very conducive to the

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idea on which this model is built. Evidently many people see negative externalities across family status and wealth, so clarification is needed. The model also ignores the main reason why public subsidies to education have occurred: human capital cannot legally serve as collateral in the modern world and many families do not have the resources to secure these investments themselves. Surely public education goes a long way toward repairing these kinds of capital market imperfections. The optimality of family planning subsidies would also seem to require establishing the utilitarian basis on which the analysis should rest. Does it take the point of view of parents who make these decisions or of children who might have desired a different outcome than their parents chose for them? While these kinds of questions can be ignored in a Coasian world with perfect contracts, the impossibility of children contracting the conditions of their birth with their parents makes the point important to any welfare analysis of fertility control and human capital investment policies.

Comment on "Population Growth and Human Capital Investment: Theory and Evidence" by Mark Rosenzweig

Rosenzweig's paper is a synthesis of eleven papers either solely authored by Mark or written jointly with one of three co-authors, Bob Evenson, Paul Schultz, and Ken Wolpin. Each paper describes a significant empirical exercise, so the combination is truly impressive. I like people who are willing to get their hands dirty with data. I like people with substantive interests who pursue a problem through more than one phase with a reasonable amount of data. As something of an outsider, I am also attracted to the issues linking population growth and economic development.

There is a substantive theme to Mark's paper. He begins with the well-known, cross-country association between the level of income, population growth and schooling and asks what causal inferences ought to be drawn. There are three main questions. One is whether numbers and schooling of children respond to variations in child wage rates in developing countries. Another is whether child weight at birth is sensitive to fertility rates. Finally, he addresses responses to changes in the costs of contraception. These are the narrower empirical topics that arise in the context of broader, more fundamental issues.

Like all empirical work, there are questions about each result whose answers require the details of the original papers. The papers fall into a pattern. We begin with a simple correlation such as the one between schooling and numbers of children. There is a discussion giving reasons that the observed association might be either causal or spurious, and the discussion is followed by an estimation step that controls for confounding variables and/or corrects for simultaneity bias. The adjusted or clarified correlations have the same sign as the simple correlations, but the magnitude of the "true" responses is smaller than is shown by the simple relationship. Thus there are no surprises where partial correlations that reveal economic behavior differ in sign from the simple correlations. Readers will be

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impressed by the sheer magnitude of the work that is described, by the author's ingenuity in finding procedures or variables that eliminate potential bias, and by the consistency of relations across countries and data sets.

There is also a methodological theme. Unlike the substantive theme that constitutes the main part of the paper, the methodological theme detracts from the contributions. Empirical relationships will always be subject to conflicting interpretations and this is especially true of the non-experimental data of economics. For studies in economic development where institutions are less familiar to analysts than for studies of the U.S. economy and when, rightly or wrongly, data quality is often suspect, I believe that emphasis on narrow structural relationships is misplaced.

The methodological theme is first that there is a dominant research strategy. Second, that strategy is to avoid simultaneity bias regardless of costs. I do not believe there is a dominant strategy. Data are messy. We can learn from simple summary and, possibly but less probably, from severe crunching as well.

There are two Coase theorems. One is well-known, but both should be. The second theorem is that data will confess to anything if you torture them long enough. This is not a comment by a large sample statistician, but it is believed by all theorists and by empiricists describing the work of others.

Mark's procedures rely heavily on structure and use instruments whenever a scent of simultaneity is perceived. If we infer preferences from behavior, we will conclude that Mark's empirical utility weights consistency much more than efficiency. That's his method and it is fine for his work. My objection is to the dogmatic stance that this strategy is dominant. It is one among many.

Begin with the introductory assertion that "[e]vidence cannot be interpreted without a theoretical framework." While the truth of this proposition may be transparent, one wonders where the theories came from originally. To my mind, a more correct statement

would be that there is a dialogue between theory and data in which they are mutually informative. Certainly there is more to empirical work than testing theories. Do you suppose that Newton ignored all those apples until he developed the theory of gravity?

Later, there is the longish comment:

> Testing proposition (a) requires, first, that there be a clear prediction with respect to the influences of a variable characterizing the economic environment and, second, that the variable be measurable and vary exogenously to family size and human capital decisions.

Proposition (a) is the one saying that population growth and human capital investments reflect the economic circumstances of a country. Although it is not explicit, I read it as saying that there is one-way causality from wealth to population growth and to investments in human capital. The tests that are described refer to three studies (two for India and one for the Philippines) in which the wage rate of children is used to explain school enrollment and fertility rates. My objection is to both the first and second parts of the quote.

It is in fact only an amplification of the original view that models rather than data are what gets analyzed. You can't reject a theory that makes ambiguous predictions, but you clearly can learn about empirical relationships. Suppose the theory of gravity initially posited a gravitational pull both by the earth and its moon. The source of the pull was not initially known, so the theory might not have predicted that the earth would dominate. In this case the theory would be that if an apple's stem were disconnected from its branch, it might either fall (the earth's pull wins) or fly away (the moon wins). The Rosenzweig method in this case would be to polish the theory before the apple. Yet science would probably have advanced just as rapidly had the theory set out to explain the empirical observation that apples fall.

The presumption that one only examines empirical relations when theories are unambiguous is used by Mark to rule out an examination of changes in school enrollment rates to increases in rates of return to investments in schooling. In this case an income

effect potentially confounded a substitution response to a price change. At this point, even Mark broke rank and noted in passing that in India during the Green Revolution it appeared that returns to schooling and school enrollment rates had increases together.

The second point in the quote is that one examines only those relationships where the direction of causality is clear. If this were rigorously followed, almost all empirical work in economics would stop. As an example, consider the only empirical case Rosenzweig was willing to examine for proposition (a). In this case the presumed exogenous variable is the child wage rate.

Each of the studies cited is cross-sectional based on area-average observations for parts of a country. We are not told why the wage is high when it is high. Might it partially reflect the availability of child labor? Nor are we told how the wage is denominated. High relative to what? If they are high relative to adults because the adults have little education, would it be surprising to find that when the child wage was high, school enrollment rates of children are low? And is this a wage response or just an example of children following their parents?

My point is not that Rosenzweig's simultaneity concerns are too relaxed. It is that the simultaneity game goes on forever. It is a legitimate concern, but it is not an excuse to do nothing. I am delighted that he and his coauthors went on to examine the empirical relation.

In closing, there are two sides to this paper. The substantive one is a compilation of a decade of empirical work on related issues. The combination is outstanding. A secondary theme is the running commentary describing how one analyzes data. I find his suggestions narrow and restrictive.

Finis Welch

Endogenous Technological Change

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Abstract

This growth model is driven by an endogenous process of discovery, innovation, invention, and refinement. Human capital is assumed to be the key input in the research technology that produces these components of technological change. The equilibrium is one with monopolistic competition, since firms must charge a price that is higher than marginal cost to recoup fixed investments in research. The main conclusions are that the stock of human capital determines the rate of growth, that too little human capital is devoted to research, that integration into world markets will increase growth rates, and that having a large population is not sufficient to generate growth.

According to data for the United States presented in Maddison (1982), the output produced today by an hour of work is ten times as valuable as the output that was produced by an hour of work 100 years ago. Since at least the work of Solow (1957), economists have attributed much of this growth to technological change, and from a naive point of view this seems reasonable. The basic raw materials that we combine to yield utility are the same as they have always been, but by a process of trial and error, experimentation, refinement, and inspiration, the instructions that we follow for combining these materials have become vastly more sophisticated. One hundred years ago, all we could do to get visual and intellectual stimulation from iron oxide was to make it into pigment and spread it on fibers that are woven into canvas. (Canvas was itself an big improvement over cave walls.) Now we know how to spread iron oxide on long reels of plastic tape and use it with copper, silicon, petroleum, iron, and assorted other raw materials that have been mixed together to make television sets and video cassette recorders. It is true that implementing new sets of instructions for combining raw materials always takes additional physical capital and additional training for workers, but it is the instructions themselves which have changed most dramatically over the last 100 years.

The growth model in this paper is based on the premise that technological change—improvement in the instructions for mixing together raw materials—is at the heart of economic growth. In many ways, the model is similar to the original Solow (1956) model with technological change. Technological change provides the incentive for continued capital accumulation, and together, capital accumulation and technological change account for most of the increases in output per hour worked. The model goes beyond the Solow model in two respects. First, it adds a research and development sector which uses valuable resources to produce improvements in the technology, and in this sense it is a model of endogenous rather than exogenous technological change. Second, in the description of the output producing sector, the model makes an attempt to capture Allyn

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Young's observation (1928) that "an increasingly intricate nexus of specialized undertakings has inserted itself between the producer of raw materials and the consumer of the final product." Cave painting was a do-it-yourself proposition, and even 100 years ago, the chain of individuals and firms that intervened between the collection of pigment and fibers for canvas and the sale of a painting was relatively short and simple. Today, a consumer of home videos takes advantage of the work of tens of thousands, perhaps hundreds of thousands, of specialized workers and firms spread all over the globe.

Growth in the model presented here can be described in terms of an aggregate, reduced form production function like the one Solow used. Viewed from this perspective, the model is consistent with the standard accounting framework for the analysis of growth. However, what underlies this reduced form view of the economy is a large number of specialized firms, each with its own unique role in the production process. What is hidden by the aggregate perspective is that growth takes place in large part because of increases in the number of firms and in the number of specialized inputs in production.

The notion of a fixed cost is the link between the explicit research sector in this model and the process of growth driven by the introduction of new inputs in production. Investments in technological change have an inherent fixed cost character; the cost of finding a better set of instructions is unrelated to how many times the instructions are used. Fixed costs also are crucial to understanding what determines the number of specialized inputs in production that are available at a point in time. Without the fixed costs, one would expect all conceivable inputs to be available right from the start. The fixed costs lead to a form of increasing returns at the aggregate level, and as one should expect from the static theory of trade with differentiated goods (see for example Helpman and Krugman 1985), they lead to gains associated with size, and therefore to gains from trade between different countries. One of the novelties of the analysis here is that it focuses on a dynamic model with differentiated inputs in production. As a result, it shows

how trade policy can have permanent effects not only on the level of welfare, but also on the rate of growth.

The analysis also suggests why population is not the right measure of size, and why the presence of a large domestic market in countries like China or India is not a substitute for trade with the rest of the world. What matters for the rate of growth of the technology is the stock of specially trained human capital that can be used in research, not the stock of raw labor. In a closed economy, the growth rate is increasing in the stock of human capital, but it does not depend on the total size of the labor force or the population. If the stock of human capital is too low, growth may not take place at all. If two closed economies become integrated through free trade, the rate of growth in each will increase.

These kinds of implications of the model are taken up briefly in the final section of the paper. Section 1 begins by defining the variables that are used in the model and describing how they might be matched up with data. A key task is to make a distinction between knowledge that should be ascribed to human capital and knowledge that should be attributed to the technology. The basis for this distinction is whether the knowledge is embodied in an individual or instead is of a kind that can be captured in a form that exists outside of any individual. (Note that this use of the notion of embodiment is quite different from, and has little in common with, the older notion of technological change that is embodied in a particular vintage of capital goods. Throughout this paper, "embodied" means embodied in a person.) Human capital skills like those of Auguste Renoir or Claude Monet are for the most part embodied in individuals. They cannot be exploited without the consent of the individual, and they disappear when the individual dies. In contrast, the the technology is a list of instructions that are disembodied in the sense that they can be written down on paper. Even if every engineer who had worked on VCR design were to die, and if all production facilities for VCR's and all existing VCR's were destroyed, new VCR's could be produced in a matter of months from electrical and mechanical designs that exist on paper. As is quite clear from the experience with video tape recording (a

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technology developed by a firm in the United States, refined by firms in Japan, and copied by firms in Korea), a technological innovation can be copied and used without the consent of the developer. Legal and social arrangements may be instituted to limit the unauthorized use of disembodied knowledge, but this does not change the fact that the technology for replicating disembodied knowledge is very different from that for replicating embodied human capital.

Knowledge that is embodied in people raises no special problems for economic analysis, but disembodied knowledge poses a fundamental challenge. Because of the fixed cost elements noted above, disembodied knowledge unavoidably leads to non-convexities in production. This observation lies at the center of the analysis that follows, but it is more general than the particular model that is used in this paper. Section 2 therefore digresses into a discussion of the issues that arise in any model where disembodied knowledge affects production possibilities. These issues have been noted many times before, but they are worth reiterating, for they have not yet been fully addressed in models of growth. There are many models that follow Solow in allowing for disembodied knowledge that evolves exogenously. On the other hand, Arrow (1962a) and Romer (1986) consider models where knowledge evolves endogenously but is intrinsically bundled with physical capital. Similarly, Lucas (1988), King and Rebelo (1987), Becker and Murphy (1988), and others have followed the lead of Uzawa (1965), allowing for the endogenous accumulation of knowledge that is embodied as human capital. All of these kinds of models preserve price taking behavior, but the discussion in section 2 suggests that this is precisely what must be abandoned in a model that allows for knowledge that is disembodied and that evolves endogenously.

Section 3 describes the specific model that is presented in this paper. It specifies the functional forms that are used to describe the preferences and the technology for the model, and it specifies an equilibrium concept with both monopolistic competition and externalities from knowledge spillovers. Section 4 offers a brief intuitive description of a

balanced growth equilibrium for the model. Section 5 formally characterizes the equilibrium and compares it to the social optimum that could be achieved by an omniscient, omnipotent planner. Algebraic details are placed in an appendix.

1. Inputs in Production

A growth model always consists of a list of inputs that are used in production, together with a specification of how additional amounts of these inputs can be accumulated. The model here relies on all four of the inputs that have been used in modern models of aggregate growth: physical capital K, labor L, human capital H, and the technology, or disembodied knowledge, A. This input list is the minimal list that allows a theory of growth to take advantage of the insights from growth accounting, labor economics, productivity analysis and the study of research and development. An analysis that took agriculture seriously would add land to the input list, but the arguments here will implicitly focus on non-agricultural output and neglect land. For the theory to be operational, these variables must at least in principle be susceptible to measurement, so some discussion of how they could be measured is called for. Because human capital and the technology have been given various interpretations in different models, a discussion of measurement also helps clarify how these concepts are used in the model proposed here.

Physical capital K can be measured as it is in studies of growth accounting. In crude applications, it is simply the result of cumulating aggregate investment from national income accounts and making an allowance for depreciation. In more refined analyses, an index describing growth in capital can be formed by weighting the rates of growth for different types of capital like structures and equipment. In principle, the argument in the production function should be the flow of services from capital rather than the stock of

capital. In practice, it is assumed that the service flow will be proportional to the stock if it is measured correctly.

Labor services L are a measure of skills like eye-hand coordination that are available from a healthy physical body. As in the case of capital, it is possible to distinguish the stock of bodies in the labor force from the flow of labor services provided by those bodies. In applications, labor services provided are measured over an interval of time and therefore have units of hours times bodies, i.e. man-hours. In an abstract model posed in continuous time, L can be taken to be the stock of bodies times the average fraction of time spent in the labor market.

As used here, human capital H is intended as a measure of the cumulative effect of activities like formal education and on the job training. Human capital is assumed to be embodied in the sense that it disappears when a person dies. Like physical capital, human capital is a stock that can be measured indirectly through observations on investment expenditures. In the economy as a whole, it has units like total man-years of education. Measured over any interval of time, the service flow from human capital that is devoted to production will have units of hours times man-years of education. In a continuous time model, the argument that appears in a production function will be the total stock of human capital, measured in terms of total man-years of education, times the average fraction of time this stock is devoted to the production activity. Although it is measured in units of man-years of education, human capital can be acquired in other ways, for example through on the job training, so years of on the job training would have to be aggregated with years of schooling. In practice, this is done by using wage equations that estimate the relative contributions of additional amounts of schooling and experience to the wages of an average worker.

In some applications, it is assumed that H and L are perfect substitutes and can be measured in common efficiency units, just as the estimates based on wage equations implicitly assume that schooling and experience are perfect substitutes and can be

measured in common units. What constitutes an appropriate degree of aggregation always depends on the uses to which a model is put, and for some purposes, aggregating H and L is a useful simplifying assumption. The model here treats H and L as different inputs to make explicit the idea that human capital is the important input in the research sector and that physical labor is an extremely poor substitute for it.

One could argue that the input list used here is still too highly aggregated, and that for understanding research, schooling and experience should be treated as separate inputs, or even that schooling itself should be disaggregated into measures that separate years in college and graduate school from other forms of schooling. In some strict sense this observation must be correct. It is not realistic to claim that two high school graduates have the same combined output in research as one individual with 12 years of schooling beyond high school, but the details of this extension are not pursued here. A rough distinction between physical labor and human capital will be sufficient to make the points that follow.

The definition of human capital used here is fairly close to the one used in labor market contexts (e.g. Rosen, 1976 or Heckman 1976). It also corresponds closely to the practice in growth accounting applications that take account of changes in the quality of the labor force that are due to changes in observables like the level of education and experience. (See for example Gollop and Jorgenson, 1980, or the discussion in Waldorf et al, 1986.) However, it is a more limited notion than that used in theoretical models of growth based on unlimited human capital accumulation like Lucas (1988), King and Rebelo (1987), Tamura (1987), and Becker and Murphy (1988). These models assume that human capital can grow without bound in a stationary population, so it refers to a broader concept that cannot be measured merely in terms of years of education or experience. Because of demographic effects, these measures must be bounded in a stationary population. In the steady state considered for the model here, individual agents implicitly go through a life cycle, acquiring human capital early in their careers, ceasing to acquire later, and

eventually dying. Losses due to deaths will just balance increments due to training by the young. Aggregate human capital remains constant. Human capital measured in this way clearly cannot capture the accumulation of knowledge noted in the introduction.

The analysis here uses the variable A to capture the accumulation of disembodied knowledge such as the instructions for recording images on magnetic tape. Like K, A is an input that can be accumulated indefinitely on a per capita basis. Examples of disembodied knowledge include scientific laws, principles of mechanical, electrical and chemical engineering, mathematical results, software, patents, designs, blueprints, and anything else that has productive value that one could find in the Library of Congress, or the Patent Office.

In principle, it would be possible to use information about the market value of all new contributions to the stock of disembodied knowledge to construct an index of growth in the aggregate stock of knowledge but doing so would require data that are not currently available. In practice, all an empirical economist can do is to follow an analog of the crude method suggested for constructing a capital aggregate, measuring cumulative investment in the production of disembodied knowledge. This process of measuring inputs into the research process rather than outputs has been implemented empirically in the literature on the effects of research and development spending on industry or firm level productivity. (See for example Griliches 1986.) It can also be cross checked with indicators of research output like the number of patents granted. Because there is a large element of chance in the production of new knowledge, research inputs for any given firm will not be a perfect measure of knowledge outputs, but at an aggregate level and for long time intervals, complete data on inputs devoted to research should be adequate to form a proxy for A. Unfortunately, it is likely that much effort devoted to small refinements of existing products and processes does not get captured in aggregate statistics on research and development. This is especially likely to be true of work that takes place in small firms, so

even with a strategy of measuring inputs into research and development, there is much room for improving the available statistics.

Just as some analyses do not distinguish between labor and human capital, growth models that rely on unbounded human capital accumulation implicitly combine human capital as measured here with disembodied knowledge. For the analysis of some issues (e.g. the correlations between fertility and income considered in Tamura 1987, and Becker and Murphy 1988), the distinction between disembodied knowledge and embodied human capital may not be particularly relevant, and in these cases combining the inputs is a reasonable simplification that is analogous to the aggregation of structures and equipment in a single capital stock aggregate.

As noted in the introduction, the key motivation for distinguishing disembodied knowledge from its embodied counterpart is to emphasize the implications that embodiment has for replication. After spending $25,000 to $30,000 and 2 years to attend business school, the recipient of an MBA degree need not be concerned with the possibility that a co-worker will be able to copy the knowledge acquired in business school and earn the same wages without incurring the costs of schooling. Similarly, an employer cannot hope to purchase one set of MBA skills and then copy them as needed. It is not technologically feasible to copy embodied human capital at a cost that is less than the cost of producing it. On the other hand, when a firm like Intel spends $100 million on the development of a new microprocessor, the result is a piece of disembodied knowledge that can be copied at a cost that is trivial compared to its production cost. No matter how many actual copies of the microprocessor Intel produces and sells, no further investment is required. For the arguments that follow, this possibility of essentially costless replication is the key distinguishing feature of disembodied knowledge.

Aside from its theoretical importance, the notion of disembodied knowledge may also be essential to explaining magnitudes found in the data from firm and industry productivity studies and from growth accounting. For example, between 1950 and 1979,

Japan increased total output and the capital stock by a factor of 10. Hours worked grew by a factor of 1.5. (The data are taken once again from Maddison, 1982.) If the share of capital in total income is around 0.3, then after correcting for capital accumulation, there is a six fold increase in output per hour worked that is left as an unexplained residual. There is very little prospect that the rate of growth in measurable attributes of the labor force like schooling or experience can explain this increase. To understand this rate of growth, it is not enough to observe that it has a good educational system and a high quality work force; it is necessary to explain why the quality of the work force has grown by roughly 6% per year for 29 years. This would imply that one worker in Japan in 1979 is equivalent to six workers in 1950.

It is sometimes argued that it is impossible to distinguish disembodied knowledge from human capital because some amount of human capital must be applied before knowledge on paper can be put to productive use. The observation that human capital is essential is correct, but it is also true that physical capital and labor are both essential in a conventional Cobb-Douglas production function. It is still useful to treat them as separate inputs, for this lets a theorist consider issues like the effects of differences in factor intensities in different industries. The distinction between human capital and disembodied knowledge serves the same purpose.

2. Increasing Returns

Before setting out the specific formal model that is used here, it is useful to consider the general implications of disembodied knowledge. Allowing for costless replication (or equivalently, allowing for goods that have a large fixed cost and negligible marginal cost) means that one is forced to work with some equilibrium concept other than perfect competition. The discussion in this section is heuristic and does not refer to a formal

model. The ideas here are embedded in the formal model in the next section and the observations made here can be rigorously established in that model, but they are more general than that model. For earlier discussions of these ideas and representations in the context of other formal models, see Arrow (1962b), Shell (1967), and Wilson (1975).

The basic thought experiment relies on the notion of replication. Essentially, one would like to argue that it is possible to double output by doubling the inputs K, L, and H, holding constant the stock of A. That is, without doing any additional research and development or introducing any new goods, slavishly replicate all existing productive activities. In so doing, it should be possible to double the output produced. Thus, a reduced form aggregate production function that relates total output to the quantities of the aggregate inputs that are used will be at least homogeneous of degree 1 in the variables K, L, and H. If A has productive value, an aggregate reduced form production function that includes A as an argument cannot be homogeneous of degree 1; a doubling of K, L, H, and A will more than double output. Whether it is actually possible to double all factors of production has no bearing on this thought experiment. If land were included as a factor, it clearly would not be possible, but the thought experiment is still a reliable guide to the mathematical form of the aggregate production function.

This thought experiment can be performed more concretely at the level of a particular industry. Suppose that over the life time of the computer industry, say from 1950 to the present, one had doubled all of the resources that were used in this industry. Some of these resources were used to produce output, others were devoted to research and development. Suppose first that the replicated set of productive resources were put to work along side of the orginal resources, but that the replicated set of research inputs were left idle. Merely by reproducing every productive activity at every point in time, using the avaliable technology, it should be possible to double the amount of computer power that was produced at every point in time. Now suppose that the second set of research inputs had also been put to work, making improvements in software, computer designs,

semi-conducting devices, and memory storage devices. Unless innovation is completely unresponsive to the resources devoted to it, discoveries should have taken place more rapidly and the quantity of computing power produced at every point in time should have been more than twice the amount that was actually produced.

In a model with perfect competition, the division of total income between different factors of production can be inferred by taking derivatives of an aggregate production function and multiplying the derivatives by the quantities of the aggregate inputs. In the standard analysis, national income $Y = F(H,L,K,A)$ is split between payments to raw labor, $L\frac{\partial F}{\partial L}$, payments for additional education and training $H\frac{\partial F}{\partial H}$, and payments to physical capital $K\frac{\partial F}{\partial K}$. If F is homogeneous of degree 1 in H, L, and K, as the replication argument suggests it must be, this exactly exhausts total income, leaving no way to compensate the factor A. Thus, in the Solow model, F is allowed to depend on A, but A is assumed not to receive any compensation in the market place. (It could receive compensation from a government through something like the National Science Foundation.) From the point of view of market incentives, the evolution of A is therefore taken to be exogenous.

Although it is not typically described in these terms, the Solow model can be thought of as a model of competitive equilibrium with externalities arising from knowledge spillovers. The factor A receives no compensation, and every individual firm is assumed to be free to exploit the entire stock of A. That is, its effects are purely external. In an attempt to make the evolution of A responsive to market incentives, Arrow (1962a) and Romer (1986) assume in effect that any increase in K necessarily leads to an equiproportionate increase in A. These papers preserve the assumptions that an increase in A has benefits that are purely external and that A receives no direct compensation. This kind of formulation has the advantage that it makes the rate of accumulation of A endogenous, but it is unsatisfactory because it takes the strict proportionality between A and K as an exogenously given and unexplained feature of the technology. This

formulation also rules out the possibility that firms make intentional invesments in research and development. Since an increase in A from whatever source has the same effects on the production possibilities of all firms in the economy, no firm has an incentive to make costly investments in the production of knowledge. (Dasgupta and Stiglitz 1988, emphasize this point, that learning-by-doing models with many firms cannot allow any of the returns from learning to be private. If they were, a decentralized equilibrium with many firms would not be possible.)

The model in Romer (1987,1988a) offers an alternative framework wherein firms do make intentional investments in research and development and do capture private benefits from these investments. Instead of relying on external increasing returns, the analysis permits internal increasing returns at the level of individual firms. This is consistent with the presence of large numbers of firms in equilibrium because firms produce goods that are not perfect substitutes. The model builds on the analysis of monopolistic competition in the supply of intermediate inputs in Ethier (1982) and is closely related to the model of patents in Judd (1985).

The model in Romer (1987, 1988a) shows how monopolistic competition can be used as an alternative to learning-by-doing and competition with externalities, but it has several weaknesses. It does not allow for any kind of spillover associated with knowledge. It uses an implausible form of production in the research sector, assuming that consumption goods can be converted on a one for one basis into new knowledge. Because it fails to distinguish between human capital and labor, the model also shares the unattractive feature found in many models of growth with specialization or increasing returns: growth rates are monotonically increasing in the population or population density of a country. The extension described in this paper shows how the introduction of human capital can lead to more satisfactory results.

3. Description of the Model

The formal model consists of an economy with three sectors. The research sector uses human capital and the existing stock of knowledge to produce new knowledge. This knowledge can be interpreted as designs for new intermediate inputs in production. An intermediate goods sector uses the designs from the research sector together with capital to produce the large number of intermediate inputs that are available for use in final goods production at any point in time. In practice, one might expect research on a new design and the production of the new good to take place within the same firm, and nothing in the analysis here rules this out; design work can either take place internally, or in a separate firm that sells the patent to the firm that will produce the actual good. A final goods sector uses labor, human capital, and the entire set of intermediate inputs to produce output goods. Output can either be consumed or saved as new capital.

Because the goal is to produce a simple dynamic model that can be used to highlight the role of disembodied knowledge in growth, the analysis is ruthless in its use of simplifying assumptions. The first assumption is that the population and the supply of labor are both constant. This rules out an analysis of fertility, labor force participation, or variation in hours worked per worker. The second assumption is that the total stock of human capital in the population is fixed and that the fraction supplied to the market is also fixed. Thus, the supply of the aggregate factors L and H is fixed. The assumption on H is partly for technical reasons. Under the definition of human capital employed here, the stock of human capital measured in units of man-years of schooling must be bounded if the size of the population is fixed. The dynamic analysis is greatly simplified by restricting attention to equilibria with constant growth rates, and the only feasible constant growth rate for H is zero.

As noted in the introduction, the premise of this paper is that growth in per capita income springs ultimately from technological change, and the intention here is to focus on

this effect. However, there is no question that the labor force participation rate, the fertility rate, and the levels of education and labor force experience show important variability across countries and over time, and any serious empirical work on growth must ultimately allow for this kind of variation. Conceptually, there is no problem in combining the features from this model with those of models like Tamura (1987) or Becker and Murphy (1988) that address these kinds of issues, but any explicit dynamic analysis will be much more difficult.

The other simplifying assumptions are factor intensity assumptions that take the extreme form of exclusion restrictions. Thus, the plausible assertion that the production of new knowledge is relatively human capital and knowledge intensive is translated into a specification where only knowledge and human capital are used to produce new knowledge. Labor and capital do not enter at all. These kinds of restrictions will reduce the analysis of the dynamics of this system to a system of equations that can be explicitly solved using high school algebra. Presumably, a relaxation of these assumptions that preserves the factor intensity orderings used here would not change the basic dynamics of the model.

The set of possible intermediate inputs is indexed by the non-negative half line $\mathbb{R}_+$. An input list is therefore a non-negative function x from $\mathbb{R}_+$ into $\mathbb{R}_+$ with the property that the integral $\int_0^\infty x(i)di$ is well defined and finite. Let $\mathcal{X}$ denote the set of all such functions. (Formally, $\mathcal{X}$ is the positive cone in the space of absolutely integrable Lebesgue measurable functions.) Final goods output is defined to be a function $Y:\mathbb{R}_+ \times \mathbb{R}_+ \times \mathcal{X} \longrightarrow \mathbb{R}_+$ that maps human capital H_1, labor L, and an intermediate input list x into output of final goods. (H_1 denotes the stock of human capital used in this production activity; H_2 will denote the stock of human capital devoted to the research sector.) The simplest interesting functional form for Y is an extension of the Cobb-

Douglas production function,

$$(1) \qquad Y(H_1,L,x) = H_1^{\alpha}L^{\beta}\int_0^{\infty}x(i)^{1-\alpha-\beta}di.$$

This function is defined on an unusually large space of potential inputs, but it is a well behaved constant returns to scale production function. Because of the constant returns to scale, output in this sector can be described in terms of the actions of a single, aggregate, price-taking firm. Output can be consumed or saved as additional capital, so the evolution of capital is given by

$$(2) \qquad \dot{K} = Y - C.$$

For a firm in the intermediate input sector, the production of a new intermediate input requires the acquisition of a design from the research sector. This represents a fixed cost in the sense that it must be incurred if any positive amount of an intermediate good is produced, but the cost is otherwise independent of the level of output. With one design, a firm is free to produce an arbitrary number of units of output. Production of these units of output also has a variable cost component; more capital is needed if more units are produced. Choosing functional forms that are as simple as possible, suppose that an indefinite flow of x units of an intermediate input can be produced with an initial investment in one design and with ηx units of capital. (Strictly speaking, because of the assumption that there is a continuum of goods, these quantities must be measured per unit length of the half line $\mathbb{R}_+$. Thus, producing intermediate inputs on an interval of length I at the level x requires an initial purchase of I units of A and the use of ηIx units of physical capital.) This kind of formulation is very close to that used in the discussion of patents in Judd (1985), which also uses a continuum of goods to study a process whereby

new goods are introduced as new patents are produced. Specifically, the model here corresponds to Judd's discussion of the case where patents are infinitely lived. The key difference is that Judd treats the differentiated goods as consumption goods rather than intermediate inputs and uses a form of exogenous technological change to generate growth.

There are two equivalent interpretations of the intermediate goods. Under the first interpretation, the firm producing the intermediate good buys a design, purchases and installs capital, and produces a flow of intermediate inputs that is sold in a spot market. The language used in what follows will refer to this interpretation. The alternative interpretation is that an intermediate input producing firm buys a design, buys raw capital in the form of forgone output, and converts this raw capital into a specialized capital good according to the design. These specialized pieces of capital then provide a stream of specialized capital services. Rather than selling services at every point in time, these firms can be thought of as leasing or selling the specialized capital. Under either interpretation, the analysis is simplified by assuming that physical capital does not depreciate.

Thus, H and L are fixed, and K grows by the amount of forgone consumption. It remains to specify the process for the accumulation of new knowledge. As noted above, research output depends on the amount of human capital devoted to research. It also depends on the stock of disembodied knowledge that is available to an individual doing research. Thus, if individual i devotes human capital H^i to research and has access to an amount A^i of the total stock of knowledge, the rate of production of new knowledge will be $\delta H^i A^i$ where δ is a productivity parameter.

Although other assumptions about secrecy and property rights could be made, the equilibrium here will be based on the idea that anyone engaged in research has free access to the entire stock of knowledge. Thus, the output of individual i will actually be $\delta H^i A$.

Summing across all individuals, the aggregate stock of knowledge will evolve according to

$$\dot{A} = \delta H_2 A. \tag{3}$$

At the aggregate level, H_1 and H_2 are related by the constraint

$$H_1 + H_2 = H.$$

The interpretation of these equations is that any individual can devote human capital to either the final output sector or the research sector. Implicitly this neglects the fact that L and H are supplied jointly. To take the equations used here literally, one must imagine that there are some skilled individuals who are endowed with zero physical coordination, and therefore can supply no labor. They invest instead in human capital and supply it to either the final goods sector or the research sector. In fact, as noted by Becker and Murphy (1988), factor intensity differentials between industries that use labor and human capital will lead to incentives for this kind of specialization in the supply of human capital and labor.

It is important to emphasize that knowledge enters into production in two ways in this model. The stock of knowledge determines the set of intermediate goods that can be produced, and thereby has a direct effect on the output of final goods. The existing stock of knowledge also affects the productivity of human capital in the research sector. The equilibrium concept used in the analysis that follows is based on the idea that the owner of a design or a patent has property rights over its use in the production of a new intermediate good but not over its use in the production of new knowledge. If an inventor has a patented design on widgets, no one can make or sell widgets without signing a contract with the inventor. On the other hand, other inventors are free to spend time

studying the patent application for the widget and reverse engineer any widgets that are produced. In so doing, they may learn knowledge that helps in the design of wadgets and wodgets. The inventor of the widget has no ability to stop the inventors of wadgets and wodgets from learning from the design of a widget.

At a theoretical level and in practice, there is always some ambiguity about what constitutes a new design for a different good and what constitutes a copy of an existing design. In the model, this ambiguity is artificially resolved by the form of the production function Y. This form implies that new goods are never close substitutes for existing goods since all of the intermediate inputs enter into production in an additively separable fashion. Although it greatly simplifies the analysis, this is not a realistic feature of the model. Nonetheless, the general results here should be robust to more careful modeling of the nature of the interaction between different specialized intermediate inputs. What matters for the results is that the production of knowledge confers some private benefits and some public or external benefits.

Equation (3) shows that the technology for producing A exhibits increasing returns; a doubling of A and of H_2 will quadruple $\dot{A}$. The presence of A in the equation for $\dot{A}$ is intended to capture the idea that someone doing research is not hampered or preempted by prior work; on the contrary, prior work increases the productivity of current research work. (In a letter to Robert Hooke, Isaac Newton gave the definitive description of this effect: "If I have seen further ... it is by standing on the shoulders of giants." It might better be said that Newton was a giant standing on a large pile of pygmies, but there is no question that those who followed got to stand on his shoulders.) Like the role of A in the Solow model, A here has a purely external effect in the research sector.

To fix notation for prices, let spot prices at any point in time be measured in units of current output, and let r denote the interest rate on loans denominated in goods. Let

P_A denote the price of new designs, and let w_H denote the rental rate per unit of human capital. Because goods can be converted into capital on a one for one basis, the spot price for capital is 1 and its rate of return is r. Because of the assumption that anyone engaged in research can freely take advantage of the entire existing stock of designs in doing research to produce new designs, it follows from equation (3) that P_A and w_H are related by

$$w_H = P_A \delta A.$$

Associated with each i in $\mathbb{R}_+$, there is a potential intermediate input producing firm. All agents other than the intermediate goods suppliers act as price takers in their input and output markets. Each of the intermediate input firms takes the spot price P_A for designs, the price of 1 for capital goods, and the interest rate as given, but sets prices for output. Formally, each of these firms can be thought of as setting a price $p(i) \in \mathbb{R}_+ \cup \{\infty\}$ for output and producing to meet the demand. If a firm chooses $p(i) = \infty$, the demand is zero, and outputs and inputs are zero, so this is equivalent to a decision not to produce.

Faced with a price list $p(\cdot)$ for intermediate inputs, the representative final output producing firm chooses a profit maximizing quantity of each intermediate input $x(i)$. Because it is a constant returns to scale firm, its input demands are defined only once the scale of operation is pinned down. Let L and H_1 be the total amounts of labor and human capital that are used in the production of final output goods. (The split of total H between H_1 and H_2 remains to be determined.) Given values for H_1 and L, it is possible to derive the demands for intermediate inputs from a maximization problem that

is conditional on H_1 and L:

$$\max_{x \in \mathcal{X}} \int_0^\infty [H_1^\alpha L^\beta x(i)^{1-\alpha-\beta} - p(i)x(i)]di.$$

By differentiating under the integral sign, this leads to an inverse demand function

$$p(i) = (1-\alpha-\beta)H_1^\alpha L^\beta x(i)^{-\alpha-\beta}. \tag{4}$$

(There is an uninteresting technical issue here about what it means to the final goods producer if prices change on a set of measure zero. Because of the symmetry in this model, equation (4) can readily be derived by a limiting argument. For a general discussion of these issues, see Pascoa, 1987.)

The demand curve in equation (4) is what each intermediate input producer takes as given in choosing the profit maximizing price to set. Faced with given values H_1, L, and r, an intermediate input firm that has already incurred the fixed cost investment in a design will choose a level of output x to maximize its revenue minus marginal cost at every point in time:

$$\begin{aligned} \pi &= \max_x p(x)x - r\eta x \\ &= \max_x (1-\alpha-\beta)H_1{}^\alpha L^\beta x^{1-\alpha-\beta} - r\eta x. \end{aligned} \tag{5}$$

Because each intermediate goods producer must sell its output to a large number of final goods producers that can operate at any scale, it is assumed that this simple form of monopoly pricing is the only option available.

The decision about whether to produce an intermediate good involves a comparison of the discounted stream of revenue minus marginal cost with the cost P_A of the initial

investment in a design. For intermediate input producing firms that are not producing to be indifferent between remaining inactive and entering to produce at the profit maximizing level, the present value of entry must be zero at every point in time. If profits were positive, entry would occur, driving up the price P_A and the interest rate r. At every date t, it must therefore be true that

$$\int_t^{\infty} e^{-\int_t^{\tau} r(s)ds} \pi(\tau)\, d\tau = P_A. \tag{6}$$

If P_A is constant (as it will be in the equilibrium described below) this condition can be put in a more intuitive form. Differentiating with respect to time t yields

$$\pi(t) - r(t)\int_t^{\infty} e^{-\int_t^{\tau} r(s)ds} \pi(\tau)\, d\tau = 0.$$

Substituting in the expression for P_A from equation (6) yields

$$\pi(t) = r(t)P_A. \tag{6'}$$

This says that at every point in time, the instantaneous excess of revenue over marginal cost must be just sufficient to cover the interest cost on the initial investment in a design. (This formulation of the intertemporal zero profit constraint is taken from Grossman and Helpman, 1988.)

To complete the description of the model, it remains to specify preferences and endowments. Consumers have standard, discounted, constant elasticity preferences in

continuous time:

$$\int_0^\infty U(C)e^{-\rho t}dt, \text{ with } U(C) = \frac{C^{1-\sigma}-1}{1-\sigma} \text{ for } \sigma \in [0,\infty).$$

Consumers are endowed with fixed quantities of labor L and human capital H that are supplied inelastically. At time 0, consumers own the existing intermediate goods producing firms, and the net revenues of these firms are paid to consumers as dividends. Final goods firms earn zero profits and own no assets so they can be ignored in the specification of endowments.

An equilibrium for this model will be paths for prices and quantities such that:

i) consumers make savings and consumption decisions taking interest rates as given;

ii) final output producers choose labor, and human capital, and a list of intermediate inputs taking prices as given;

iii) each potential and actual intermediate input producer maximizes profit taking the interest rate, the price for designs and the downward sloping demand curve for output as given;

iv) supplies are equal to demands;

v) profit in the intermediate goods industry is zero.

4. Discussion of the Model

A reasonable intuition for the behavior of this model can be inferred by considering the Solow model where the evolution of A is given exogenously, and the Uzawa (1965) model where the evolution of A is determined by the allocation of resources between a

research sector and a final goods sector. For a fixed amount of A, and therefore a fixed quantity of intermediate inputs, the model is almost identical to the Solow model. Because of the symmetry in the model, at any point in time, all the intermediate inputs that are available are supplied at the same level, henceforth denoted as $\bar{x}$. If they were not, it would be possible to increase profits in the intermediate goods sector by reducing the output of high output firms and diverting the capital released in this way to low output goods. Since A determines the range of intermediate goods that can be produced and since η units of capital are required per unit of intermediate goods, it is possible to solve for $\bar{x}$ from the equation $K = A\bar{x}$. Then output Y can be written as

$$(7) \qquad \begin{aligned} Y(H_1,L,x) &= H_1^{\alpha}L^{\beta}\int_0^{\infty}x(i)^{1-\alpha-\beta}di \\ &= H_1^{\alpha}L^{\beta}A\bar{x}^{1-\alpha-\beta} \\ &= H_1^{\alpha}L^{\beta}A\left[\frac{K}{\eta A}\right]^{1-\alpha-\beta}. \end{aligned}$$

For fixed A, this is just like a conventional constant returns to scale production function except for the fact that L and H_1 are treated as separate inputs. In particular, it exhibits the usual diminishing returns to capital accumulation. Given the assumed form of preferences, a fixed level of A will lead to an equilibrium with a steady state level of K that is determined by the property that the marginal product of capital is equal to the discount rate. If A grew at an exogenously specified exponential rate, the economy would converge to a path where K grows at the same exponential rate as A, just as it does in the Solow model. To see this, note that in the reduced form equation (7) for output, A acts just like a form of labor and human capital augmenting technological change:

$$(7') \qquad Y(H_1,L,K,A) = \eta^{\alpha+\beta-1}(AH_1)^{\alpha}(AL)^{\beta}(K)^{1-\alpha-\beta}.$$

When A is treated as an input like the others, this equation demonstrates the increasing returns that are present in the aggregate reduced form production function. Y is homogeneous of degree $1+\alpha+\beta$.

In the Uzawa extension of the Solow model, the rate of growth of A is determined by the allocation of resources between output and research. In the interpretation of the Uzawa model that has been pursued by Lucas (1988) and King and Rebelo (1987), A is treated as an amalgam of the human capital H and disembodied knowledge A that are considered here. In those papers, growth in A is assumed to depend only on the amount of A that is devoted to producing new amounts of A, and it is assumed that any A that is used in production cannot be used to produce new A. The model here asserts that growth in A depends on both the entire stock of A in existence, and on the amount of human capital devoted to doing research. As noted above, the functional form used here imposes a form of increasing returns in the research sector that is distinct from the increasing returns in the final goods sector exhibited in equation (7′).

The increasing returns evident in the reduced form equation (7′) are supported in a decentralized equilibrium that relies on monopolistic competition as exhibited by the price setting behavior in the intermediate input sector. In contrast, the increasing returns in the research sector implied by equation (3) are supported through competition with external effects that arise from knowledge spillovers. Both these elements seem essential to capturing the features of disembodied knowledge. There is little doubt that much of the value to society of any given innovation or discovery is not captured by the inventor, and any model that missed these spillovers would miss important elements of the growth process. Yet it is still the case that private, profit maximizing agents make investments in the creation of new knowledge and that they earn a return on these investments by charging a price for the resulting goods that is greater than the marginal cost of producing the goods.

5. Solution of the Model for a Balanced Growth Equilibrium

The strategy for solving the model that is followed here is to solve for an equilibrium in which the variables A, K, and Y grow at constant exponential rates. Following the accepted terminology, this will be referred to as a balanced growth equilibrium. Using the intuition from the Solow model, such an equilibrium will exist if A grows at a constant exponential rate. Using the intuition from the Uzawa model, it is possible for A to grow at a constant rate because equation (3) for $\dot{A}$ is linear in A, and it will do so if the amount of human capital H_2 that is devoted to the research sector stays constant. Verifying that a balanced growth equilibrium exists therefore reduces to the problem of showing that prices and wages are such that H_1 and H_2 remain constant as Y, K, C, and A all grow at the same rate. By focusing only on balanced growth paths, the analysis neglects the transitory dynamics that arise when the economy starts from a ratio of K to A that differs from the ratio that is maintained along the balanced growth rate path. It should be a routine matter to consider the process of convergence to the balanced growth ratio of K to A using the tools used for studying the Solow model and Uzawa model, and this analysis is not attempted here.

Given results from the previous models, it is easy to guess what the behavior for some of the prices and other quantity variables will be. Since output and investment grow at a constant rate, consumption grows at the same rate. Given the assumption of constant elasticity preferences, this will imply a constant interest rate. Results for the simpler model of differentiated inputs considered in Romer (1988a) suggest that along the balanced growth path, all the growth in K will be devoted to producing new goods rather than to increasing the quantities of the goods that are already being produced. Thus, the balanced growth solution should also have a constant level $\bar{x}$ for all inputs that are produced.

Because of the accumulation of K and A, the wage paid for human capital will not be constant, but the productivity of human capital will grow at the same rate in the final output and research sectors. This permits H_2 to remain constant. Since the wage for human capital will increase at the same rate as productivity in the research sector, the price P_A for new designs will be constant.

It remains to check that this description of a balanced growth path is consistent with all the equilibrium conditions. The condition determining the allocation of human capital between the final output and research sectors says that the wage paid to human capital in each sector must be the same. In the final output sector, the wage for human capital is its marginal product. In the research sector, the wage is $P_A \delta A$, and human capital receives all the income from this sector. To equalize returns to human capital in both sectors, H_2 must be chosen so that

$$w_H = P_A \delta A = \alpha(H-H_2)^{\alpha-1} L^{\beta} \int_0^{\infty} x(i)^{1-\alpha-\beta} di. \tag{8}$$

Implicitly, the allocation of H between the two sectors is constrained by the requirement that H_1 and H_2 be nonnegative. If either of these constraints is binding, equation (8) will hold as an inequality.

Substituting the constraint relating H_1 and H_2 into equation (7) and retaining the variable $\bar{x}$ gives

$$\begin{aligned} Y(H_1,L,x) &= (H-H_2)^{\alpha} L^{\beta} \int_0^{\infty} x(i)^{1-\alpha-\beta} di \\ &= (H-H_2)^{\alpha} L^{\beta} A(\bar{x})^{1-\alpha-\beta}. \end{aligned} \tag{9}$$

Combining equations (8) and (9), the price for new knowledge can then be written as

$$P_A = \frac{\alpha}{\delta}(H-H_2)^{\alpha-1}L^{\beta}(\bar{x})^{1-\alpha-\beta}. \tag{10}$$

For a given value of H_2, the implied exponential growth rate for A is δH_2. By equation (9), Y must grow at the same rate as A if L, H_1, and $\bar{x}$ are fixed. If $\bar{x}$ is fixed, then K must grow at the same rate as A since total usage of capital will be $A\bar{x}\eta$. Since consumption is the difference between output Y and investment $\dot{K}$, it follows that the rate of growth of consumption must also take on this same value. If g denotes the growth rate of A, Y and K, the fact that K/Y is a constant and that $\frac{\dot{K}}{K} = g$, implies that $\frac{C}{Y} = 1 - \frac{\dot{K}}{Y} = 1 - g\frac{K}{Y}$ must also be constant. The common growth rate g for all these variables is therefore

$$g = \frac{\dot{C}}{C} = \frac{\dot{Y}}{Y} = \frac{\dot{K}}{K} = \frac{\dot{A}}{A} = \delta H_2.$$

From the form of preferences, it then follows that the constant interest rate for this equilibrium is

$$r = \rho + \sigma\frac{\dot{C}}{C} = \rho + \sigma\delta H_2. \tag{11}$$

Equations (10) and (11) form two of the four equations needed to solve for the four values H_2, P_A, $\bar{x}$, and r that should be constant in a balanced growth equilibrium. One of the remaining two equations comes from the zero profit condition for the intermediate

goods industry. Rewriting the intertemporal zero profit condition in equation (6′), we have

$$\pi = rP_A. \tag{12}$$

The other equation comes from the first order condition for the profit maximization problem for an individual firm in that industry. From equation (5), the instantaneous profit maximization problem of an intermediate good firm is

$$\pi(H-H_2,L,r) = \max_x \ (1-\alpha-\beta)(H-H_2)^{\alpha}L^{\beta}x^{1-\alpha-\beta} - r\eta x.$$

The first order condition for this problem is

$$r = \frac{1}{\eta}(1-\alpha-\beta)^2(H-H_2)^{\alpha}L^{\beta}(\bar{x})^{-\alpha-\beta}. \tag{13}$$

Equations (10), (11), (12), and (13) form the system of equations that can be solved for the four variables H_2, P_A, $\bar{x}$, and r. Because of the exclusion restrictions built into the model, this can be done by direct substitution. The details are given in the appendix.

The key result from the solution is the expression for the growth rate as a function of the underlying parameters:

$$g = \frac{\delta H - \Lambda\rho}{\Lambda\sigma + 1}, \tag{14}$$

where Λ is the constant

$$\Lambda = \frac{\alpha}{(1-\alpha-\beta)(\alpha+\beta)}. \tag{15}$$

(The expression for the growth rate suggests a minor technical restriction. For the integral in the consumer's preferences to be finite, the rate of growth of current utility $(1-\sigma)g$ must be less than the discount rate ρ. Thus, for $\sigma \in [0,1)$, it must be the case that $\frac{(1-\sigma)\delta H}{\Lambda+1}$ is less than the discount rate ρ. If this does not hold, the integral can be infinite and some kind of overtaking criterion must be used to describe the behavior of the consumer.)

As one would expect from the original Uzawa model, the preference parameters σ and ρ both influence the growth rate. A reduction in σ or in ρ, either of which makes individuals more willing to substitute consumption today for consumption tomorrow, will lead to faster growth. What may be more surprising is that the growth rate depends on neither the size of the labor force L nor the cost parameter η that determines the amount of capital needed per unit of intermediate good. This result stands in contrast to the implausible result from Romer (1988a) that growth rates are monotonically increasing in L, and confirms the conjecture that adding human capital as a separate variable and specifying a more reasonable research technology removes the dependence of the growth rate on L.

One of the interesting results about this expression is that it suggests the possibility of stagnation based on an inadequacy of human capital. Strictly speaking, the negative growth rates suggested in the formula will not be observed, for they correspond to choices of H_2 that are negative. Since the growth rate g is equal to δH_2, equation (14) can be restated as an expression for H_2 in terms of H:

$$H_2 = \frac{H - \rho\frac{\Lambda}{\delta}}{\Lambda\sigma+1}. \tag{16}$$

If H is too low, the non-negativity constraint on H_2 will be binding. In this case, all of

the feasible growth rates for A are too small relative to the discount rate to justify the sacrifice in current output necessary for growth to take place. If H is like income, research in this model is like a luxury good; H_2 increases more than proportionally with increases in H. This result is suggestive of the wide variation in growth rates observed across countries, and of the finding that in some countries per capita growth has been effectively zero. This model cannot offer a complete explanation for these observations because it treats the stock of H as given, but it does suggest directions for further work.

The expression from the appendix for P_A is

$$P_A^{\alpha+\beta} = \frac{\Gamma}{\delta^2}\left[\frac{\delta\sigma\Lambda H+\Lambda\rho}{\sigma\Lambda+1}\right]^{\alpha-1} L^{\beta}\eta^{\alpha+\beta-1} \tag{17}$$

where Γ is the constant

$$\Gamma = [\alpha(1-a-\beta)^{1-\alpha-\beta}(\alpha+\beta)^{\alpha+\beta}].$$

From this it follows that while η and L do not affect the growth rate, they do affect the relative price of designs; an increase in L or a decrease in η causes an increase in P_A. This causes the intermediate input sector in effect to substitute away from A towards K. The expression for $\bar{x}$ in terms of P_A is

$$\bar{x} = \frac{1}{\eta} P_A \frac{1-\alpha-\beta}{\alpha+\beta}. \tag{18}$$

An increase in L or a decrease in η will therefore cause both $\bar{x}$ and the ratio of K to A to increase.

The fact that changes in η do not affect the long run rate of growth of knowledge has implications for policies designed to encourage physical capital accumulation. Like the

Arrow (1962a) and Romer (1986) models that tie the rate of growth of A to that of K, this model has the property that along an equilibrium path, $\dot{A}/A = \dot{K}/K$. However, this model behaves differently in response to an intervention by the government designed to subsidize capital. In the previous models, the ratio of A to K was implicitly fixed, so any intervention that increased the accumulation of K also increased the accumulation of A and therefore increased growth rates in the model. Here, the ratio of K to A is determined endogenously. If the government offers a subsidy to the accumulation of capital that is financed by a lump sum tax, this has the same effect on growth rates as a reduction in η. (To see a demonstration of this kind of result, see Romer 1988b). In this model, this subsidy will have the effect of increasing the ratio of K to A, but it will not affect the rate of accumulation of A and therefore will not affect growth rates in the long run. This rules out neither the possibility that a subsidy to capital can be welfare improving, nor that the subsidy might increase growth rates as the economy makes the transition to a new balanced growth rate path with a higher ratio of K to A. It merely shows that the strong arguments for subsidies to capital that emerge from the previous analyses are strongly dependent on the assumption that the ratio of K to A is fixed.

The effects of a subsidy to capital can be contrasted with a policy designed to encourage research. A subsidy to employment in the research sector that is financed through lump sum taxes has the same effects on growth as an increase in the productivity parameter δ in equation (3). In the long run, this will cause an increase in the growth rate, a fall in P_A, and a reduction in $\bar{x}$ and in the ratio of K to A.

Because of the externality associated with the production of knowledge, there is a presumption that this kind of subsidy to the accumulation of A will be welfare improving, but demonstrating this result rigorously forces the analysis to depart from consideration of balanced growth paths. Any intervention designed to move an economy from one balanced growth path to another must consider the transition dynamics along the way, and an

explicit analysis of these dynamics is beyond the scope of this paper.

However, it is easy to compare growth rates along the balanced growth path that emerges from the equilibrium and the one that would emerge from the solution to a social planning problem. Using the symmetry arguments that lead up to equation (7′), the social planning problem for this economy can be written as:

$$\max \int_0^\infty \frac{C^{1-\sigma}-1}{1-\sigma} e^{-\rho t} dt$$

$$\text{s.t. } \dot{K} = \eta^{\alpha+\beta-1} A^{\alpha+\beta} H_1^{\alpha} L^{\beta} K^{1-\alpha-\beta} - C$$

$$\dot{A} = \delta H_2 A$$

$$H_1 + H_2 \leq H.$$

As is shown in the appendix, the balanced growth solution to the first order necessary conditions for this problem has a growth rate g^* that is given by

$$g^* = \frac{\delta H - \Theta\rho}{\Theta\sigma + (1-\Theta)}, \tag{19}$$

where $\Theta = \frac{\alpha}{\alpha+\beta}$. Since Θ is less than the corresponding coefficient Λ in equation (14) and since $1-\Theta$ is less than 1, it follows that the socially optimal growth rate is greater than the growth rate in the decentralized equilibrium. In the social optimum, more human capital is devoted to research and less to the production of final output goods.

The final observations about this model pertain to its implications for trade and growth. These can be seen most simply by comparing the equilibrium for two identical closed economies that operate in isolation with the equilibrium that would obtain if the economies were fully integrated. Thus, suppose that there are two economies that are totally isolated, each with the same level of H, K and L and each of which is using the same (independently produced) stock of knowledge A. In the case least favorable to gains

from trade, suppose that each country faces the same technological problems, develops the same goods, and has the same stock of A. When these two economies are integrated, there are no immediate gains. Eventually, the two economies will start to specialize in the production of different intermediate inputs, but initially there are no gains from trade because they possess the same goods. However, equation (16) shows that in the balanced growth equilibrium for this model, the fraction of the total worldwide stock of human capital that is devoted to research is greater after integration than it is under isolation. Therefore the rate of growth is higher. Thus, in contrast to models of specialization that imply that trade has a positive effect on the level of income but not on the growth rate, this model highlights the possibility that it has long term growth rate effects. To the extent that the two isolated economies develop different goods and have non-overlapping stocks of knowledge, the dynamic benefits from trade will be augmented by the usual static gains.

This suggests why a decision to engage in trade may be important even for very large economies like that of China or India. If access to a large number of individuals or consumers were all that mattered, having a large population would be a good substitute for trade with other nations. The model here suggests that what is important for growth is not integration into an economy with a large number of people, but rather into one with a large amount of human capital that can be devoted to research and the production of new goods. Many of the details of trade between different economies of this kind remain to be worked out, but based on the observation that growth does seem to be closely correlated with the degree of integration into worldwide markets but not closely related to population size or density, the results from this model seem promising.

Appendix

A1. Calculation of the Balanced Growth Equilibrium

Equations (10), (11), (12), and (13) can be solved for the variables $\bar{x}$, P_A, r, and H_2, by first substituting out the variables $\bar{x}$ and H_2, leaving two equations in P_A and r. By inserting equation (13) into the expression (5) for π, equation (12) can be written as

$$\bar{x} = P_A \frac{1-\alpha-\beta}{\eta(\alpha+\beta)}. \tag{A.1}$$

Solving equation (11) for H_2 in terms of r yields,

$$H_2 = \frac{r-\rho}{\sigma\delta}. \tag{A.2}$$

Substituting the expressions from (19) and (20) for $\bar{x}$ and H_2 into equation (13) gives P_A implicitly as a function of r:

$$P_A^{\alpha+\beta} = \frac{\Omega}{r} L^{\beta}\left[H - \frac{r-\rho}{\sigma\delta}\right]^{\alpha} \eta^{\alpha+\beta-1}. \tag{A.3}$$

The constant Ω in this expression is a function of the exponents α and β:

$$\Omega = (1-\alpha-\beta)^{2-\alpha-\beta}(\alpha+\beta)^{\alpha+\beta}. \tag{A.4}$$

The second equation for $P_A^{\alpha+\beta}$ in terms of r follows by substituting the expressions for H_2 and $\bar{x}$ into equation (10), the equation describing equality of returns to human capital

in both the final output and research sectors. The result can be written as

$$P_A^{\alpha+\beta} = \frac{\Gamma}{\delta} L^{\beta}\left[H - \frac{r-\rho}{\sigma\delta}\right]^{\alpha-1} \eta^{\alpha+\beta-1}, \tag{A.5}$$

where the constant Γ is given by

$$\Gamma = \alpha(1-\alpha-\beta)^{1-\alpha-\beta}(\alpha+\beta)^{\alpha+\beta-1}.$$

Equating equations (A.4) and (A.5) and simplifying gives the expression

$$r = \frac{\sigma\delta H+\rho}{\sigma\Lambda+1}, \tag{A.6}$$

where Λ is as defined in the text. Using the relationship between r and H_2 to solve for H_2, then multiplying to get $g = \delta H_2$ gives equation (14) in the text,

$$g = \frac{\delta H - \Lambda\rho}{\Lambda\sigma+1}.$$

Substituting equation (A.6) into equation (A.5) and simplifying gives equation (17) in the text,

$$P_A^{\alpha+\beta} = \frac{\Gamma}{\delta^2}\left[\frac{\delta\sigma\Lambda H+\Lambda\rho}{\sigma\Lambda+1}\right]^{\alpha-1} L^{\beta}\eta^{\alpha+\beta-1}$$

where Γ is the constant

$$\Gamma = [\alpha(1-a-\beta)^{1-\alpha-\beta}(\alpha+\beta)^{\alpha+\beta}].$$

Equation (18) in the text follows from equation (A.1).

A2. Calculation of the Balanced Growth Social Optimum

To derive the necessary conditions for the social optimization problem PS, construct the current valued Hamiltonian:

$$\mathcal{H} = \frac{C^{1-\sigma}}{1-\sigma} + \lambda[\eta^{\alpha+\beta-1}A^{\alpha+\beta}(H-H_2)^{\alpha}L^{\beta}K^{1-\alpha-\beta} - C] + \mu\delta H_2 A.$$

The necessary conditions follow by maximizing $\mathcal{H}$ with respect to the control variables C and H_2, and from the equations for the evolution of the multipliers λ and μ:

$$\dot{\lambda} = \rho\lambda - \frac{\partial\mathcal{H}}{\partial K}, \quad \dot{\mu} = \rho\mu - \frac{\partial\mathcal{H}}{\partial A}.$$

The first order condition for maximizing $\mathcal{H}$ with respect to C gives the usual expression relating marginal utility and the multiplier λ:

(A.7) $$C^{-\sigma} = \lambda.$$

If the symbol Δ is used to represent the term $\eta^{\alpha+\beta-1}A^{\alpha+\beta}(H-H_2)^{\alpha}L^{\beta}K^{1-\alpha-\beta}$ from the Hamiltonian, the first order condition for maximizing $\mathcal{H}$ with respect to H_2 can be written as

(A.8) $$\Delta = (H-H_2)\frac{\delta\mu}{\alpha\lambda}A.$$

Then using equation (A.8), the evolution equation for μ can be simplified to yield

$$\frac{\dot{\mu}}{\mu} = \rho - \delta[\frac{\alpha+\beta}{\alpha}H - \frac{\beta}{\alpha}H_2]. \tag{A.9}$$

For a balanced growth equilibrium, it must be the case that $\frac{\dot{\mu}}{\mu} = \frac{\dot{\lambda}}{\lambda}$ and that $\frac{\dot{C}}{C} = \frac{\dot{A}}{A}$. Using equation (A,7), these can be combined to yield $\sigma\frac{\dot{A}}{A} = \frac{\dot{\mu}}{\mu}$. Then combining the evolution equation for A, $\frac{\dot{A}}{A} = \delta H_2$, with equation (A.9) gives an equation in H, H_2, and the basic parameters of the model:

$$\delta H_2 = \rho - \delta[\frac{\alpha+\beta}{\alpha}H - \frac{\beta}{\alpha}H_2]. \tag{A.10}$$

Equation (19) in the text can be derived from this equation by solving for H_2 and using the fact that the growth rate g is given by $g = \delta H_2$.

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Comment on "Endogenous Technological Change" by Paul M. Romer

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This is an interesting and well-motivated paper. Its basic motivation stems from the observation cited in Maddison (1982) that output per hour worked has risen dramatically, but that this rise cannot be explained by increases in physical capital or even man-hours of education. Romer follows Solow (1957) in ascribing this enormous increase in output per hour worked to advances in the technology available to workers. Romer wants us to think about technology as disembodied knowledge, as in a blueprint, a scientific formula, etc. Technology in Romer's model is a list of instructions that can be costlessly replicated and passed on to others. This is distinct from human capital, which is a set of skills embodied in the worker and which are costly to pass on to others. Several other recent papers, including Lucas (1988) and Becker-Murphy (1988), focus on human capital as an omitted factor in the production function that can account for large increases in output per worker. It seems reasonable that both increases in embodied skills and advances in technology have been quite important as determinants of long-run growth. Depending on the specification of the accumulation possibilities for human capital and disembodied knowledge, both factors can easily produce perpetual growth.

While I agree with Romer that the production of new disembodied knowledge is crucial in explaining recent growth in developed nations like the U.S. and Japan, I do not think that studying new disembodied knowledge is very useful in understanding the recent growth experience of much poorer nations. The binding constraint on the growth of poorer nations is clearly not the location of the technological frontier. If only these nations could successfully employ a greater part of the existing technology they would probably be much

better off. If disembodied knowledge is easily replicated and applied outside of its original sphere then something other than the state of the world's knowledge must explain the large cross-sectional differences between countries. I think papers emphasizing the diffusion of knowledge and the accumulation of human capital are more relevant in understanding the problems of underdevelopment than the disembodied knowledge approach taken by Romer.

Strictly speaking, growth in Romer's model comes from devoting human capital to the research sector that produces new disembodied knowledge. This new knowledge then "spills over" and produces other new knowledge (new designs). As I said above, I think the more relevant issues are the costly accumulation of human capital, the costly diffusion of new technology, or any other impediment (such as disincentives provided by bad government policy) to setting up production using the available technology. At the same time, I think there are aspects of Romer's model that may be suggestive of these effects. For example, Romer wants to think about poor nations getting stuck in a low human capital trap from which they cannot extricate themselves. Alternatively, growth is modeled as a luxury good in the sense that as the economy accumulates human capital a more than proportionate amount of this human capital is devoted to activities (research on new designs in Romer's model) that produce growth. This is accomplished in the model by positing a decreasing returns technology for the use of human capital in producing output but constant returns to human capital in the research sector. Intuitively, this could be interpreted as meaning that when management talent is extremely scarce, the economy cannot spare having such talent diverted from managing the production of output in order to refine new production methods or spend time training others. In order to properly explore these issues, Romer would

really need a model of the costly accumulation of human capital. This is done in Becker-Murphy (1988).

Another important set of considerations determining the relation between the stock of human capital and the rate of growth is introduced by international trade. It is also useful to discuss trade briefly here since Romer loosely discusses the possible role of trade in his framework. While it is clear that integration into the world economy can provide such benefits as easier transfer of modern technology to poorer nations, I would like to point out the possibility that the specialization induced by international trade may actually slow the growth of nations with a low initial stock of human capital. Intuitively, in an open economy, nations with a bigger stock of human capital will end up operating the industries which are more human capital intensive. Moreover, it seems plausible that human capital is accumulated at a faster rate when operating in these more technologically advanced sectors. This means that nations that are initially behind and end up exporting goods such as cash crops, minerals and light manufactures may accumulate human capital and grow at a slower rate than the more advanced nations who concentrate on the more human capital intensive sectors.

Of course, this does not mean that the LDCs do not benefit from innovation and human capital accumulation in the developed countries. Not only do they get to adapt some of the technology developed elsewhere, but they can also purchase much cheaper and better goods with their raw labor due to innovations adopted elsewhere in the world. I think that Romer's discussion of the effects of trade on growth could be made more complete by drawing a distinction between the benefits of technology transfer on the one hand and the effects of unfettered (unprotected) trade in goods on the other. Through the forces of comparative advantage, the latter may lead to less human capital

accumulation in LDCs (especially for nations that would have had access to large domestic markets in the presence of trade barriers).

A final set of points I would like to make concerns the role for policies such as subsidizing capital accumulation and allowing for expensing of R&D in a model like Romer's. The presence of technological spillovers seems to create a clear presumption that the accumulation of A should be subsidized in Romer's setup. The question that arises is: what seems to be the best way to subsidize innovations? Do we just treat R&D favorably or do we want to subsidize capital as well, say with accelerated depreciation or an investment tax credit? Romer appears to say that the current incarnation of his model does not provide a basis for thinking that capital subsidies will affect steady state growth rates. I think the basic reason is the following. The long-run growth rate in his model depends on the amount of human capital devoted to the research sector. A subsidy to capital does not have the effect of causing human capital to be reallocated toward producing new designs because the subsidy also encourages the accumulation of capital used in producing output (with old designs) and this increases the marginal product of human capital in producing output. With the cost of foregone output higher, no more human capital is shifted to the new design sector. In short, a subsidy to capital does not differentially favor new designs over more intensive use of old designs.

I have a couple of comments about this. First, as Romer emphasizes in the current draft, this is only a result about steady state growth rates and does not really speak to the question of whether there are any welfare gains from a capital subsidy. Second, I am not sure I agree with the basic assumption that cheap capital does not differentially favor new technologies over existing technologies. My view is that subsidies to new capital would,

at a minimum, get firms to put down plants employing the latest technology much sooner (and more often) than otherwise. That is, the rate of diffusion would be higher when new capital was subsidized, say through accelerated depreciation. This higher rate of diffusion would also lead to more technological spillovers on others since an unadopted innovation presumably has many fewer spillovers. Any benefits from learning-by-doing would also be stalled until the new technology were adopted on a large scale. In general, I think that this model puts too much emphasis on basic research and too little on learning-by-doing and human capital accumulation on the job. I also think there is a basic presumption that, at least for many LDCs, the potential new technologies to be adopted are more capital intensive than the existing technology. This would also cause a capital subsidy to differentially favor the new technology.

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ENDOGENOUS INNOVATION, INTERNATIONAL TRADE, AND GROWTH

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The recent interest in models of economic development[1] where technological change is endogenous has primarily been based on the assumption of some kind of technological externality, which makes the social return to investment exceed the private return. This is in the tradition of Arrow (1962), who simply postulated that investment raises the efficiency of future vintages of capital goods, in a way that cannot be captured by firms.The effort of Romer (1986b) to provide a microeconomic foundation for external economies in the growth process returns to an even earlier tradition, that of Young (1928), in which increasing returns in the production of intermediate goods leads to de facto external economies in the production of final goods.

While external economy models shed an interesting light on some of the possible reasons for self-sustaining economic growth, they share a common feature that is less than satisfactory. In such models technological change is an accidental byproduct of economic activities undertaken for other purposes. While this sometimes happens, in the real world much technical change is surely the result of deliberate efforts on the part of firms to improve their products and/or processes -- and a key issue of economic policy (perhaps <u>the</u> key issue) is how institutions and taxation affect the incentives for such knowledge generation. One would therefore like to have a set of models in which

[1]Key papers include Lucas (1985); Romer (1986a,b); Kohn and Marion (1987); Shleifer (1986); Murphy, Shleifer, and Vishny (1988); and Helpman (1988).

technological change is not only endogenous but also at least in part deliberate, a result of active efforts at innovation.

Now there already exists a tradition in economics that takes just such an approach to economic growth. This is the line of thought associated with Schumpeter (1942), who placed deliberate technological change by firms at the heart of his economic analysis. In the basic Schumpeterian framework, firms are willing to invest in developing knowledge because this knowledge is at least temporarily appropriable, and thus allows them to establish monopoly positions that yield private returns. In time, new technologies become public knowledge; but in the meantime innovators have developed still newer technologies, creating a new set of temporary monopolies, and the economy rolls on.

Several recent papers adopt a Schumpeterian framework for thinking about growth. Notable examples include Shleifer (1986) and Murphy, Shleifer, and Vishny (1988). There is also a strong tradition of Schumpeterian models of endogenous technological progress in the international trade literature -- perhaps because the analysis of increasing returns in international economics was already well advanced by the time it began to appear in growth theory, and perhaps also because of the traditional emphasis on the role of the "product cycle" in determining patterns of international trade and specialization. In any case, there now exists a small literature arising from the international side in

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which endogenous R&D is the source of technological progress[2].

Oddly, however, while there now exists a reasonably large Schumpeterian growth literature, few of the papers in this literature focus on the issue of growth per se. The papers by Shleifer and by Murphy, Shleifer and Vishny focus primarily on the possibility of multiple equilibria (including dynamic multiple equilibria giving rise to cycles); the international papers focus primarily on the determinants of the pattern of trade, including the product cycle. The purpose of this paper is to back up from these issues, which I regard as properly the second rather than the first step in development of a Schumpeterian paradigm of growth. Instead I try to set out in a minimalist form what I regard as the basic insights that arise from a Schumpeterian approach to the growth process.

The first point is a familiar but often misinterpreted one: in a market economy there is a conflict between static efficiency of resource allocation and growth. The Schumpeterian idea is often misinterpreted as the proposition that monopolies are more innovative than competitive firms, but that is not the point. The point is instead that the incentive for innovation depends on the expectation of the innovator that she will be rewarded with a temporary monopoly. In the context of this model we can show that there is a conflict between static efficiency, which would require

[2]See in particular Feenstra and Judd (1982), Dollar (1986), Jensen and Thursby (forthcoming), Segerstrom, Anant, and Dinopoulos (1987), and Grossman and Helpman (1987).

elimination of monopolies, and the need to provide an incentive for technical change -- and we can show that the static costs are worth paying.

The second point is a less familiar one: a Schumpeterian economy is characterized by important dynamic increasing returns. These increasing returns offer a powerful non-traditional case for the gains to a country from participating in an integrated world economy. Quite aside from the usual gains from trade due to comparative advantage and static economies of scale, a Schumpeterian world is one in which international integration increases the incentives for and the benefits from innovation. On one side, access to a world market makes the temporary monopoly of an innovator more valuable, raising the return to innovation. On the other, when temporary monopolies end and knowledge becomes a public good, each country gains from innovations made elsewhere.

In order to bring these points out in as clear and simple a fashion as possible, I offer here a stripped-down model that makes no pretense at realism. In the real world innovation, the exploitation of temporary monopoly positions, and the diffusion of proprietary knowledge to the public at large are all going on simultaneously, and the future stretches out indefinitely. For most of the paper, I instead assume a world with a finite horizon divided into three neat periods: one during which firms invest in innovation, one in which they reap the rewards of their investment, and one in which their innovations become common property. This formulation brings out the essential principles

very clearly, but an obvious next step must be to develop an infinite-horizon model without such arbitrary asymmetries between periods. The paper concludes with a brief exposition of such a model, focussing only on its steady-state dynamics; the main conclusion of this final exposition is that an integrated economy will not only be more productive than an isolated national economy, but will exhibit a permanently higher growth rate.

The paper is in seven parts. The first part lays out the basic assumptions of the model. The second part derives the equilibrium for a single closed economy. The third part examines the welfare economics of this equilibrium, focussing on the gains to society from allowing innovators to establish temporary monopolies. The fourth part then considers the effects of international integration, and the nature of the gains that such integration brings. The fifth part then asks whether integration through trade or investment is necessary for these gains, or whether the exchange of ideas is enough. The sixth part takes a step toward realism, by describing steady-state growth in an infinite horizon world where innovation, exploitation of monopoly positions, and diffusion of technology are happening at the same time. The paper concludes with a discussion of the results and some ideas for future extensions.

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1. Assumptions of the model[3]

We consider a world that will last three periods. In this world there are L individuals, who all share identical tastes. These tastes can be represented by a two-level utility function. The upper level may be written

$$U = \theta^{-1}[C_1^{\theta} + \delta C_2^{\theta} + \delta^2 C_3^{\theta}] \qquad \delta, \theta < 1 \qquad (1)$$

where C_t is an index of overall consumption in each period. That is, utility is additively separable across periods and there is a

[3]This model is very close in form to the models used in recent work by Shleifer (1986) and Murphy, Shleifer, and Vishny, et al (1988). The main modelling difference is that I assume free entry zero-profit equilibria, where they assume restricted entry that allows some profits to remain. The important difference is however in the kind of questions asked; they are primarily concerned with the possibility of mutiple equilibria, where I am concerned with comparative dynamics.

In all of these models strong assumptions are made about functional forms that are not really necessary for the results. All that is really needed is additive separability of utility among periods, and symmetry among goods within each period. However, given the unrealistic and illustrative nature of the model in any case, it does not seem worth while to take up extra time and space in return for a marginal increase in generality.

constant elasticity of substitution $1/(1-\theta)$ between each pair of periods.

Within each period N goods are produced. The aggregate consumption for each period is defined as

$$C_t = \prod_{i=1}^{N} c_{it}^{1/N} \quad (2) \qquad (2)$$

where c_{it} is an individual's consumption of good i in period t. Within-period tastes are therefore Cobb-Douglas, with all N goods receiving equal expenditure shares.

There is only one primary resource, labor. In each period each individual has an endowment of one unit of labor. The unit labor requirement to produce a good depends on whether or not an investment has been made in improving the technology. If no such investment has been made, the unit labor requirement is 1. Once an investment has been made, the new process reduces the labor required to $\gamma < 1$. That is, if a_{it} is the unit labor requirement for good i in period t, we have

$$a_{it} = 1 \text{ if no innovation} \qquad (3)$$
$$= \gamma < 1 \text{ if an innovation has been made}$$

The economy is assumed to need to go through a rigid sequence of moves. In the first period, labor can be used either to produce goods for current consumption or to invest in innovation, developing improved production technology. We assume that the cost

of an innovation is F units of first-period labor. In the second period, innovators have a monopoly of the technology they have developed -- although, crucially as it turns out, the original unimproved technology is still available to the general public. Finally, in the third period the technology developed in the first period becomes common property.

We have now laid out all the assumptions of our model. Surprisingly, even this rudimentary framework can yield some valuable insights about technological change in a market economy, as we will see once we derive the model's equilibrium.

2. Intertemporal equilibrium

To solve the model we work backwards from the third period to the first.

Suppose, then, that in period 1 the economy had invested nF units of labor to pursue technological improvement in $n < N$ goods. Then in the third period these improved technologies will be common property, so that the economy will consist of n sectors in which the unit labor requirement is γ, N-n sectors in which it is 1. All sectors will be perfectly competitive, and price at average cost.

The key variable we need is the period three consumption of a representative individual, which may be conveniently expressed as

$$C_3 = w_3/P_3 \tag{4}$$

where w is the wage rate expressed in terms of any numeraire, and P_3 the period price index in terms of the same numeraire. In turn, we may define

$$P_3 = \prod_{i=1}^{N} p_{i3}^{1/N} \tag{5}$$

where p_{i3} is the price of good i, and

$$p_{i3} = w \text{ if there has not been an innovation} \tag{6}$$
$$= \gamma w \text{ if there has}$$

implying a consumption index

$$C_3 = (1/\gamma)^{n/N} = \gamma^{-(n/N)} \tag{7}$$

Now back up to period 2. In this period the n improved technologies are still proprietary, allowing the innovators to establish monopoly positions. So we need to examine their monopoly pricing.

Assuming that N is a very large number, the elasticity of demand facing each individual monopolist is approximately unity. Now for a pure monopolist a demand elasticity of 1 would imply an infinite markup. However, these are not pure monopolists. They have a monopoly of the improved technique of production, but the original, less productive technique is still available to others.

Thus the firms cannot raise their price above the cost of production with $a_{i2}=1$; and given the unitary elasticity of demand they will always raise their price up to that point. So the equilibrium is one in which p=w in all sectors -- that is, monopolists with higher efficiency charge the same price as competitive industries with lower efficiency, passing none of their lower costs on to consumers[4].

Per-capita consumption of each good in the second period is the same; it may be expressed as

$$c_{i2} = (1/N)(Y_2/L) \qquad \forall i \tag{8}$$

where Y_2 is second-period income measured in terms of the (common) price of all goods in that period. This income includes both labor income and the monopoly profits of innovators. Note that each innovator gets to collect as a rent the cost savings from original technology on the product she makes, which are equal to a fraction

[4]Nordhaus (1969), in a pioneering analysis of endogenous technical progress, made the useful distinction between "run-of-mill" innovations, in which the innovator does not cut her price, and "drastic" innovations, in which the optimal monopoly price lies below the cost of producing with older techniques. In this model I have set things up so that innovations are all "run-of-the-mill", which greatly simplifies the analysis. The approach was introduced in the seminal paper of Shleifer (1986), and also Segerstrom, Anant, and Dinopoulos (1987).

$(1-\gamma)$ of sales. Thus Y_2 may be calculated as

$$Y_2 = L + (n/N)(1-\gamma)Y_2 \tag{9}$$
$$= L/[1 - (n/N)(1-\gamma)]$$

Since the goods produced in period 2 all have the same price, and since all income must be spent in that period, the per-capita consumption in that period may be simply expressed as

$$C_2 = Y_2/L = [1 - (n/N)(1-\gamma)]^{-1} \tag{10}$$

We now turn to the first period, in which the decision must be made about how much labor to allocate to current production as opposed to innovation. We begin by noting that the price of the aggregate first-period consumption good in terms of labor is 1, since all sectors share the same original technology.

Now consider the incentives for innovation. The developer of an improved production technique gets to have a second-period monopoly that yields rents of

$$R = (1-\gamma)Y_2/N \tag{11}$$

The second-period return per unit of first-period consumption foregone is therefore

$$r = (1-\gamma)Y_2/NF = (1/NF)[L(1-\gamma)]/[1 - (n/N)(1-\gamma)] \tag{12}$$

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The return to innovation, as a function of the volume of innovation, is shown as the curve II in Figure 1. The curve is upward-sloping, as apparent from inspection of (12). The reason is that the more innovation there is, the larger is second-period income, and thus the larger the market for each good.

To close the model we need another relationship between n and r. This may be derived from the demand side. First, we note that first-period consumption per capita may be written

$$C_1 = (L - nF)/L \tag{13}$$

given the unit labor requirement of 1 in all goods. We also note that the marginal utility of consumption in the first and second periods are

$$\partial U/\partial C_1 = C_1^{\theta-1} \tag{14}$$

$$\partial U/\partial C_2 = C_2^{\theta-1}$$

Now r represents the rate at which individuals can trade off period-one consumption for period-two consumption; it must also therefore represent the price of period-one relative to period-two consumption, so that

$$r = (\partial U/\partial C_1)/(\partial U/\partial C_2) = \delta^{-1}(C_1/C_2)^{\theta-1} \tag{15}$$

Substituting from previous equations, we therefore have

$$r = \delta^{-1}\{[L/(L - nF)][1 - (n/N)(1-\gamma)]^{-1}\}^{1-\theta} \qquad (16)$$

Like (12), this relationship has r increasing in n. At n = 0 -- that is, with no resources devoted to innovation -- we have $r = \delta^{-1}$, the rate of return equal to the rate of time preference.

The relationship (16) is illustrated in Figure 1 by the curve CC. As drawn, this curve intersects II in the positive quadrant -- which we will assume to be the case -- and is steeper than II where they intersect. This assumption amounts to saying that the increase in the rate of return required to induce consumers to release more resources to innovation exceeds the increase in the actual rate of return induced by higher innovation. This seems as though it is a kind of stability condition that we will want to assume is satisfied; in any case, a sufficient but not necessary condition for the relative slopes to obey this rule is $\theta < 0$, i.e., the intertemporal elasticity of substitution less than one.

We should note that there is a possibility of multiple equilibria in this kind of model -- this is the lesson of the ingenious papers by Shleifer (1986) and Murphy, Shleifer, and Vishny, (1988). The possibility of multiple equilibria may be seen by considering the example of Figure 2. In that case, the CC curve lies above the II curve at n=0. This means that if nobody is expected to innovate, nobody will find it profitable to innovate

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-- so no innovation is a possible equilibrium, illustrated by point 1. However, the more people that innovate, the larger the per-firm sales in period 2, so there may also be equilibria in which innovation does take place, illustrated by points 2 and 3. Of these, 2 will be unstable under most pseudo-dynamic stories of how equilibrium gets established, so we can think of 1 and 3 as the two possible outcomes. Once we have mutiple equilibria, of course, many stories become possible. For the purposes of this paper, however, I want to assume that equilibrium is unique, so that I can do comparative dynamic exercises.

We also want to assume that $n < N$, that is, that innovation does not take place in all sectors.

3. Welfare economics of monopoly

In the world we have now described, innovation in the first period leads to the establishment of temporary monopolies in the second period. This means that there is deviation from static efficiency of resource allocation. What we need to understand is that this deviation is desirable, in the sense that it is better to allow the establishment of temporary monopolies as a way to induce innovation than to seek static efficiency at the cost of technological progress.

First we need to define the static efficiency loss in period 2. This may be most concisely seen by realizing that goods produced in the second period may be divided into two composite

commodities: the n "improved" goods whose production technology has been improved by innovations, and the N-n "unimproved" goods where this has not happened. Once the innovative effort has been made, the economy faces an ex-post opportunity cost of improved goods in terms of unimproved goods of γ. This is illustrated by the production possibility frontier in Figure 3. Given this PPF, the optimal consumption of the two goods is at point 1. However, the temporary monopolies that control the improved technologies will, as we have seen, charge the same price for improved as unimproved goods, so that the relative price consumers face will be 1 instead of γ. This leads to the inferior consumption basket 2.

If the technology in period 2 were exogenous, then, it would be optimal to deny monopoly power to innovators. However, the technology is of course not exogenous. Without the prospective reward of temporary monopoly, firms would not have the incentive to innovate in the first place. And in fact, we can show that it is unambiguously better to allow the monopoly as the price of innovation than to forbid it.

To see this, we can break the problem into two parts. First, let us ignore period 3, the period in which new technology becomes common knowledge, and focus on the sub-utility in periods 1 and 2. We can then return to period 3 and complete the analysis.

Does the equilibrium with temporary monopoly yield a higher subutility in the first two periods than an equilibrium without? To see that it does, rather than explicitly calculating utility,

we can use a simple revealed preference argument. Each individual has one unit of labor income to sell in each period. Whether there is innovation or not, the price of consumption in terms of labor in each period is unity. Thus each individual can be thought of as having an endowment of 1 unit each of C_1 and C_2, as illustrated by point 1 in Figure 4. If there is no ability to convert innovation into temporary monopoly, then individuals will simply consume their endowment in each period. The slope of the indifference curve passing through 1 is $1/\delta$ at that point.

Now suppose that innovation leading to temporary monopoly is allowed. If the intersection in Figure 1 is in the positive quadrant, that is, if any innovation takes place at all, then the return on innovation is $r > 1/\delta$. The effect is to allow individuals to trade up to a higher level of sub-utility at point 2.

Nor is this the whole welfare gain. In period 3 any innovations become available to the general public and are thus passed on in lower prices. Since the availability of temporary monopoly shifts n from zero to a positive number, and since n enters positively into period-3 consumption (see equation (7)), this represents a further gain.

We see, then, that this model makes the basic Schumpeterian point that monopoly, while distorting the economy at any point in time, may still be socially productive. The ability of innovators to realize a temporary monopoly position as a result of their innovation is a necessary incentive, and the benefits of allowing

this incentive outweigh the costs.

It is assumed in this model that the monopoly conferred by innovation lasts one period. In a more realistic model, the length of time for which an innovator enjoys a monopoly would be an important parameter, and perhaps a policy variable as well. Clearly the optimal length of monopoly represents a tradeoff between the incentive to innovate and the costs of restricting the output of goods whose true marginal cost is less than their price. Nordhaus (196?), working in a partial equilibrium setting, used this tradeoff to develop an analysis of optimal patent length. Presumably a more complex general equilibrium model would allow a similar analysis.

4. International integration

We now turn to some less familiar territory, examining the implications of this model for the effects of international integration. Suppose that a country, instead of being an isolated economy, is part of a larger world economy in which residents of other countries are also able to innovate. How does this change the results?

The simplest case is where all countries have the same tastes, original technology, and costs of innovation -- and also where the temporary monopoly established by an innovator extends to the international market as well as the domestic market. In this case residents of a country are in effect simply part of a

larger economy than they would be otherwise, and the effects of international integration are the same as the effects of a larger labor force.

To see what these effects are, we examine the two relationships (12) and (16). First, consider (12): how does the II curve in Figure 1 shift when L is increased? It is immediately obvious that r will be higher for any given n, so the II curve shifts up. The economic intuition for this is that a larger market means more rents per innovation for any given number of innovations; thus the upward shift in II in effect represents the inventives for innovation resulting from increased demand.

Turning to (16), we note that for any given n an increase in L reduces the implied r. That is, the larger the labor force the lower the required rate of return for any given number of innovations. The reason for this is that since there is a fixed cost per innovation, when a given number of innovations are undertaken by a larger economy they require a smaller fraction of first-period resources. This amounts to a kind of supply-side reason why a larger economy will generate more technological progress.

Putting these results together, we have Figure 5: The upward shift in II and the downward shift in CC imply a shift in the equilibrium from point 1 to point 2. An integrated world economy will generate more innovations, and yield a higher rate of return on these innovations, than any of the national economies that make up this world would do on their own.

Which country does the innovating, and which country produces the goods with improved technology? The answer is that in this model it is indeterminate -- and it does not matter. Given the assumptions about identical initial technologies and identical ability to improve technology through innovation, we cannot describe the precise pattern of international innovation and trade. A natural extension would be to introduce some kind of comparative advantage in innovation and/or production of new goods; but this will be left for future research.

An interesting question is whether the integrated world economy will not only generate more innovation than independent national economies, but will also devote a higher share of its resources to innovation than the national economies. This amounts to asking whether n will increase more or less than proportionately to L. Not too surprisingly, the answer is ambiguous, because both income and subsititution effects are involved. The higher return on innovation both raises wealth, tending to raise first period consumption per capita, and encourages substitution, encouraging saving. A sufficient but not necessary condition for an increase in the share of resources going to innovation is $\theta > 0$, i.e., a more than unity intertemporal elasticity of substitution.

In any case, the benefits of being part of a larger world do not depend on there being an increase in the share of resources devoted to innovation. We can use the same tricks to demonstrate gains from integration that we used to demonstrate gains from

allowing innovators to establish temporary monopolies. First, we put the third period on one side, and consider sub-utility in the first two periods. The situation is illustrated in Figure 6. In an autarchic equilibrium the representative individual would have an endowment at point 1, and would consume at point 2. The effect of making this economy part of a larger world is to raise the rate of return; this rotates the budget line clockwise, allowing the individual to achieve a higher subutility at point 3. Thus utility in the first two periods unambiguously rises. Since the number of goods with improved technology is increased, consumption per capita in the third period also unambiguously rises, so that there is a definite gain from international integration.

We see, then, that it is better to be part of a world economy than to be isolated, even if all countries are alike and there are no static economies of scale. The reason is that innovation is in this model is a process that involves both private increasing returns in a dynamic sense, and an external economy -- the spillover of knowledge when technologies become part of the public domain -- that amounts to a further degree of increasing returns at the aggregate level.

However, we need to be careful before making this argument a case for free international trade and investment. The exercise carried out in this part of the paper assumed that being part of a world economy is an all-or-nothing affair, in which a country is either completely integrated or is shut off not only from selling

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its goods but from learning about innovations elsewhere. A natural question is whether such full integration is better or worse than a world in which countries can learn from each other without necessarily selling freely to one another.

5. Are trade and investment necessary?

A key question for assessing the effects of international integration is the extent to which trade and investment flows are associated with flows of knowledge. In practice, no doubt, much knowledge crosses borders only by being embodied in goods and services or by being transferred by multinational firms. However, it is possible to analyze a world in which non-proprietary knowledge diffuses internationally even without trade, simply through countries reading each others' journals and watching each others' television shows. Is such a world necessarily worse off economically than one with trade and/or investment?

To implement this question in our model, suppose that in period 2 innovators cannot establish property rights over their technologies if they sell goods abroad, and that they therefore sell only to the domestic market. In period 3, however, improved technology becomes available to foreigners and domestic residents alike.

It is immediately apparent that the equilibrium in the first two periods is the same as in the case of pure autarky. Thus the subutility in these periods is lower than it would be if

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innovators were able either to export or to produce abroad.

However, it is not certain that consumption in the third period will be lower than with full integration. Two issues arise: How large will be the resources that are devoted to innovation, and how efficiently will these resources be used?

We have already seen that the effect of integration on the share of resources devoted to innovation is ambiguous. This implies that a world economy that does not allow innovators to capture rents in foreign markets might actually devote larger resource to innovation than one that does. As we noted, an intertemporal elasticity of substitution greater than one is sufficient to rule out this case, but it is not impossible.

Suppose that the imperfectly integrated world actually does spend more on innovation than the perfectly integrated one. Does this imply higher third-period consumption? Not necessarily. The reason is the following: as long as the world constitutes an integrated market, there will be no duplication of innovative effort. Remove this integration, and there may well be some overlap, with resources in two or more countries being devoted to the same innovation. This may mean that the number of goods with improved technologies will therefore be less than the number of

innovative efforts made[5].

Putting these arguments together, there would seem to be a presumption but not a certainty that it is better to have an integrated marketplace in innovative industries, not simply an efficient international exchange of information. However, this is only a presumption, not a certainty -- in the second-best world of Schumpeterian competition, markets don't always do the right thing.

6. Long term growth

The analysis in the paper up until now has been simplified by the assumptions that there is a finite horizon and a rgid sequence of periods in which innovations are made, become temporary monopolies, and then become common knowledge. The next step toward realism is to allow an economy with no end in sight, where our three stages are all taking place simultaneously. In this section I briefly examine such an economy.

Suppose, then, that individuals live forever and maximize a discounted function of future subutilities of the form

[5]Realistically, innovation is not an arbitrary choice from a number of equally attractive areas. Instead, there are some areas where given the current state of knowledge an innovative effort looks most promising. This would seem to imply that in practice there will be heavy duplication of effort if there is no market incentive to avoid it.

$$U = \theta^{-1} \sum_{t=0}^{\infty} C_t^{\theta} \delta^t \tag{17}$$

where C_t is defined the same way as in (2). The technology of innovation and growth is also assumed to be the same: an innovation in any good requires F units of labor in this period, and lowers the unit labor requirement to γ its former level in all subsequent periods.

For this paper I restrict analysis to the consideration of steady states. Shleifer (1986), from whose work this model is almost completely derived, has shown that it is possible that non-steady state paths may occur, and indeed that there may be a multiplicity of cyclical equilibria. I simply ignore these possibilities, to focus on the case of steady growth.

The defining feature of a steady state is that there are n sectors in which innovation takes place every period. Thus uach period n innovators invest F units of labor; n innovators from the previous period are reaping their reward of temporary monopoly; and n innovations from the period before that become common knowledge. Some of these may be the same goods -- that is, a temporary monopoly may have been established in a good where the innovation from two periods back has just become comon knowledge, or someone may now be making an innovation in a good where somoeone else currently has a monopoly. However, given the Cobb-Douglas assumption on demand, plus the fact that prices are connstrained by the cost of producing using the most recent

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common-knowledge technology, this doesn't matter. All that we need to know is the number n, not which goods are playing which roles.

The key point is that in a constant-n economy, both consumption and the real wage will grow at a steady rate: the ratio of next period's real wage and consumption to today's is $\gamma^{-n/N}$ (see equation (7)). Clearly, the larger is n, the higher the economy's rate of growth.

To analyze the steady state, we follow the same procedure as in the finite-horizon model: we look for two schedules that simultaneously determine the rate of return and the rate of innovation. One such relationship comes from the consumer side. We note, as in equation (15), that

$$r = (\partial U/\partial C_t)/(\partial U/\partial C_{t+1}) = \delta^{-1}(C_t/C_{t+1})^{\theta-1} \tag{18}$$

where t is any period. It follows that

$$r = \delta^{-1}\gamma^{-(n/N)(1-\theta)} \tag{19}$$

which is illustrated as CC in Figure 7. The intuition behind the upward slope is straightforward: the higher the rate of innnovation, the higher is tomorrow's consumption realtive to today's, and thus the higher the marginal utility of present relative to future consumption.

The second schedule comes from the return to investors. To derive this, we first note that in each period the income of L-nF

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units of labor is spent on consumption goods (the rest being spent on innovation), so that the sales of each good are (L-nF)/N times the wage rate. If the good is sold by a temporary monopolist, she collects a fraction $(1-\gamma)$ of this, so that her return is $(1-\gamma)(L-nF)/N$ units of labor. However, because of the rising real wage rate, labor next period is more valuable than labor this period; so the real rate of return to innovation is

$$r = F^{-1}N^{-1}(L-nF)\gamma^{-n/N} \tag{20}$$

This relationship may be either upward- or downward-sloping. In Figure 7 it is show as II, upward-sloping but less steep than CC. It is apparent from comparison of (19) and (20) that a sufficient but not necessary condition for II to cut CC from above is $\theta < 0$, i.e., an intertemporal elasticity of substitution less than one.

The intersection of II and CC determines the rate of return and the rate of innovation. It is now straightforward to examine in this context the effect of the size of the economy. From (20), an increase in the labor force will shift II up, as illustrated by the shift to I'I' in Figure 7. Meanwhile, CC will not be affected (a difference from the mechanics of the finite-horizon case). Thus the equilibrium will shift from 1 to 2: the rate of innovation, and thus the rate of growth, will be larger in a larger economy.

As before, we can interpret this as a benefit from international integration. What we learn from this extension is

that the gains from being part of an integrated world economy may be more than a one-shot increase in efficiency: in this context they imply a permanently higher rate of growth than each national economy would achieve on its own.

7. Conclusions

This paper has set out just about the simplest possible model of technological progress in a world in which innovators are induced to do their job because they hope to reap the rewards of temporary monopoly. The paper demonstrates, convincingly I hope, two main points: that the static market distortion of monopoly can play a socially useful role, and that endogenous technological development increases the gains from international integration.

There are several direction in which it would be useful to extend this research. The single-economy model would be more attractive if there were room for investment in physical capital as well as knowledge; in the current framework, acquisition of a temporary monopoly is the only form of investment allowed, which is an extreme case. The open -economy model would gain richness if countries were to be allowed to differ, so that comparative advantage would pin down more of the pattern of innovation and trade. However, it is unlikely that either of these extensions would change the basic message very much.

The real problem with this approach, as with the other work in the new growth theory, is going to be one of attaching any

empirical substance to these ideas. The new growth theory is currently in a state very similar to that of the new trade theory, with its emphasis on increasing returns and imperfect competition, about six years ago. At that point the new ideas had opened up an exciting new set of concepts, offering a rigorous language for talking about issues that had previously been poorly articulated and ignored by much of the profession. However, once the language and concepts were in place, the next question became, "How important are these effects? How much difference do they make for policy?" No good answer has yet been provided in the international area, and this has put something of a damper on further work in the area. The same will happen in the near future in the growth area; so the priority is really not how to construct cleverer models, but how to build a bridge to reality.

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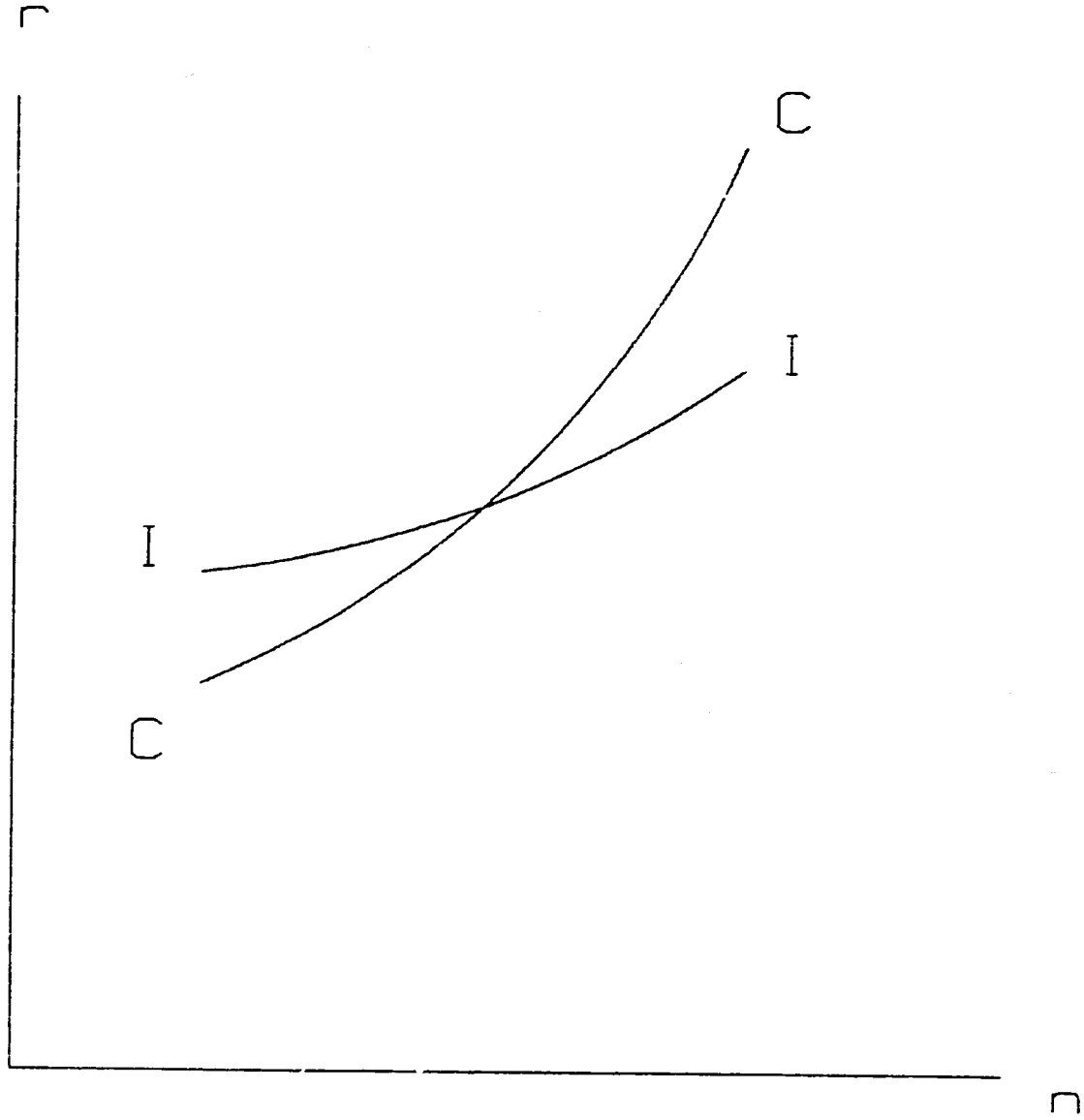

FIGURE 1

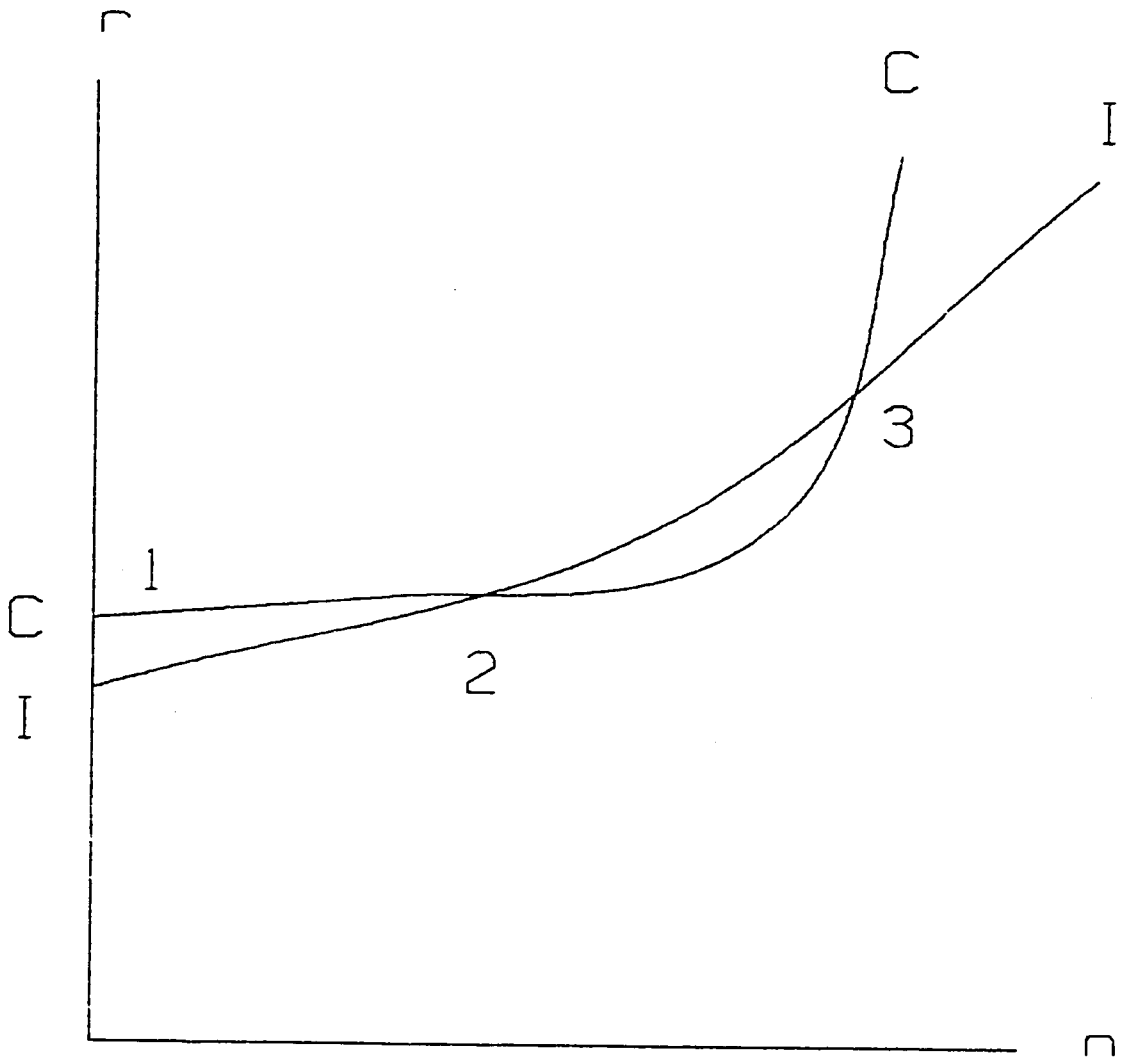

FIGURE 2

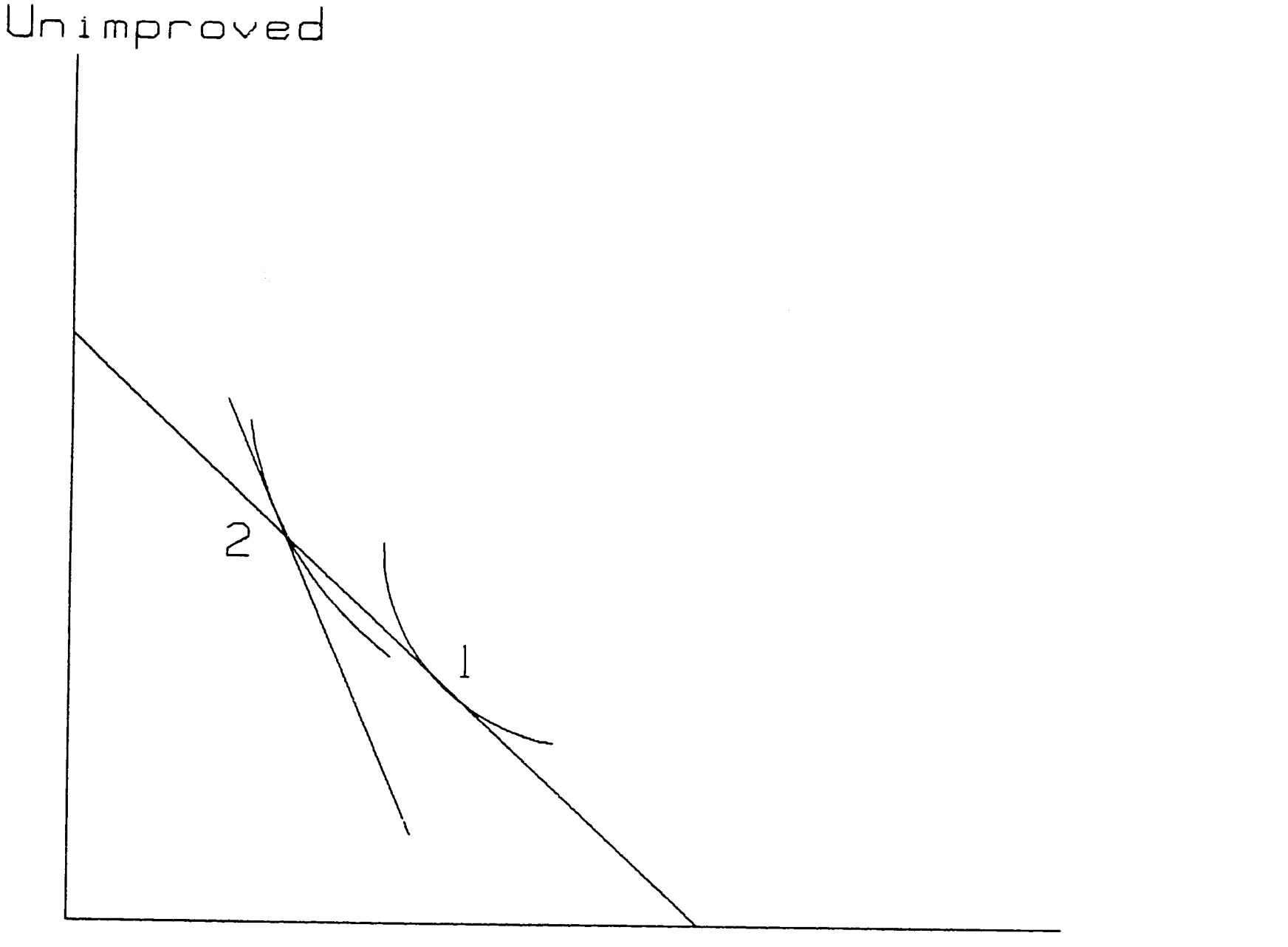

FIGURE 3

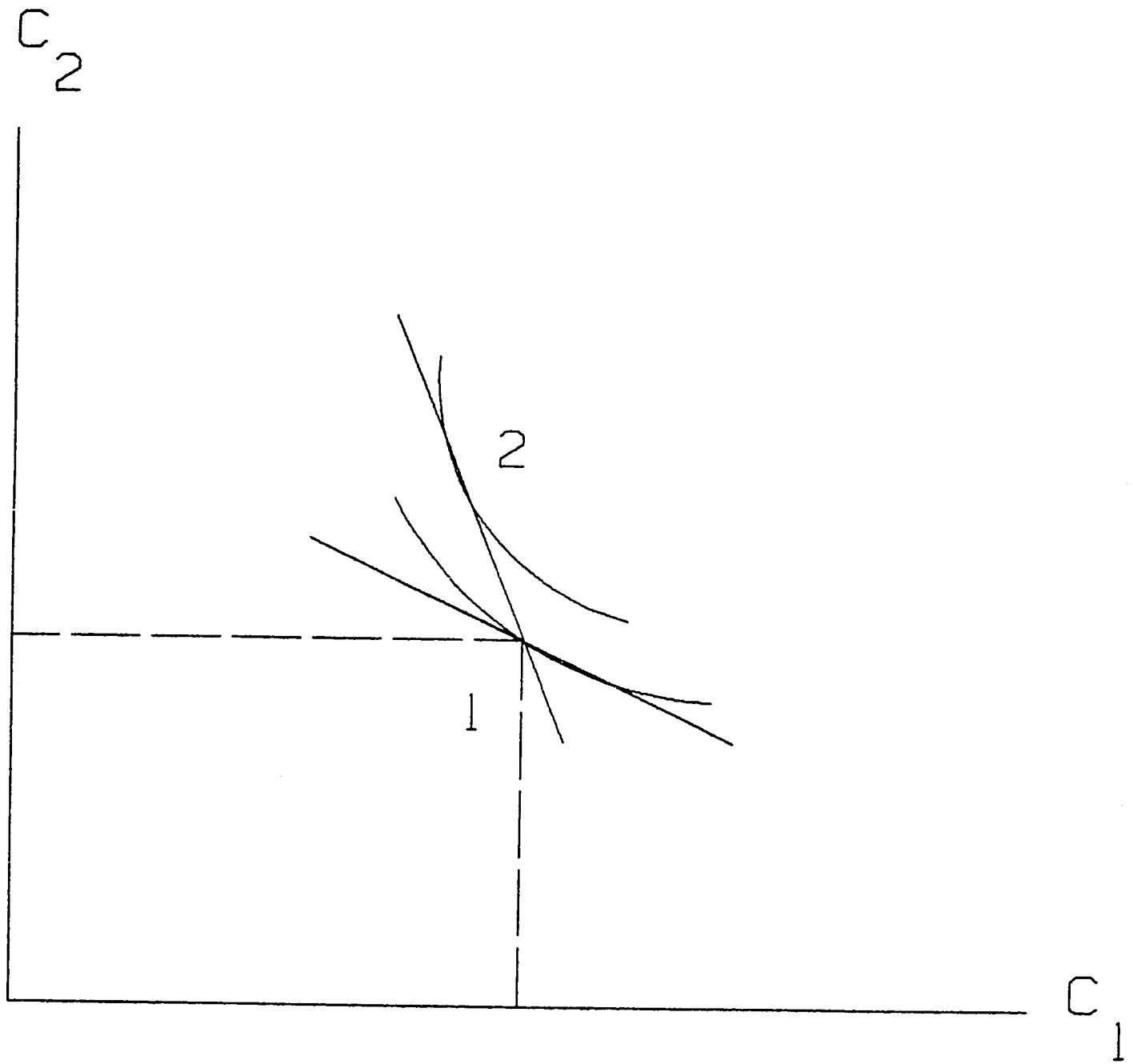

FIGURE 4

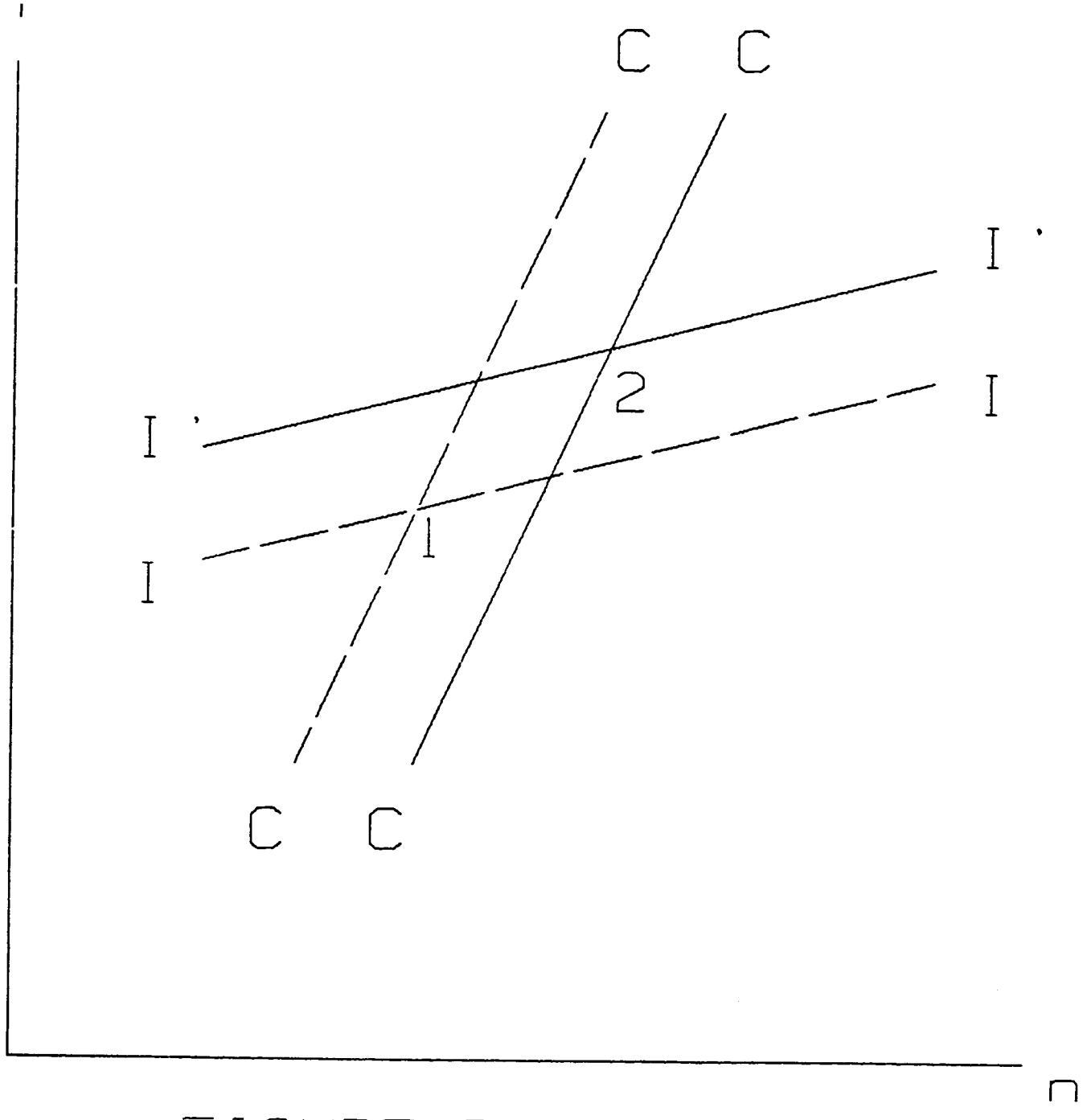

FIGURE 5

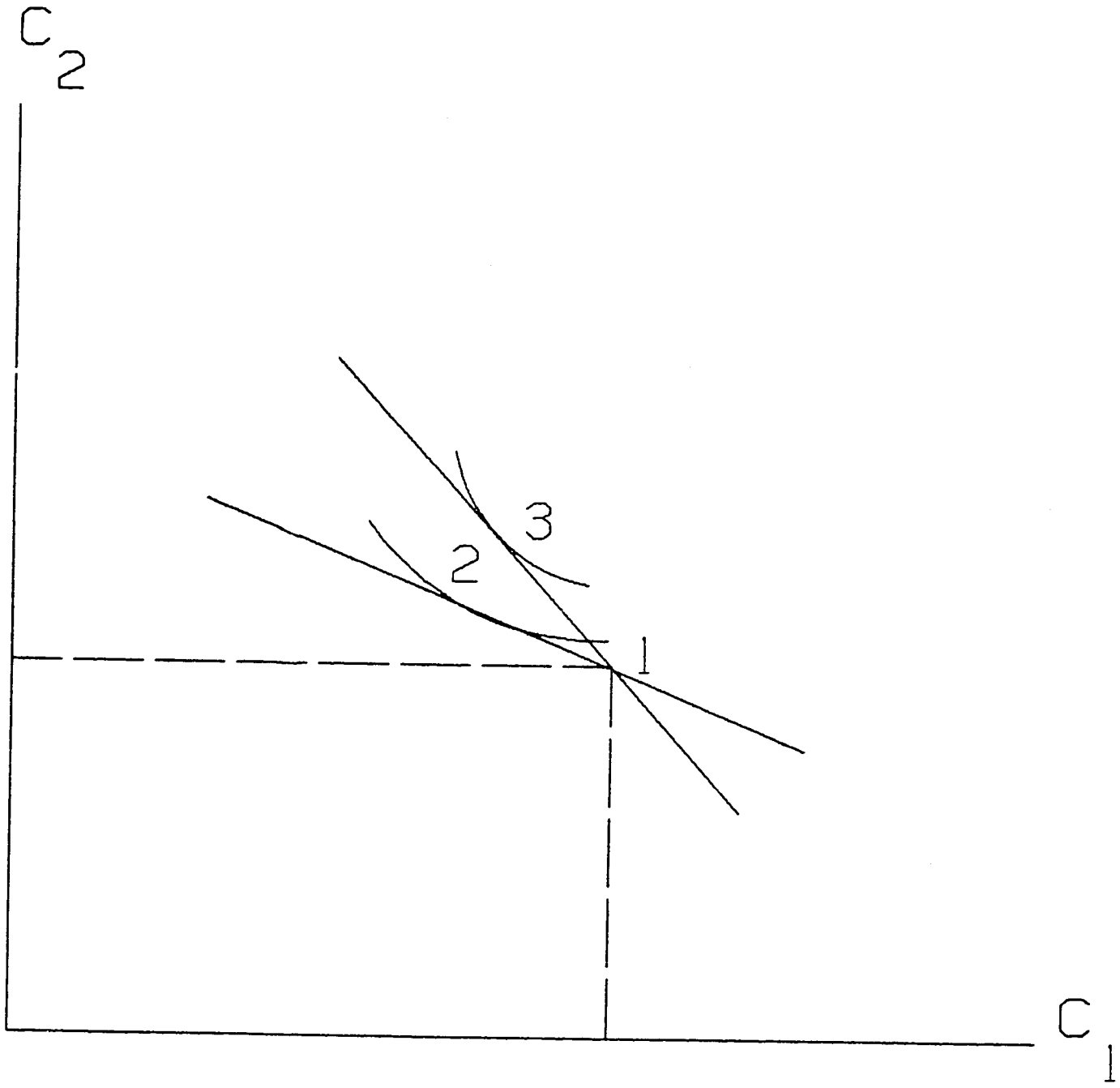

FIGURE 6

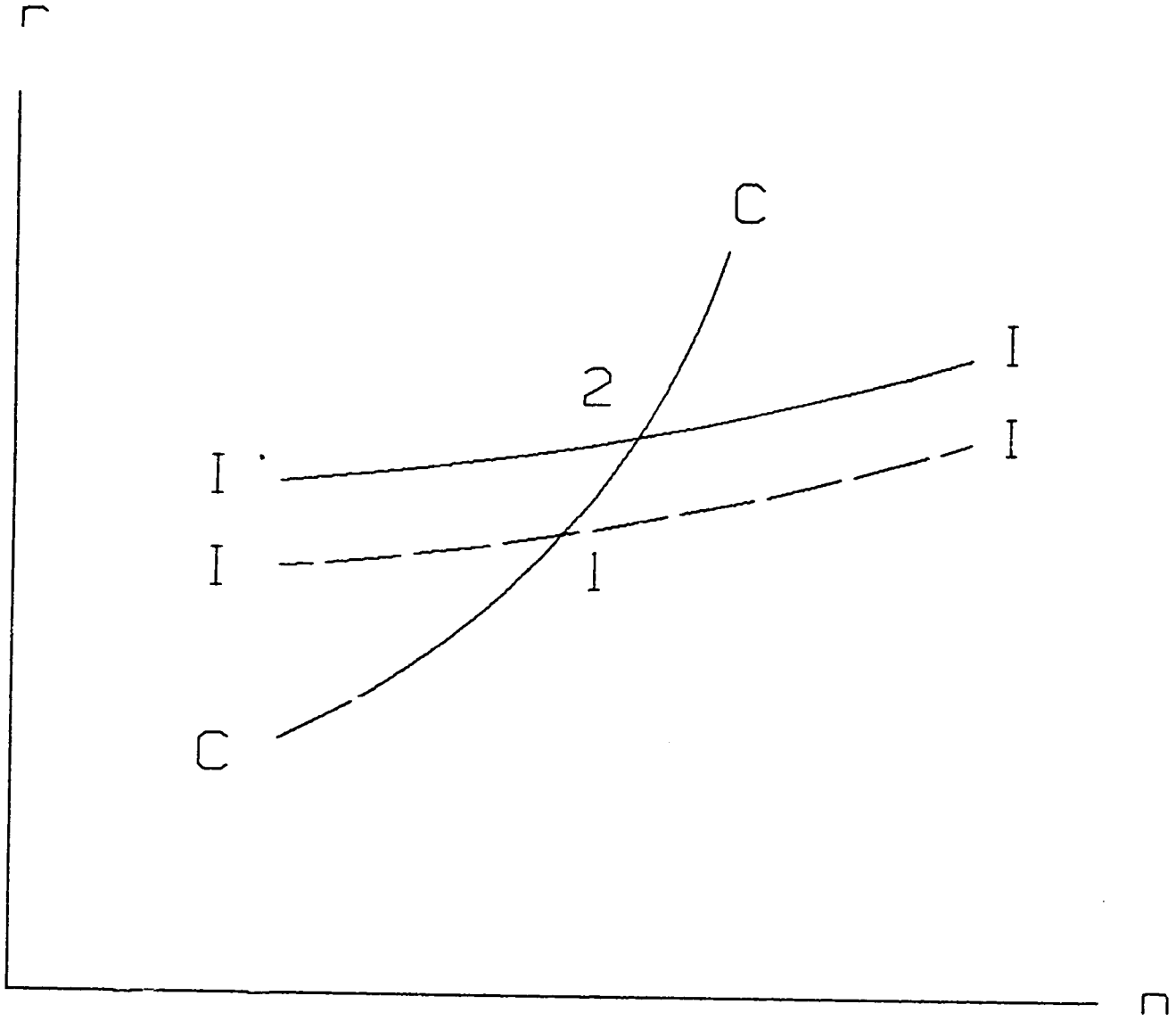

FIGURE 7

Discussion of "Endogenous Innovation, International Trade, and Growth" by Paul R. Krugman

by

Gene M. Grossman
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Surely the most important issue confronting international trade economists concerns the relationship between trade policy and long-run growth. Yet remarkably, trade theory has until now been totally silent on this central question, concentrating instead on issues of static allocative efficiency. Recent advances in the economics of research and development and in the construction of "endogenous-growth" models based on acquisition of knowledge and increasing returns to scale hold out the hope that, at long last, this gap in our understanding can be redressed, and that we will soon be able to say something systematic about the long-run, dynamic effects of alternative trade strategies and policies. Paul Krugman's interesting paper is a first step in this direction, exploring as it does the implications of an integrated world economy for Schumpeterian innovation.

Krugman identifies three channels through which international integration can contribute to the accumulation of knowledge and thence to the rate of growth. First, to the extent that research expenses are largely fixed costs independent of the scale of final output, a world market allows these costs to be amortized over a larger production base, thereby reducing average costs. Second, since profits vary positively with the size of the market ceterus paribus, if integration does not imply any greater competition, as is the case in Krugman's model, then the resultant increase in profit opportunities from integration will augment the incentive to conduct R&D. (Of course, integration can have the opposite effect on the incentive to innovate if the

introduction of foreign trade means that a given product must compete with closer substitutes, so that the return from product improvement in the form of monopoly profits is reduced.) Finally, global integration opens the possibility for international diffusion of ideas and know-how, and thus greater spillovers from a given expenditure of resources on knowledge creation.

But Krugman leaves unexplored a number of important issues concerning the relationship between trade opportunities and trade policy on the one hand, and the incentives to conduct R&D and the uses to which the resultant knowledge are put on the other. In particular, Krugman limits his analysis to comparison of a fully integrated equilibrium to equilibria with symmetric, bilateral departures from complete integration. What he does not consider at all is the incentives that a single country might have to depart unilaterally from free trade in goods, capital, and ideas in a world in which comparative advantage is created and production technologies are endogenous.

The effects of unilateral departures from full integration are simple, but I think misleading, in Krugman's model. Consider for example the possibility that one country might refuse to protect the intellectual property rights of foreign firms. This, of course, is a major issue of contention in the current trading environment and a topic of negotiation at the ongoing GATT talks in Uruguay. In Krugman's model, the positive effects of such a policy measure are drastic but the normative effects are nil. The country that fails to respect the patents granted by its trade partner will come to perform all product improvement in the first period, while foreign firms will concentrate entirely on production of old goods. But since the original pattern of specialization is indeterminate and immaterial under Krugman's assumptions

about identical technological and identical abilities to improve technology through innovation, the change in the pattern of international trade and innovation induced by this unilateral action of one of the country's will, in most circumstances, have no real effects.[1] And since Krugman assumes that free entry eliminates excess profits, the altered pattern of specialization also has no effect on the world distribution of income.

But failure to protect foreign intellectual property can have real effects in a variety of contexts. If, for example, the two countries exhibited comparative advantage in innovation and/or the production of new goods, then the change in the pattern of specialization would have implications for the level of innovative activity and the world distribution of income. As an extreme but not entirely unrealistic case, suppose that one country (or group of countries) was unable to conduct any research at all. Then this country might well benefit from appropriating the knowledge generated abroad, thereby augmenting its static consumer surplus and turning the terms of trade in its favor. Absent any retaliation, it might gain even though such a policy would mean that less knowledge is created in the long run.[2] Even without any comparative advantage, a country might benefit from a policy that shifts innovative activities to within its borders if domestic residents hold a majority interest in local firms and restricted entry implies

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[1]If the labor force in the country that does not protect foreign intellectual property is not large enough to conduct all of the innovation called for in the integrated equilibrium, then this country will completely specialize in innovation, the foreign country will conduct no R&D, and the aggregate number of improvements in the world economy will fall. Such effects are unambiguously harmful in the current context.

[2]The incentives facing a non-innovating country to protect intellectual property created by residents of its trade partners are explored in Chin and Grossman (1988).

extra-normal returns to research investment, or if the extent of local technological externalities exceeds that of cross-border spillovers.

Consider next the implications of unilateral trade policy in Krugman's model. A country that erected barriers to imports of new-and-improved products would again capture all of the innovative activity here. The reason is that innovating firms in the foreign (un-protected) country would find themselves at a comparative disadvantage in conducting R&D inasmuch as their return on export sales would be reduced by the amount of any tariff or by any sales lost sales to a quota. Home country firms, facing no such impediments to trade and being equally proficient in innovation and perfectly free to enter, would come to specialize in thi. activity. But again, this policy-induced re-structuring of the pattern of specialization and trade would have no real consequences under the symmetry assumptions adopted here. If, however, we were to introduce into the model considerations that give rise to comparative advantage and a determinate pattern of trade, and/or the possibility that innovating firms could earn super-normal profits, then beggar-thy-neighbor trade policies that served to capture dynamic industries might enhance the national interest. And unlike the analogous proposition from the literature on the static, profit-shifting effects of trade policy under oligopoly,[3] this advantage might be realized as an augmented rate of growth due to increased innovative activity (with reduced rates of growth abroad). As Krugman himself has argued in other contexts (see, for example, Krugman (1987)), in the second-best world of imperfect competition, knowledge-based externalities and imperfect international policy coordination, there is little reason to believe that free trade and full international integration

[3]See, for example, Spencer and Brander (1983).

best serves the selfish interests of individual countries, or that it is the likely outcome of a non-cooperative policy-setting process.

Turning to more general issues, I think that one of the major challenges facing trade theorists today is to explain the stylized fact that the outward-oriented or export-promoting less developed countries have performed so much better (in terms of aggregate growth in the post-war period) than the inward-oriented or import-substituting countries.[4] What is the mechanism by which a country's trade regime affects its long-run performance? And what policy approach is more conducive to rapid growth, one that provides neutral trade incentives, or one that involves active promotion of specific exports activities?[5] Part of the answer to these questions surely lies in an understanding of the different incentives that exist for technological improvement under alternative trading strategies.

Even though the less developed countries generally are not engaged in pushing back the frontiers of technical knowledge, nonetheless much growth in these countries can be attributed to increases in factor productivity. This is because, in contrast to the simple first-pass assumption of the Krugman model, the acquisition and assimilation of knowledge already available in the world at large seems not to be costless and automatic even after patent protection has expired, but rather it requires investment in learning of a sort that is not unlike that needed to develop the technology in the first place. Investment may take the form of small-scale research, or trial-and-

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[4]This observation is documented in Bhagwati (1978), Krueger (1978), and elsewhere.

[5]Bhagwati (1978) and Krueger (1978) have argued that export promotion has in practice meant a neutral policy environment with no bias for or against exports, whereas Pack and Westphal (1986) claim that active promotion of infant industries lies behind the superior performance of the Asian NIC's.

error production, or it may simply be a concomitant of accumulated experience in producing. In any event, the successful developing countries have been those that have been able to import technologies developed in the North, adapt them to local conditions, and ultimately become competitive in production with the innovating foreign firms in the developed world. Economic incentives must certainly play an important role in this process.

Those interested in trade policy for the developed countries face a not dissimilar set of concerns. To what extent is the Japanese manufacturing "miracle" attributable to its trade and industrial strategy, which often entails infant-industry protection during an initial learning phase, followed by relatively neutral incentives once international competitiveness has been achieved? What are the implications for the long-run rates of growth in Japan's trading partners of failing to respond to such policies with innovation-promoting policies of their own and also failing to convince the Japanese to desist from such beggar-thy-neighbor strategies? Is should be possible to address these types of issues using the tools and approaches of the "new growth theory", suitably extended to incorporate an integrated world economy with international trade in goods and ideas.

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Comment on Krugman's "Endogenous Innovation, International Trade, and Growth"

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Paul Krugman addresses a very interesting question: is free international trade conducive to innovation? His answer is yes, and the reason is a market size effect. If an innovator enjoys a temporary monopoly, then international trade increases the size of his market during this period of temporary monopoly, and therefore the innovator's profits from selling in a larger market rise. Because international trade raises these temporary profits, it increases the incentive to devote resources to innovation. This, in brief, is Krugman's argument for international trade as a stimulus to innonvation.

Let me begin with a historical note on the market size argument in the discussions of innovation. Although Krugman gives credit for this argument to Schumpeter, there is not much emphasis on market size in Schumpeter's writings. Schumpeter had the notion that entrepreneurs create markets where there were none before, as opposed to being attracted to already large markets. The economist who stressed the importance of market size as a stimulus to innovation is Jacob Schmookler, who in his 1962 congressional testimony and his 1966 book presented considerable evidence that innovations are concentrated in markets where demand is already very large. For example, there was considerable innovation in the railroad industry at the time when this industry was already mature and booming. Krugman's model then in its spirit is much closer to Schmookler's conception of the determinants of innovation than to Schumpeter's.

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Krugman of course goes considerably further and presents a model in which the pace of innovation also determines the level of national income, and therefore the size of the market. The general equilibrium features of the model, however, are not essential, although they make Krugman's specification extremely neat and attractive. Because the paper presents the model so clearly, I will avoid reviewing it and will instead discuss some of the additional issues that the paper raises and that have not been addressed.

The substantive issue raised by the paper is the following: does international trade really encourage innovation? Krugman's effect is probably very important in some markets. For example, an airplane maker will probably invest more in developing new technology when he has access to the world market rather than just the domestic market. The same is probably true for pharmaceutical companies when it comes to investment in developing new drugs. The distinguishing feature of these examples is that innovation gives the firm making it a significant lead time, because imitation is costly and takes a long time, because there are few potential imitators, and because there is considerable patent protection in the market.

But it is important to remember that although international trade means larger markets, it also can mean faster and more damaging imitation. Krugman assumes a fixed imitation lag, but, in practice, it might well be the case that imitation is faster when the foreign competitors have the innovator's market to sell into. For example, Korean and Taiwanese imitators' ability to sell in the US probably damages US computer companies more than their own ability to sell in the Korean and Taiwanese markets. If trade opens the home market to potential imitators, it can accelerate the incentives to imitate and the pace of imitation, and as a result reduce the period of temporary monopoly from innovation. To the extent that opening up trade has this

effect, it can reduce rather than raise the incentive to innovate.

A related point is that imitation can be a lot more damaging when it comes from trade partners with much lower labor costs than those prevailing in the innovator's home country. Take the case of a US innovator, and compare what happens if he is imitated with a delay by a US company or alternatively by a Far Eastern producer. If the imitator is another US company, that faces high labor costs, the imitation might not be very damaging, particularly if the innovator can keep a technological lead thanks to learning by doing or additional innovation. The effect of such imitation would be to reduce the price of the product, but to still allow the innovator to earn some profits. If on the other hand the imitator is a much lower cost producer, he can really cut the price and eliminate any profit opportunity for the US innovator, even if the latter has some technological lead. As a result, foreign imitation can reduce profits much more than domestic imitation, and therefore reduce the incentive to innovate to a greater extent. This is another reason why international trade can be damaging to innovation.

A final reason why opening up trade can make imitation more aggressive and in this way hinder innovation is the foreign imitators' disrespect for patent laws. If the innovator has temporary protection of his monopoly from domestic imitators by patent laws, but does not have such protection from foreign imitators, than of course trade reduces the value of his patent, and therefore his incentive to innovate.

One can respond to these arguments by noting that in some cases competition and aggressive imitation foster innovation, since they force the innovator to always try to stay ahead of the competition. This is Schumpeter's old "quiet life of the monopolist" argument that suggests that

monopoly need not necessarily be conducive to innovation. This argument doubtless has some validity, but one should note that it is almost opposite of Krugman's argument. If opening up trade raises the size of the market and so fattens up the innovator, it might reduce his incentive to strive for further profits, and so inhibit his drive for further innovation.

In addition to the problem of more aggressive imitation, there is a second, more conventional argument why opening up trade can reduce the incentive to innovate. This is essentially the standard patent race argument in which more than one competitor invest in R & D in hopes of making the same innovation first. When a potential innovator realizes that other firms are involved in the race to make the discovery, his incentive to invest might fall. The reason is that the firm making the R & D investment realizes that other firms might make the discovery first, and therefore the expected return from R & D declines. In this case, potential discovery by a firm in another country can limit the home firm's incentive to innovate, and even delay the time at which the innovation is made in the world.

Even if the effect of competition from a potential innovator in another country is to raise the home firm's investment in R & D, it is not clear that such increase in resources devoted to innovation is socially desirable. The reason is that there is now duplication of R & D efforts, which from the point of view of the world as a whole is a waste. We see then, that integration of world markets can reduce innovative effort because of R & D competition, and even if it raises such effort, world welfare might fall.

The upshot of these comments is not to deny that Krugman has a very interesting model of the effects of world trade on innovation, which he most certainly does. Rather, my point is that the effects of world trade on innovation might be extremely complicated, and not easily aggregated into a

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simple bottom line. Professor Krugman's paper serves the important function of bringing the issue of the effecs of trade of innovation to our attention. His work will undoubtedly stimulate considerable future research.

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PUBLIC POLICY AND ECONOMIC GROWTH:
Developing Neoclassical Implications

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Sergio Rebelo**

September 1988

This paper is a substantially revised version of one prepared for the conference on "The Problem of Development" held at the State University of New York at Buffalo in May 1988. We have benefited from comments by Stanley Fischer and Arnold Harberger—who discussed the paper at the Buffalo conference—as well as by Kenneth Judd, who discussed the paper at the Summer Econometric Society meetings.

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Economists have long suspected that there is a link between national economic policies and the long term rates of growth of countries. For example, Schultz (1981) suggests that many public policies contain disincentives for growth, in that they act to reduce the rewards to accumulation of a comprehensive concept of capital that contains human as well as tangible resources. In this paper, we show that a basic Schultzian model—constructed following leads provided by Uzawa (1965), Lucas (1988b), and Rebelo (1987)—can yield a wide disparity of growth rates in response to modest variations in taxation. Thus, in our analysis, changes in public policy can potentially explain the emergence of periods of secular stagnation or high economic growth.

The specific model that we construct is part of a larger program of research into models of endogenous economic growth, i.e., models in which sustained positive average rates of growth in percapita income arise in the absence of exogenous sources of productivity increase. Generally, these new models depart from the basic neoclassical model of Solow (1956), Cass (1965) and Koopmans (1965) by altering intertemporal technology in ways that make sustained growth feasible in the absence of time dependent elements in technology. The specific model that we study is an important class that originates in Uzawa (1965) and retains many of the key properties of the basic neoclassical model: (i) asymptotic growth occurs at a constant rate; and (ii) competitive and optimal allocations coincide in the absence of public interventions. The crucial attributes of the class—as developed in Rebelo (1987)—is that there are (i) constant returns to scale; and (ii) that all factors necessary for economic growth can be reproduced and accumulated. Recent work indicates that this class of models is very large, including

structures with many capital stocks in the growth "core" and with nonreproducible factors outside the growth "core" (Rebelo (1987)); or with steady states that are only asymptotically obtained (Jones and Manuelli (1988)). An essential attribute of these models is that labor be viewed as reproducible, i.e., as human capital in the sense of Schultz (1961) and Becker (1964).[1]

In addition to its main conclusion, our investigation is notable in two other ways. First, in examining the potential relation between public policy and long term growth, we require that the parameters of the model economy—governing aspects of preferences and production technology—are restricted to accord with existing microeconomic and macroeconomic evidence, a methodology that has proven to provide a powerful organizing tool in other areas of research in aggregate economics.[2] Second, we apply our methodology to versions of the basic neoclassical model, which has served as the workhorse of public finance theory for the last several decades. We find

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[1]An alternative class of endogenous growth models stemming from Romer (1986) stresses social increasing returns to capital formation in the core of capital stocks necessary for economic growth. Since models constructed along these lines generally also feature productive externalities—to reconcile existence of competitive equilibrium with increasing social returns—one need not require that nonreproducible factors are unimportant. Further, these alternative models generally differ from the class studied here in that: (i) growth rates accelerate over time (due to increasing returns); and (ii) policies that intervene in competitive markets to promote growth are socially desirable.

[2]Lucas (1980) provides cogent arguments for combining aggregate and microeconomic evidence to restrict dynamic macroeconomic models of business fluctuations. Other applications of this strategy include Mehra and Prescott's (1985)) work on asset pricing and recent work on real business cycles as surveyed by King, Plosser and Rebelo (1988a,b).

that neoclassical models have positive implications that are grossly at variance with major features of long term economic growth. Notably, with a central role for nonreproducible factors, the basic neoclassical model cannot readily explain why there are relatively small secular movements in market indicators of the return to capital. Thus, our paper simultaneously provides (i) a demonstration of the feasibility and desirability of exploring a new class of economic models; and (ii) an indication of the limitations of further pursuing conventional directions.

The details of our investigation of public policy and economic growth are as follows. In section I, we provide some stylized facts about the process of economic development, drawing on prior work by Kaldor (1961). In section II, we provide a discussion of the consistency of these facts with the basic neoclassical model of Solow (1956), Cass (1965), and Koopmans (1965). For the past thirty years this framework has served as a basic analytical tool for studying aspects of long term growth and as a laboratory in which to undertake policy experiments. This lengthy tradition makes many of us unwilling to discard the neoclassical model without a demonstration of central deficiencies, so we begin our paper with a thorough critical review. We begin by discussing the conventional set of cross-sectional empirical tests that have been used to explore a major implication of the basic neoclassical model, which is that in the absence of different rates of technological progress countries should converge to the same long run growth rate. We express a critique of the power of these tests in the presence of cross-country differences in public policies. However, we then provide simulations of parametric economies that demonstrate what we believe to be the major empirical failing of the basic neoclassical model: it cannot account for the pattern of cross-country diversity in rates of growth without

introducing substantial heterogeneity in the rate of technological progress across countries or generating counterfactual predictions for the behavior of the real rate of return.

Section III provides our analysis of growth through human capital accumulation and the incentive effects of public policy on this process. Our analysis proceeds in three stages. Following Rosen (1976) and Heckman (1976), we discuss optimal individual accumulation of human capital and the influence of various taxes on it. To highlight the role of taxes and to conform to prior microeconomic studies, our analysis takes key prices as exogenous—the wage rate per unit of human capital; the price of investing in human capital; and the real interest rate on consumption loans. Our next two stages make these relative prices endogenous. First, we specify technologies for producing consumption and investment goods, while retaining an exogenous borrowing and lending rate. This provides a framework to discuss a small open economy's accumulation of nontraded human capital. In this section, policies can alter prices through changes in factor mix, as well as through the direct tax effects analyzed in the individual's problem. Second, we study a full general equilibrium in which the rate of return adjusts to equate borrowing and lending or, equivalently, savings and investment. This provides a final set of policy influences on the growth rate.

Not surprisingly, the magnitude of policy effects on the rate of growth depend on the specification of preferences and technology. But a virtue of our approach is that it indicates microeconomic measurements that would be valuable in isolating the effects of policies on growth.

I. Stylized Facts of Economic Growth

A natural reference point in terms of summarizing the empirical evidence on the growth process is the set of stylized facts identified by Kaldor (1961). These empirical regularities constitute the motivation for the basic neoclassical model, and hence, can also be used to provide an informal assessment of of the adequacy of the new theories we discuss.

Kaldor observed that three variables seem to be relatively constant over time: the rate of return on capital, the capital and labor shares in national income, and the capital-output ratio. In contrast, he identified a tendency for the productivity of labor and for the capital-labor ratio to rise at a steady pace. Finally, Kaldor observed that the growth rate of labor productivity differed significantly across countries.

Romer (1988a) recently reviewed the evidence on Kaldor's descriptions of the behavior of labor productivity, labor and capital shares, and of the capital-output ratio. He concluded that, except for some evidence of a downward trend in the share of capital income, the stylized facts described above continue to be reasonable descriptions of the data.[3]

Our discussion focuses on the behavior of the real interest rate and of the growth rate of percapita real gross domestic product, relying on data from Summers and Heston (1984) and Maddison (1982).

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[3]Maddison (1987), p. 660, also reports evidence that points to a secular decline in the share of capital in GDP. However, he discusses several forms of measurement error that may have caused this decline and proceeds to use a constant capital share in his growth accounting calculations.

I.1. Real Gross Domestic Product Percapita

We provide three descriptions of the behavior of the growth rates of percapita real GDP in the Summers and Heston data set. The first consists of Table 1 which provides a list of average growth rates, and their standard deviation by country for the period 1950 to 1981. The number of observations available for each country is also reported. The second is Figure 1 which associates the level of percapita real GDP in 1960 with its average rate of change over the period from 1960 to 1981. The third is Figure 2 which shows the relationship between growth rates for two consecutive subperiods: 1950-1969 and 1970-1981.

To complement this evidence we study the long run behavior of percapita real GDP for sixteen advanced market economies using data form Maddison (1982).

Table 1 documents the large diversity in average rates of growth to which we alluded in the introduction. There seems to be a small negative relationship between growth and its volatility—the correlation between the average rate of change of GDP and its standard deviation is -.07.

Figure 1 shows that the level of income percapita in the beginning of the period seems to be unrelated to whether a country subsequently grows slowly or fast. The estimate of the correlation between the rate of growth and the level of income percapita in the beginning of the period is .13. This estimate indicates that if any relationship exists between the level of economic activity and the subsequent growth rate it is likely to be positive. This fact is often invoked to dismiss the convergence predictions of the neoclassical model.

Figure 2 documents the extent to which there is persistence in the growth process.[4] It considers two subperiods, 1950–1969 and 1970–1981. The correlation between growth rates in the first subperiod and in the second is .39, indicating a tendency for an initial period of high (low) growth to be followed by another period of high (low) growth.

Table 2 uses data from Maddison (1982) to examine the presence of trends in the rate of change of percapita GDP. The sample includes the US, Canada Japan, Australia, and twelve European countries. These countries were chosen for having data on real GDP and population available for most of the 1870 to 1970 period (in some cases this time interval had to be divided in two parts due to missing observations). The evidence is hard to interpret—the data for the 19th century and beginning of the 20th century is not very reliable and the sample is influenced by three major events, the two World Wars and the Great Depression. Nevertheless, the vast majority of the trend estimates is positive although not statistically different from zero at conventional significance levels. Among the countries with data available for the full sample period Italy and Norway are the only cases in which the (positive) trend estimates are significantly different from zero. The four countries with data for only part of the sample (Austria, Belgium, Japan, and Switzerland) show higher average growth rates in the second part of the sample than in the first part and (except for Japan) exhibit trends in the rate of growth not significantly different from zero in each subperiod. We interpret these results as supporting the view that there seems to be no

[4]In Figures 2, 3 and 4 the symbol * denotes the mean across countries of the two variables represented on the axes.

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general long run tendency for the rate of growth to decrease in advanced economies.

I.2 Public Policy and Growth

One of our main focuses in the theoretical sections will be on policy implications of public policy for economic growth. The Summers and Heston data set contains only one policy measure, the share of government in GDP. The relationship between this share of the rate of growth GDP percapita is illustrated in Figure 3. For the full Summers and Heston sample the correlation is −.13. However, over subsamples this correlation is not stable: it is basically nil in the period 1950–1969 and −.33 in the period 1970–1981. This is associated with the relatively small persistence in the share of government expenditure in GDP. Figure 3 suggests that public policy does not offset growth through the expenditure channel.

Finally, Figure 4 plots the rate of growth in real per capita GDP against the share of national product devoted to investment. The correlation between these two variables for the entire sample is .46. Further, there is considerable persistence in the share of GDP that countries devote to investment. Thus, if policy affects growth, its influence may well derive from an influence on the share of investment.

I.3. Real Interest Rates

As will be clear from the theoretical discussion, evidence on the behavior of the real interest rate plays a crucial role in allowing us to distinguish between different models of economic development.

The modern evidence largely supports Kaldor's contention that the real interest rate has been relatively constant over time. Even though there are

well-known difficulties in obtaining meaningful estimates of real rates of return, namely controlling for risk and correcting for anticipated inflation, we believe that if pronounced trends were present in the data these would eventually surface despite measurement error problems.

Our first source of evidence is Homer's (1963) historical study of interest rates, which examines the behavior of interest rates since Ancient times until the 20th century. From the spectrum of interest rates existing in any country at any given time, Homer considers the lowest regularly reported rate to be the one suitable for studies of long run trends. This is preferable to the average rate which bundles together the returns to assets with different risk characteristics.

Although the rates of return reported are nominal and the nature of the underlying assets extremely diverse, we believe that the evidence presented by Homer and summarized in Table 3 is useful in terms of judging whether or not Kaldor's description of the behavior of the real interest rate is adequate. Table 3 makes it hard to view the early stages of development as being accompanied by very high or very low real interest rates. Further, it indicates that for most countries the real interest rate seems to have decreased over time. However, its rate of decrease is extremely small so that for one hundred year periods—the time frame we will consider—Kaldor's contention that the real interest rate appears to be constant is not inconsistent with Homer's evidence.

Our second source of information on the behavior of the real rate of return is Ibbotson and Sinquefield's (1982) compilation of returns on various U.S. securities in the period 1926 to 1981. Table 4 tests for the presence of trends in the real returns to common stocks, small stocks, long-term corporate bonds, long-term government bonds and U.S. Treasury Bills. At

standard significance levels, we cannot reject the hypothesis of no trend in the returns to stocks and treasury bills. The trend coefficients on the real rate of return on long-run government and corporate bonds are negative, of the order of −.02 percent and significantly different from zero at levels of significance of 2 and 10 percent, respectively.

We interpret these two sets of evidence as being broadly consistent with the view that growth in percapita income is not accompanied by systematic increases or decreases in the real rate of return on capital.

II. Counterfactual Implications of the Neoclassical Model

This section is devoted to our critique of the neoclassical model. The essence of our argument is that the transitional dynamics associated with capital accumulation are inconsistent with Kaldor's facts, so long as there is an empirically reasonable amount of diminishing returns to capital.

II.1 Outline of the Model

We start by reviewing a discrete time version of the standard neoclassical model with exogenous technical progress. Our discussion focuses on general properties of this model economy as a framework for explaining long term growth in percapita quantities, so our exposition abstracts from population growth.

Output, denoted by Y_t, is produced according to a constant returns to scale production function with the usual neoclassical properties.[5] The factors of production are capital (K_t) and labor (N_t), augmented by the productivity index X_t. We often refer to X_t as representing "technological progress" but, as discussed in section III, this is really a catch-all phrase to summarize all the sources of productivity growth exogenous to the model. For simplicity, labor supply is viewed as exogenous.

$$Y_t = F(K_t, N_t X_t) \tag{II.1}$$

Output can be used for consumption (C_t) or devoted to investment (I_t).

[5]The production function is assumed to be constant returns to scale, concave, twice continuously differentiable, to satisfy the Inada conditions, and be such that both factors are essential in production.

$$Y_t = C_t + I_t \tag{II.2}$$

Capital depreciates at rate δ.

$$K_{t+1} = I_t + (1-\delta)K_t \tag{II.3}$$

Technical progress grows at rate $\gamma_x - 1$.

$$X_{t+1} = \gamma_x X_t \tag{II.4}$$

Finally, the initial conditions K_o and X_o are given.

It is well known that the only sustainable growth path is one in which Y_t, C_t, I_t, and K_t grow at the rate of expansion of technical progress, γ_x-1. This trajectory is an example of a steady state path, which we define as a trajectory along which the rate of growth of labor supply and of the production of capital and consumption goods are constant.[6]

II.1. The Convergence Implication

When a description of savings behavior is added to the basic neoclassical model, there is generally a strong implication that all economies should converge to the steady state growth path. For example, if we follow Solow

[6]This concept of steady state allows for changes in the number of hours worked. Although this is beyond the objectives of this paper, the motivation for this is to accommodate the secular decrease in percapita hours worked documented in Maddison (1982). In endogenous labor models this phenomenon can be incorporated by choosing preferences that imply a (extremely small) constant decrease in the fraction of time devoted to work in the market.

(1956) by assuming a fixed savings rate and constant labor supply, then the dynamics of accumulation are given by

$$K_{t+1} - K_t = sF(K_t, NX_t) - \delta K_t, \tag{II.5}$$

where s is the savings rate. Relative to the steady state growth path this process is just

$$\gamma_x k_{t+1} - k_t = sF(k_t, N) - \delta k_t, \tag{II.6}$$

where $k_t = K_t/X_t$. From any initial capital stock k_o, this difference equation converges monotonically to a unique stationary value k^* satisfying $(\gamma_x - 1)k^* = sF(k^*, N) - \delta k^*$. Thus, if countries begin with a relatively low capital and, hence, low income, they will initially grow faster. However, in Figure 2, we saw little tendency for a low initial level of income (in 1960) to be followed by high rates of expansion over the subsequent two decades. This fact is often taken to be a strong refutation of the neoclassical model but we are skeptical about relying on it in a world with potential heterogeneity in production possibilities, preferences and public policies. The basis for our skepticism can be illustrated by using a version of the Solow (1956) model that incorporates heterogeneity by adding a country superscript j and specializing the production function to the Cobb-Douglas form. Solow's difference equation then takes the form:

$$K_{jt+1} - K_{jt} = s_j A_j K_{jt}^{\alpha_k} (N_{jt} X_t)^{\alpha_n} - \delta_j K_{jt} \tag{II.5'}$$

with $\alpha_k + \alpha_n = 1$. The implied dynamics of transformed capital are:

$$\gamma_x k_{jt+1} - k_{jt} = s_j A_j k_{jt}^{\alpha_k} N_{jt}^{\alpha_n} - \delta_j k_{jt} \qquad \text{(II.6')}$$

with a stationary value $k^* = [(\gamma_x+\delta_j-1)/(s_j A_j N_j^{\alpha_n})]^{1/(\alpha_k-1)}$

In this simple extension of the Solow model there is potential heterogeneity in initial conditions (k_o) and terminal conditions (k^*) so that one might expect levels and growth rates to be roughly uncorrelated as in Figure 2.

Thus, we believe that one cannot understand the deficiencies of the basic neoclassical model without undertaking a detailed quantitative evaluation of its properties when its parameters are restricted by empirical evidence.

II.3 The Real Interest Rate and Technology

One can extract some information about the behavior of the real interest rate in the neoclassical model without specifying preferences. Using the fact that percapita GDP increased in the U.S. by a factor of 7 in the last century (see Maddison (1987), Table A-4) and the knowledge of today's real interest rate, we can compute what the real interest rate should have been one century ago according to the model. Since in 1960 the percapita GDP of most underdeveloped countries was about 1/7 of that of the U.S. (see Figure 1) this calculation also provides information about the interest rate differential that would have to exist between the U.S. and those countries in the absence of international capital markets.

Suppose that technology is Cobb-Douglas, labor supply exogenous and that there is no technological progress. The capital stock that rationalizes a

given value r_T of the real interest rate today is $K_T = [\alpha_k A N^{\alpha_n}/(\delta+r_T)]^{1/(\alpha_k-1)}$. In this expression (as above), α_n is labor's share, α_k is capital's share, N is the supply of labor, A is the level parameter of the production function, and δ is the depreciation rate. Given K_T and the fact that output increased 7 times over the course of a century we can compute the capital stock that should have been in place one century ago, $K_o = K_T/(7^{1/\alpha_k})$, and the associated real interest rate, $r_o = \alpha_k A K_o^{(\alpha_k-1)} N^{\alpha_n} - \delta$. To construct a baseline scenario, we choose parameter values that reflect the U.S. experience in the post-war period. We choose the capital share to be 1/3, which accords with the estimates reported in Maddison (1987), Table 8. The labor supply is set to .2 which is the average fraction of time devoted to work in the period 1948-1986.[7] The real interest rate in the end of the period is set equal to the average return to equity in the 1948-1986 period—6.5% per annum. The rate of capital depreciation is set to 10%, which is within the range reported by Maddison (1987), Table 7. This parameterization of the neoclassical model implies that the real interest rate one century ago, r_o, should have been a staggering 789.5% a year!

Table 5A summarizes the predicted values for r_o under different hypotheses for the growth rate of exogenous technical progress. The value of the real interest rate in the beginning of the period is lower when a smaller fraction of growth is associated with transitional dynamics. Naturally, if the economy is at the steady state at time zero, so that there are no transitional dynamics, the rate of interest is the same in the beginning and

[7]King, Plosser and Rebelo (1988) discuss derivation of this number from the Household Survey published by the Bureau of Labor Statistics.

in the end of the period. The first column of Table 5A is devoted to the baseline model which has the technology we just described. Columns 2, 4 and 5 consider perturbations of this baseline scenario which involve different rates of depreciation, capital shares and terminal real interest rates. In Column 3 labor supply is taken to be .36 in the beginning of the period and .2 at the end of the period, so as to reflect the decrease in hours devoted to market work occurred in the last century (see Maddison (1987), table A-9).

The message implicit in Table 5A is clear: transitional dynamics cannot account for a large fraction of the expansion in output without generating implausible values for the real interest rate in the beginning of the period. In order for all the output expansion to be associated with transitional dynamics the real interest rate one century ago should have been higher than 100%, unless we postulate an implausibly high share of capital in production.

Table 5B explores a variation of the baseline model in which the elasticities of substitution in production are different from the unitary elasticity associated with the Cobb-Douglas production function. All economies have a CES production function with elasticity of substitution ρ and the same terminal capital stock, $K_T = 100$. The remaining two parameters of the production function are chosen so that r_T is 6.5% and the share of capital in output at time T is 1/3. This ensures that at time T all the economies have the same capital stock, real interest rate, production and capital share but different elasticities of substitution.

One might expect that with elasticities of substitution lower than one the value of r_o would be higher than that associated with Cobb-Douglas production. This is not necessarily true as the last line of Table 5B shows—without technological progress, a decrease in the elasticity of substitution from .9 to .5 actually decreases r_o. This is partly due to the

fact that the marginal products schedules for these two CES production functions intersect twice, at K_T and at a value of the capital stock between zero and K_T.

With non-unitary elasticity of substitution in production the capital share is no longer constant over time when the economy is not following a steady state path. It decreases over time when $\rho < 1$ and it increases for $\rho > 1$. Table 5B indicates that varying the elasticity of factor substitution away from one moderates in some cases the predicted values for r_o—with no exogenous productivity growth the value of r_o associated with $\rho = .5$ is 111.6, roughly seven times smaller than that associated with Cobb-Douglas production. However, the values of r_o continue to be extremely high in light of the historical evidence (see Table 3) when the role of transition dynamics is significant. Furthermore, varying the elasticity of substitution generates implausible implications for the evaluation of the share of capital in production (for instance, with $\rho = .5$ the share of capital decreases by roughly 3 fold over the course of a century).

II. 3. Preferences and Dynamic Competitive Equilibrium

To discuss the form of preferences consistent with steady state growth in the presence of labor augmenting technical progress, it is easiest to examine the economy's competitive equilibrium. For expositional purposes, we consider a market structure with spot labor markets and one-period loan markets under perfect foresight.

Profit maximization by firms implies that in any period the real interest rate (r_t) must equal the net marginal product of capital: $r_t = D_1F(K_t, N_tX_t) - \delta$, where $D_iF(.)$ denotes the ith partial derivative of the function F(.). In the steady state the real interest rate is constant since K and X grow at the

same rate. This implies that the steady state path will only be an equilibrium if households choose to expand their consumption at a constant rate when faced with a constant interest rate. If preferences are time separable this implies that momentary utility must be isoelastic, i.e. life-time utility must take the form:

$$U = \sum_{t=o}^{\infty} \beta^t u(C_t) \qquad \text{(II.7)}$$

with $u(C_t) = \dfrac{C_t^{1-\sigma}-1}{1-\sigma}$.

Given these preferences, households choose the growth rate of consumption to be $\gamma_C = [\beta(1+r)]^{1/\sigma}$. Since feasibility requires that $\gamma_C = \gamma_x$, the steady state real interest rate must be $r = (\gamma_x^{\sigma}/\beta) - 1$. This pins down the steady state capital-labor ratio (K/NX). The real interest rate, the output-capital ratio, the shares of capital and labor in income and the consumption and investment shares in output are constant along the steady state trajectory.

Transitional Dynamics

Specifying preferences allows us to go beyond the simple calculations of the real interest rate at time zero. We analyze the transitional dynamics of the model by studying the optimal (and competitive) path of an economy whose capital stock has associated a level of percapita output seven times smaller than that associated with the steady state. This analysis adopts the baseline parameters for technology that underlies Table 5A; specifies preferences to be (II.7); and chooses β to be consistent with a steady state real interest rate of 6.5% (the steady state real interest rate is

$r_s = (1/\beta) - 1)$. We experiment with various forms for the momentary utility function u(C).

Figure 5 depicts the trajectories of capital, output, consumption and investment for the case of logarithmic monentary utility. The dynamic equilibrium displays high real interest rates and fast expansion in early stages of development.

Table 6A lists the average annual rates of growth of output and capital and the average annual real interest rate for successive 5 year periods within the first 50 years.[8] Line one of the table reports numerical results that correspond to Figure 5, i.e., for the case in which the intertemporal elasticity of substitution $(1/\sigma)$ is equal to one. The transitional dynamics are remarkably rapid in this model—after 8 years half of the adjustment toward the steady state is completed. Average real interest rates are very high in early stages of development, that is approximately 100% per annum.

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[8]The numerical results reported in Tables 6 and 7 were obtained by shooting methods. The easiest way to study the model's transitional dynamics is to consider a planning problem in which a benevolent planner maximizes welfare of the representative agent subject to the technological constraints spelled out in the main text. The first order conditions for this planning problem can be expressed as a system of two autonomous first order non-linear difference equations in K and λ, the Lagrange multiplier associated with the resource constraint. Given knowledge of λ_o and K_o we can solve this system of equations forward. The value of λ_o has to be such that the "transversality condition" $\lim_{t\to\infty} \beta^t \lambda_t K_{t+1} = 0$ is satisfied. This condition is the analogue of the complementary slackness condition that arises in T period problems associated with the restriction $K_{T+1} \geq 0$. Shooting methods are iterative procedures that start with a guess for λ_o, solve the system of difference equations forward, and check whether the transversality condition is satisfied. In case it is not, the initial guess is revised, using methods for finding zeros of equations (e.g., Newton-Raphson). A detailed discussion of shooting methods can be found in Lipton et al (1982) and Roberts and Shipman (1972).

With lower intertemporal substitution ($\sigma = 20$) the growth process is much more protracted, as the second line of Table 6A demonstrates. The half life of the system dynamics is now 61 years. The low elasticity of intertemporal substitution leads agents to prefer a smoother path for consumption than in the baseline model (when $\sigma = 1$). On the one hand, less intertemporal substitution leads to lower rates of growth in early development periods than in the baseline scenario. However, on the other, it implies even higher values of the real interest rate than in the case of $\sigma = 1$. This example demonstrates how reparameterizing the neoclassical model simply shifts the difficulty to another area. We will repeatedly encounter this theme as we proceed through this section.

The third parameterization modifies momentary utility to the form: $u(c) = \log(c-\bar{c})$, where $\bar{c}$ denotes the subsistence consumption level. In this model, there is an unstable steady state at the level of sustainable capital stock compatible with $\bar{c}$. This low level steady state resembles somewhat the "poverty trap" familiar from the development literature. That is, despite the good investment opportunities the country does not invest because production is barely enough to attend to subsistence consumption and to the replacement of the depreciated capital stock. In the parameterization examined, we chose $\bar{c}$ to be .04 which represents 95% of the resources available to the economy in the end of the first period (production plus non-depreciated capital). This economy displays a "hump-shaped" growth path (although this cannot be concluded from the averages reported in the table)--growth rates are low in the initial periods, subsequently rise and then decline. But again, altering preferences to produce more protracted transitional dynamics also generates higher real interest rates in initial stages of development than those associated with the baseline scenario.

In line 4, we perturb the basic model by altering capital's share to be a value of $\alpha_k = .5$, which we think is a plausible upper bound. Transitional dynamics are more persistent relative to the baseline model but real interest rates, though lower, are still high in the early stages.

The experiment reported in the last line of Table 6A is suggestive. If the share of capital is moved to $\alpha_k = .9$, so that the production function comes close to being constant returns in the factor that can be accumulated, the process of transitional dynamics is protracted and the real interest rate assumes more moderate values in early stages of development. But $\alpha_k = .9$ is counterfactual, if we maintain that capital earns a competitive factor share.

II.5. The two-sector neoclassical model

One might think that the results of the experiments above are peculiar to the one-sector nature of the model. Table 6B sheds light on this conjecture. It summarizes the adjustment path for a two-sector model in which both production functions are Cobb-Douglas with level parameters normalized to one. The labor share in the capital sector is taken to be .5. We experiment with two alternative values of the labor share for the consumption industry, $\omega_k = .25$ and $\omega_k = .75$. (When $\omega_k = .50$ the two sector model generates results identical to those reported on line 4 of Table 6A since it reduces to a one-sector economy.) The remaining parameters and initial capital stock of the economies that underlie Table 6B are identical to those of Table 6A.[9] As

[9]Output measured in terms of the consumption good is given by $Y_t = p_t I_t + C_t$. Since p_t, the relative price of investment in terms of consumption is endogenous, we cannot compute directly the value of K_o that has associated a value of output seven times larger than that of the steady state. We used instead the value of K_o implied by the one-sector model so that Table 6B can be readily compared with Table 6A. This choice did not affect the results

one might expect, separating out the consumption sector and making its production function more linear in capital makes the interest rate implications less dramatic but still generates implausible values for r_o. In order to generate empirically plausible values for r_o one has to postulate that the production function of the capital sector is close to linear in capital.

II.6. Adjustment Costs

Costs of changing the capital stock are another potential avenue for eliminating the counterfactual implications for the behavior of the real interest rate. We consider below a version of the neoclassical model with adjustment costs similar to the one developed by Abel and Blanchard (1983). To preview the results of this investigation, it is true that if one freely chooses the adjustment cost function, then one can overturn the implication for the beginning of period real interest rates. But there are then other undesirable implications. Moreover, we would like to employ adjustment cost functions that are empirically reasonable on other grounds. For this purpose, we draw on work by Hayashi (1982) that develops the connection between adjustment costs and Tobin's q—the ratio of stock market valuation of existing capital to its replacement cost. We conclude that one can only overturn the implication of implausibly high interest rates at the cost of generating counterfactual values for Tobin's q. That is, initial period q falls well outside the range of values that have been estimated in the literature on empirical investment equations.

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discussed in the main text.

The introduction of adjustment costs requires that we alter the resource constraints of the neoclassical model as follows

$$Y_t = C_t + Z_t[1 + h(Z_t/K_t)] \tag{II.2'}$$

$$K_{t+1} = Z_t + (1-\delta)K_t. \tag{II.3'}$$

In the standard model, one unit of investment increases the capital stock by one additional unit. Now it is necessary to invest $1 + h(Z_t/K_t) + (Z_t/K_t)Dh(Z_t/K_t)$, where $Dh(.)$ denotes the derivative of $h(.)$.

The adjustment cost function $h(.)$ is assumed to be homogeneous of degree zero in Z and K. As Hayashi (1982) has shown, this makes the theory operational since it allows us to determine Tobin's marginal q by measuring average q. We assume that $h(\delta) = 0$ and $Dh(\delta) = 0$, so that the steady state capital stock is not affected by the introduction of adjustment costs. Without this assumption the adjustment costs economy would have a lower steady state capital stock than the comparable standard model. This would contribute to an *increase* in r_o. To make clear that our conclusions do not hinge on this effect, we chose to eliminate it.

Finally, we postulate that both the adjustment costs and the total cost of investing are increasing: $Dh(.) \geq 0$, and $2Dh(Z_t/K_t)) + (Z_t/K_t)D^2h(Z_t/K_t) > 0$, where $D^2h(.)$ denotes the second derivative of $h(.)$.

The value of Tobin's (marginal) q implied by this model is

$$q_t = 1 + h(Z_t/K_t) + (Z_t/K_t)Dh(Z_t/K_t) \tag{II.8}$$

and the real interest rate is given by:

$$r_t = [DF(K_t) + (Z_t/K_t)Dh(Z_t/K_t)]/q_{t-1} + (1-\delta)q_t/q_{t-1} - 1 \qquad \text{(II.9)}$$

The consideration of adjustment costs introduces two conflicting effects on the real interest rate. First, the fact that the cost of increasing capital by an extra unit is now higher than one ($q_{t-1} = 1 + h(Z_{t-t}/K_{t-t}) + Dh(Z_{t-t}/K_{t-t})(Z_{t-t}/K_{t-t}) \geq 1$) lowers the real interest rate relative to the non-adjustment cost case. Second, the fact that an additional unit of capital lowers adjustment costs ($(Z_t/K_t)Dh(Z_t/K_t) \geq 0$) contributes to a higher value of the real interest rate. Equation (II.9) makes clear that low values of the real interest rate can only be obtained by introducing adjustment costs that imply large values of q.

Summers (1981) showed that when h(.) takes the functional form (II.10), the model described above predicts a linear relationship between Z_t/K_t and q_t.

$$h(Z_t/K_t) = \frac{(b/2)(Z_t/K_t - a)^2}{Z_t/K_t} \qquad \text{when } Z_t/K_t \geq a$$

$$h(Z_t/K_t) = 0 \qquad \text{when } Z_t/K_t < a \qquad \text{(II.10)}$$

Estimating this linear relationship correcting q_t for the effects of taxation, Summers (1981) obtained the following estimates: b = 32.2 and a = .088. The requirement of no adjustment costs at the steady state implies that the rate of depreciation must be equal to a, so we set δ equal to .088.

With these parameter values in hand we can study the model's implications for the behavior of real interest rate. Table 6C summarizes the transitional dynamics of a version of the baseline model in which we introduced the form

of adjustment costs described above. This Table confirms what expression (II.9) led us to expect. While the introduction of adjustment costs moderates the implications of the model for r_o, it does so by simultaneously generating implausibly high values for Tobin's q. The average value of q in the first five years of the simulation is 13.4. This value is well outside the range of values for q estimated in the investment literature (the highest value of q reported by Summers for the period 1933-1978 is barely above 2).

The conclusion that low values of r_o can only be obtained by postulating empirically unacceptable adjustment costs is independent of the connection between adjustment costs and Tobin's q which we used to organize our discussion. To demonstrate the implausibility of the adjustment costs that underlie the first line of Table 6C it is sufficient to cite the fact that they imply that—at time zero—the marginal adjustment costs associated with increasing installed capital by one unit are equal to 20.3 units of output.

II. 7. Implications for open economies

The numerical results reported so far have been interpreted using the neoclassical model as a model of a closed economy or alternatively of the world as a whole. Taken together, the versions of the model considered involved implausibly high real interest rates for the beginning of this century. Alternatively, one might view the neoclassical model as predicting how the real interest rates should be related to the level of development in the absence of international capital markets. Under this interpretation $r_o - r_T$ becomes the differential between the rate of return to capital in developed and underdeveloped countries predicted by the model. This differential is so large that it is hard to believe that investment flows

from rich to poor countries would not take place, even taking into account such factors as political risk, transaction costs, etc.

In fact, in the standard open economy neoclassical view, capital flows would instantaneously equalize the rate of return in all countries so the process of adjustment would be instantaneous. Again, one might think that introducing adjustment costs would eliminate this unrealistic implication by creating a wedge between the marginal product of capital and the real rate of return to capital. In other words, making the cost of investment increasing in the rate of expansion of the capital stock might potentially smooth out the flow of investment from rich to poor countries so that the transition period might be very long. Table 7 summarizes the transition path of an economy with adjustment costs identical to the one that underlies Table 6C but that can borrow and lend in the international capital market at the rate of 6.5% per year. This Table shows that, even with adjustment costs that imply values for Tobin's q greater than 20, the model still predicts a fast process of convergence—the average growth rate of output in the first five years is 18% per annum. This leads us to conclude that it is not possible to attribute an important role to transitional dynamics in accounting for the expansion of percapita income observed in the last century. On the basis of the neoclassical model, we cannot reconcile the presence of (possibly imperfect) international capital markets, with the absence of a very rapid process of cross-country convergence.

II.8. The Bottom Line

While we studied the most commonly used versions of the neoclassical growth model, there are (of course) many other variations we could have considered.[10] However, we believe that the inconsistency of the neoclassical transitional dynamics with Kaldor's stylized facts is a basic feature of this class of environments.

Thus, the neoclassical models discussed to this point are deficient as an explanation of economic growth. Steady state growth is compatible with the stylized facts presented by Kaldor but the long run growth rate is determined exogenously. In order to explain a given pattern of diversity in rates of growth as the outcome of steady state dynamics, one would have to assume that countries that grow faster have higher rates of exogenous "technical progress," i.e. we have in effect assume a priori the pattern of diversity we are trying to explain.

[10]One commonly used extension of the standard neoclassical model which we have not considered in the main text makes the supply of labor endogenous. This model leads, in general, to higher values of r_0 than the baseline model since labor supply tends to move inversely with the capital stock (see King, Plosser and Rebelo (1988)).

III. Public Policy and Endogenous Economic Growth

In the neoclassical model reviewed in the previous section, there were two sources of economic growth, transitional dynamics and exogenous increases in productivity. We argued that the empirical importance of transitional dynamics is limited. The presence of sharply diminishing returns to capital leads to counterfactual implications about real interest rates during transition periods. Hence, variations in the growth rate have to be mainly a result of increases in productivity that are exogenous to the neoclassical model. For the neoclassical model to possess relative constancy of growth and interest rates--Kaldor's stylized facts—it must be the case that exogenous productivity growth are expressible in labor augmenting form.

Typically, we refer to this exogenous component as "technical progress", but in fact the residual factor summarizes a broad range of activities responsible for secular growth in productivity. These activities include formal education, on-the-job training, basic scientific research, product development, innovation in systems and management, etc. The natural starting point for quantitative model building is to assume that the result of these activities can be summarized by a composite capital good. Thus, one of the societal decisions is to determine the rate at which it increases its stock of labor in efficiency units, by varying the composite capital good that augments its workers' time.[11]

Analysis of human capital investment following Schultz (1961) and Becker (1964) similarly investigates the accumulation of capital that augments the

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[11]An important assumption in this approach is that changes in productivity summarized by the evolution of the composite capital good are embodied in the representative worker. See Romer (1986, 1988b) for analyses that do not rely on this embodiment assumption.

productivity of time, so we make use of this approach in developing our analysis of the effects of public policy on economic growth below. However, our sense is that our analysis will carry over to the more comprehensive concept of technical progress discussed above.

In our analysis of the neoclassical model, we studied transitional dynamics for two alternative economies. First, we considered a closed economy in which there was general equilibrium determination of output growth and the interest rate. Second, we studied output growth for a small open economy, taking the real interest rate as given from the rest of the world. We follow that procedure in the present investigation of endogenous economic growth.

Our interest is in models of endogenous growth that are compatible with Kaldor's stylized facts. For this reason, we focus on economies in which the real interest rate is constant along steady state paths. This requires that the production of both physical and human capital goods take place according to constant returns to scale technology. We also carry along the assumptions on preferences that lead individuals to choose a constant growth of consumption when faced with a constant interest rate.

Discipline on aggregate model building requires that we be explicit about microeconomic underpinnings so that key parameters can potentially be estimated from other than aggregate relations. For this reason, we begin in section III.1 by developing a variant of the dynamic microeconomic model of human capital accumulation, drawing on prior work by Becker (1964), Ghez and Becker (1975), Heckman (1976) and Rosen (1976). Motivated by our empirical section, we look for specifications of preferences and technologies that make steady state growth an outcome when there is a constant wage rate (in

efficiency units), a constant price of investment in human capital, and a constant real interest rate. When human capital occurs in an environment with borrowing and lending (or physical capital accumulation), there is the standard potential for knife-edge investment decisions, i.e., either specialization or indeterminacy of portfolio fractions. To break this result, we require that human capital accumulation be subject to diminishing returns at each point-in-time, while maintaining the feasibility of sustained growth. As in Rosen (1976), this is accomplished by specification of a suitable technology for transforming investment in human capital into changes in the stock of human capital. Then, in section III.2, we consider a "small open economy" reinterpretation of this consumer choice problem. As in Baxter's (1988) analysis of the Heckscher-Ohlin model with international borrowing and lending, it turns out that the world interest rate, national taxes and production structures dictate the wage rate and price of investment in human capital independent of the rate of human capital investment. This analysis moves us part way to a full general equilibrium but retains an exogenous interest rate. Section III.3 then indicates that a full general equilibrium can be obtained by imposing the Fisherian requirement that the interest rate equal the marginal rate of substitution in consumption, with consumption growing at the rate of human capital accumulation.

The model economy that we construct in these three sections is of the class studied previously by Uzawa (1965), Lucas (1988b) and Rebelo (1987) in that it highlights the societal allocation of resources between current consumption and a comprehensive accumulation (physical and human capital) under constant returns to scale. However, because we want to understand (i) the decentralization of accumulation decisions and (ii) growth in an open economy with traded physical capital and nontraded human capital, we require

that the rate of human capital investment is subject to diminishing point-in-time returns as in Rosen (1976).

III. 1. Individual Human Capital Accumulation

Our analysis of individual human capital accumulation follows the now standard microeconomic treatment, presenting a discrete time version of the analyses of Heckman (1976) and Rosen (1976).

Costs and Benefits of Human Capital Accumulation

The basic treatment of human capital as developed by Schultz (1961) and Becker (1964) starts by analyzing the rate of return to its accumulation. If human capital augments time then the value of an additional unit of human capital just for next period will be

$$w_{t+1}N_{t+1} + (1-\delta_H)\, p_{IH,t+1},$$

where w_{t+1} is the wage rate per efficiency unit of labor; N_{t+1} is the number of units of time, which represents the utilization base for human capital; and $(1-\delta_H)\, p_{IH,t+1}$ is the value of reducing next period's investments in human capital to keep the subsequent path unchanged, involving the standard components of depreciation $(1-\delta_H)$ and the price of the investment good $p_{IH,t+1}$. The gross rate of return on a date t investment in human capital—which costs $p_{IH,t}$—is thus

$$[w_{t+1}N_{t+1} + (1-\delta_H)\, p_{IH,t+1}]/[p_{IH,t}].$$

If the wage and investment good price is independent of the scale of human capital investment, then—in a perfect capital market—there are three possibilities: (a) no investment in human capital (specialization in other investments); (b) indifference between quantities invested in human capital and other assets; and (c) specialization in human capital investment. Letting the interest rate between t and t+1 be r_t, these situations occur depending on the relative magnitudes of rates of return,

$$1+ r_t \gtreqless [w_{t+1}N_{t+1} + (1-\delta_H)\, p_{IH,t+1}]/[p_{IH,t}].$$

To avoid these extreme implications in the analysis below, we will study a formulation of the human capital process that blends the investment "adjustment cost" technology of Rosen (1976) with the investment production function of Heckman (1976). At each point-in-time human capital accumulation will occur according to

$$H_{t+1} - H_t = \Theta(I_{Ht}/H_t)H_t - \delta_H H_t, \qquad \text{(III.1)}$$

where I_{Ht} is human capital investment and where the Θ function reflects diminishing point-in-time capacity to grow, as in Rosen (1976), i.e., $D\Theta > 0$ and $D^2\Theta < 0$. This structure permits steady state growth if I_{Ht} and H_t grow at the same rate. Further, it is consistent with the view that investment in human capital combines time and other inputs according to a production function as in Heckman (1976), in ways that we detail in section III.2 below.

We start by studying the individual's decision problem when there is a given wage rate and price of investing in human capital. These are assumed constant over time, as they will be in a steady state.

Optimal Growth of Consumption and Human Capital

The individual under study seeks to maximize lifetime utility subject to an intertemporal budget constraint with the interest factor $R=(1+r)$. That is, the formal problem is:

$$\max \sum_{t=0}^{\infty} (\beta)^t u(C_t).$$

subject to
$$\sum_{t=0}^{\infty} (\tfrac{1}{R})^t C_t \leq B_0 + \sum_{t=0}^{\infty} (\tfrac{1}{R})^t [wNH_t - p_{IH} I_{Ht}]$$

and
$$[H_{t+1} - H_t]/H_t = \Theta(I_{Ht}/H_t) - \delta_H,$$

where B_o represents initial financial assets. As in section II above, we restrict momentary utility to constant elasticity form so that consumption will grow at a constant rate when the interest rate is constant ($u(C_t) = [C_t^{1-\sigma} - 1]/[1-\sigma]$).

To examine the determination of the optimal growth rate, consider increasing investment in human capital by a small amount (dI_{Ht}). This increases human capital at t+1 by $dH_{t+1} = D\Theta_t \, dI_{Ht}$, where to simplify the notation in this expression and those that follow we define $D\Theta_t = D\Theta(I_{Ht}/H_t)$ and $\Theta_t = \Theta(I_{Ht}/H_t)$. In order for human capital to remain unchanged in periods t+2 and later, there must be a change in investment at date t+1. The amount of this change is given by:

$$dI_{H,t+1} = \{[(I_{H,t+1}/H_{t+1})D\Theta_{t+1} - \Theta_{t+1} - (1-\delta_H)]/D\Theta_{t+1}\} \, dH_{t+1}.$$

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In the absence of diminishing returns to investment ($\Theta = I_H/H$), so that $dI_{H,t+1} = -(1-\delta_H)\, dH_{t+1}$. But with diminishing returns to investment, an altered saving on future investment occurs, which incorporates changes in "marginal adjustment costs." As previously, the marginal return associated with the change in investment is expressible as

$$[w\, N\, dH_{t+1} - p_{IH}\, dI_{H,t+1}]/p_{IH}.$$

When $\Theta = I_H/H$, this collapses to $[w\, N + p_{IH}\, (1-\delta_H)]/p_{IH}$, the rate of return in the previous section.

The efficient rate of investment (I_H/H) is obtained by equating this gross rate of return to $R = 1+r$. Equivalently, using $I_{Ht}/H_t = \Theta^{-1}[(H_{t+1}/H_t) - (1-\delta_H)]$, we can solve for the efficient rate of human capital growth (H_{t+1}/H_t) from this requirement. The optimal rate of human capital growth thus depends on (i) the relative price (w/p_{IH}); (ii) the real discount factor R; (iii) the depreciation rate of human capital δ_H; and (iv) the parameters of the Θ function.

There is a separation of consumption and production decisions in this model, so that preferences do not influence the rate of human capital formation. Consumption growth occurs at the familiar rate $(C_{t+1}/C_t) = [R\beta]^{1/\sigma}$, reflecting the relative magnitude of the force of interest and time preference along with the intertemporal elasticity of substitution ($1/\sigma$).

Finally, suppose that we follow Heckman (1976) in modifying the consumer's preferences to the form $u(C_t^*)$ with C_t^* being a composite good that

is produced according to the constant returns to scale production function $C_t^* = z(C_t, L_t H_t)$, where L_t is a portion of time spent working at home. Then, there is only one change along a steady state path: the utilization rate of human capital rises from N to N+L reflecting the enhanced productivity at home. Outside of the steady state there would be, of course, additional implications of this modification.

III. 2. Production Structure and a Small Open Economy Interpretation

For the purpose of studying a small open economy interpretation of this problem, we need to specify the production structure and explore its implication for the prices w and p_{IH}. Thus, in this section, we proceed part way to a full dynamic general equilibrium, but we retain the assumption that the interest rate r is exogenous. More specifically, we follow Baxter (1988) in assuming that there is international borrowing and lending; trade in capital and consumption goods; and international immobility of labor/human capital. In the process of fleshing out the production side, we also add a richer specification of taxes to the analysis.

The economy under study has access to two constant returns to scale production functions. The first produces commodity output from units of capital and labor input (in efficiency units),

$$Y_t = F_1(K_{1t}, N_{1t}H_t), \tag{III.3}$$

where K_{1t} is capital employed in the production activity and $N_{1t}H_t$ is labor input in efficiency units. (A special case is when production depends only on labor input $F_{1t} = A_1 N_{1t} H_t$, which can be interpreted as market labor income

at wage rate A_1). The second produces an intermediate product that represents gross investment in human capital accumulation,

$$I_{Ht} = F_2(K_{2t}, N_{2t}H_t), \tag{III.4}$$

where K_{2t} is the amount of capital allocated to investment in human capital and $N_{2t}H_t$ is the amount of labor in efficiency units allocated to this activity.[12]

The constraint on allocation of time is $N_{1t} + N_{2t} \leq 1$, where the endowment of time is normalized to one.

Capital in each of these activities evolves according to standard accumulation technologies, possibly with differential rates of depreciation. That is, the capital stocks accumulate according to $K_{1,t+1} - K_{1,t} = I_{K1t} - \delta_{K1} K_{1t}$ and $K_{2,t+1} - K_{2,t} = I_{K2t} - \delta_{K2} K_{2t}$, where $0 \leq \delta_{K1} \leq 1$ and $0 \leq \delta_{K2} \leq 1$. Similarly, as in the preceding discussion, human capital evolves according to $H_{t+1} - H_t = \Theta(I_{Ht}/H_t)H_t - \delta_H H_t$.

With borrowing and lending, financial assets evolve according to $B_{t+1} = [1 + r(1-\tau_r)]B_t + b_t$, where τ_r is the tax rate on income on financial assets and b_t is the flow of acquisitions. These acquisitions obey

$$b_t = [(1-\tau_Y)Y_t - (1+\tau_C)C_t - (1+\tau_{I1})I_{K1,t} - (1+\tau_{I2})I_{K2,t} + T_t],$$

where τ_Y is the tax on income; τ_C, τ_{I1}, and τ_{I2} are taxes on alternative uses of incomes; and T_t is transfer payments.

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[12]Uzawa (1965) and Lucas (1988) study a special case with only human capital used to produce human capital: some implications of this assumption are discussed in Rebelo (1987) and section III.3 below.

Maximizing Wealth with Given Growth

It is useful to begin by considering the small country's static competitive equilibrium or, equivalently, an individual decision maker's efficient production decisions with a given path of human capital accumulation (i.e., a given sequence of investments $\{I_{Ht}\}_{t=0}^{\infty}$). Maximizing wealth requires that one solve the following income maximization problem for each date $t > 0$.

$$\max\ [(1-\tau_Y)\ F_1(K_{1t}, N_{1t}H_t) + T_t - q_1K_{1t} - q_2K_{2t}]$$

$$\text{subject to} \qquad F_2(K_{2T},\ N_{2t}H_t) = I_{Ht}$$

$$\text{and} \qquad N_{1t} + N_{2t} \leq N,$$

where the maximization is undertaken with respect to N_{1T}, N_{2t}, K_{1T}, K_{2t}. The rental prices of capital are $q_1 = [r(1-\tau_r) + \delta_{K1}]\ (1 + \tau_{I1})$ and $q_2 = [r(1-\tau_r) + \delta_{K2})](1 + \tau_{I2})$.

The structure of this "two sector" problem can be best understood as by following the line of argument developed in Baxter's (1988) analysis of the two-sector neoclassical (exogenous growth) model. First, for any positive amount of labor input allocated to production of commodities, maximizing income with respect to K_{1t} requires that its value marginal product equal its rental price, i.e., $(1 - \tau_Y)D_1F_1(K_{1t},\ N_{1t}H_t) = q_1$. This efficiency condition implies an optimal capital labor ratio, call it ρ_1, which is a function of $q_1/(1-\tau_Y)$ with $D\rho_1 < 0$. That is,

$$K_{1t}/(N_{1t}H_t) = \rho_1[q_1/(1-\tau_Y)].$$

In turn, this equilibrium input ratio implies a commodity wage rate

$$w = (1-\tau_Y)D_2F_1(K_{1t}, N_{1t}H_t) = (1-\tau_Y)D_2F_1(\rho_1(\frac{q_1}{(1-\tau_Y)}), 1),$$

using the zero degree homogeneity of marginal products.

Thus, the marginal activity of producing for the market sets a key relative price that partly determines the optimal mix of factors in the growth activity. From standard arguments about production in constant returns-to-scale industries, we know that we can express the factor demands as

$$N_{2t}H_t = \nu_N(w/q_2)I_{Ht}$$

$$K_{2t} = \nu_K(w/q_2)I_{Ht}$$

and derive an expression for the implicit unit price of investment in human capital production

$$p_{IH} = q_2\ \nu_K + w\ \nu_N.$$

Clearly, from a public policy perspective, the tax rates on capital and labor inputs will influence the price of investing in human capital. This channel is one that was omitted in the earlier analysis of section III.1.

III. 3 General Equilibrium Determination of Interest and Growth Rates

In a closed economy general equilibrium, the interest rate will be tied to the growth rate according to the Fisherian requirement that the gross rate of return equal the marginal rate of substitution in consumption. In particular, given the specification of preferences consistent with steady state growth, it must be the case that

$$1 = R\beta[Du(C_{t+1})/Du(C_t)] = R\beta(\gamma_H)^{-\sigma},$$

since consumption and human capital will be growing at the same rate. Thus, increasing the growth rate will raise the interest rate, inducing additional affects on the rental prices not present in the previous section.

In this general equilibrium, the specification of preferences will influence the response to tax policies, in contrast to the results in section III.1 and III.2, where the choice of the efficient rate of accumulation of human capital was dictated solely by productive efficiency.

As in our section II discussion of the neoclassical model, we interpret this general equilibrium in two alternative ways: as an autarkik equilibrium and as a world general equilibrium of countries that are identical in terms of preferences, production possibilities and policies.

III. 4 Positive Implications of Taxation for Economic Growth

In the Summers and Heston (1984) panel of country experiences summarized in Table 1 and Figure 1, countries grew at widely different rates. In section II of the paper, we argued that the transitional dynamics of the neoclassical model could not account for this disparity of growth experiences without producing counterfactual implications for interest rates, asset

prices or capital flows. By extension, our argument implied that public tax and expenditure policies could not not account for the cross country disparity in observed growth rates, since such policies influence growth in the neoclassical model by setting in motion a transition from one steady state path to another.

In this section, we focus on cross country differences in tax policies as a potential explanation of the disparity of observed growth rates. Many other policies that affect the incentives for economic growth—including government provision of education, and property rights—operate via similar channels to those that we describe. The focus is entirely on the influence of public policies on the steady state growth rate, rather than on transitional dynamics. As we have seen, transitional dynamics in the neoclassical model are short lived and, in endogenous growth models, they are generally more limited in duration because agents have additional margins of choice. Further, we interpret the stylized facts of economic growth as indicating that one *must* explain sustained cross country differences in growth rates. (Since we are using technology and preferences consistent with constant interest rates along such paths, we will focus on the model's implications for the steady state growth rate rather than its implications for interest rates in the early stages of development.)

Method

Our objective in this section is to explore the effects of policies on the steady state growth rates in models that account for these general equilibrium effects on the real rate of return. For this purpose, as in the previous sections, we need to specify aspects of the investment technologies (parameters of the Θ function, δ_H, δ_{K1}, δ_{K2}); production technologies

(parameters of the functions F_1 and F_2); and tax structure. Further, we need to specify aspects of preferences—β and σ—since these influence the equilibrium interest and growth rates. Our procedure is as follows: we choose a value of the intertemporal elasticity of substitution in consumption ($1/\sigma$) and a baseline value for the interest rate and growth rate. Then, from above, we can compute the discount factor β. Fixing this discount factor, we then explore how steady state interest rates and growth rates vary as the tax structure is altered. (The details of this procedure are reported in Appendix B).

Throughout our analysis, we concentrate on the case where the production functions F_1 and F_2 are Cobb-Douglas, with $F_i = A_i K^{(1-\alpha_i)} (NH)^{\alpha_i}$. We uniformly assume that the share of labor (α_1) in sector 1 is 2/3, so that our results are compatible with those for the neoclassical models explored in section II above. Further, as in section II, we normalize the constant term in the sector 1 production function to unity ($A_1 = 1$). Our benchmark preference case is to assume that the intertemporal elasticity of substitution is unity ($1/\sigma = 1$). Throughout, we use the steady state real interest rate of .065 ($R = 1.065$) and the depreciation rate of $\delta_K = .10$. We employ a parameterization of the human capital accumulation technology which assumes that there are locally no adjustment costs at zero gross investment so that $D\Theta(I_H/H) = 1$ at $I_{Ht} = 0$. Further, we use a fairly linear form of this technology, setting the parameter θ equal to .8 in the functional form $\Theta(I_H/H) = [I/H + \theta^{\frac{1}{1-\theta}}]^{\theta} - \theta^{\frac{1}{1-\theta}}$. See Appendix A for a graph of this function and discussion of its derivation. Our intent is to keep the individual choice problem well defined, without letting specification of the Θ function dominate the results.

Influences of Production Structure

The first set of calibration experiments reported in Table 8 indicates the influence of labor's share (α_2) in sector 2, the sector producing the human capital investment good. Our motivation for exploring this parameter's influence is based on practical and theoretical considerations: (i) it is a parameter about which there is considerable uncertainty, since it is unclear exactly what sectoral output is being measured; and (ii) Uzawa (1965) and Lucas (1988b) assume that only labor is necessary to produce human capital ($\alpha_2 = 1$), which Rebelo (1987) shows theoretically restricts certain policies to have no effect on the steady state growth rate.

The calibration activity undertaken in Table 8 indicates that the productivity parameter A_2 adjusts in response to changes in α_2. Roughly, the chain of influence is as follows, using the results of our analyses in sections III.1 and III.2. First, the specified values of sector 1 production pin down the required value of the capital-labor ratio in sector 1, since $D_1F_i = A_i[K/(NH)]^{-\alpha_i} = (R - (1-\delta_K)) = .165$. In turn, this implies a steady state real wage rate (in units of sector 1 output), w. Second, specification of the growth rate of the economy (γ_H) and the adjustment technology (Θ) implies a level of marginal adjustment costs. Third, from our analysis of the individual's problem, we know that the (constant) growth of human capital depends on marginal adjustment costs, on the real interest rate, on the real wage rate (per unit of human capital) and on the price of investing in human capital (p_{IH}). But the first three of these have already been determined, so we know the relative price p_{IH} without reference to the specification of the sector 2 technology parameters (and, more generally, without reference to its parametric form). Fourth, from our analysis of the small open economy problem, we know that the factor intensity in sector 2 is

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pinned down from the sector 1 wage rate (w) and the rental price of capital ($R - (1-\delta_H)$), without reference to the "neutral" technical parameter A_2. Thus, as we vary α_2—which influences the efficient factor intensity—A_2 must change to keep the unit cost of production equal to the price p_{IH}.

These considerations are reflected in the columns of Table 8, panels A and B. In addition to the influence of α_2 on A_2 stressed above, we can see that there is an invariance of the wage rate w and the price of human capital investment good across the values of α_2. Further, as α_2 increases, the quantity of capital employed in sector 2 declines, which lowers the two investment share measures. These measures differ in their denominators: s_i scales investment relative to sector 1 output (y_1) and s_i^* scales by the more comprehensive measure ($y_1+p_{IH}y_2$). Notably, the former investment share measure is high relative to the U.S. experience, for which Summers and Heston (1984) report an average of 24% over 1950-1981. Throughout, taxes on sectoral outputs are held constant. Finally, the fact that Table 8 reflects a calibration exercise to match growth (γ_H) and interest rates (R) means that the last two columns are constant as well.

Comparing the two panels, isolates the impact of changing the rate of depreciation on human capital. Panel A treats the case of equal depreciation rates for physical and human capital ($\delta_k = \delta_H = .10$); Panel B uses Mincer's (1974) estimate of 1.28% per annum. Varying the depreciation rate in this way lowers the marginal cost of investing in human capital $D\Theta(\gamma_H - (1-\delta_H))$ used in the calibration, so that the steady state relative price of human capital must rise, following the arguments above. Lowering the depreciation rate also lowers the scale of production in sector 2 (less replacement investment) and this scaling back of capital in sector 2 is reflected in

lower physical capital investment shares (s_i and s_i^*) in panel B relative to panel A.

Implications of Taxation

The three panels of Table 9 indicates the potential magnitude of policy influence on economic growth in this general equilibrium setting. Although the panels reflect different assumptions about preferences and technology, there is a common method employed in the construction of each. First, the system is calibrated under the assumption that there are no taxes to match growth and interest rate values ($R = 1.065$ and $\gamma_H = 1.02$) for specified parameter values. Then, the tax parameters are altered, resulting in new values of growth and interest rates; of investment shares; and the relative prices (the price of investment in human capital and the wage rate).

The tax parameters are output taxes on the two sectoral outputs with the assumption being that the proceeds are rebated as lump sum transfers. We chose this method of taxation for its simplicity, although taxation of income from factor supply would also be of interest and would be perhaps more realistic. Variations are from a subsidy of −10 % through a tax of 50%. Some of the experiments considered in Table 9 involve only taxation of the commodity output sector (sector 1). A literal interpretation of the output of sector 2 as new human capital would lead us to view this sector as untaxed. However, we study as well the effects of changes in τ_2 which can be interpreted more broadly as summarizing aspects of the education system, patent policy, etc. Throughout the panels, increases in taxation lower the growth rate and this decline is accompanied by a reduction in the real interest rate.

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Panel A provides results for a benchmark case, in which there is essentially identical technology in sector 1 and 2 (i.e., we assume that $\alpha_1 = \alpha_2 = 2/3$ so that the technologies are the same up to the constant A_2). The influence of taxation on the growth rate can be dramatic. When there are uniform tax rates of 50%, the economy exhibits growth of −6% per year. When the tax is restricted to sector 1, the growth rate is −2%. The decline in growth is reflected in a decline in the rate of investment according to either investment share measure (s_i and s_i^*), as seen in Figure 4. Since the results of this benchmark experiment suggest a fairly strong role for the incentive effects of public policy, the next two panels indicate perturbations in preferences and technology that mitigate the effects of policy.

When there is a relatively high value of labor's share (human capital's share) in the production of human capital as in Panel B, then these results change in the direction suggested by the prior analyses of Lucas (1988b) and Rebelo (1987). Using a value of $\alpha_2 = .9$, Panel B shows that taxation of only sector 1 output at a 50 % rate leads to a growth rate of 1% when there is a 2% growth rate in the untaxed economy. This indicates that isolation of aspects of the production structure will be central to increasing the precision of the incentive effects of policy on growth. However, there remain substantial welfare implications of variations in growth rates of the magnitude obtained under this extreme value for α_2, as indicated by the analysis of section IV below.

Panel C indicates that preferences also play a role in the determination of the response of the growth rate to the incentive effects of policy. When there is smaller intertemporal substitution in consumption (σ larger), then there is a smaller magnitude influence of taxation on growth, although this

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influence mains negative. For an individual consumer, the value of σ controls the response of the growth rate of consumption to a change in the interest rate, according to the approximate formula, $\Delta \gamma_c = (1/\sigma) \Delta R$. Thus, the value of σ used in panel C implies that a change in the rate of return of 100 basis points results in a change in the growth rate of consumption of only .2% per annum. This reduction in substitution implies that the introduction of a 50% tax in both sectors leads to a decline in the growth rate of 1%, in contrast to the 8% decline shown in panels A and B.

Summary of Closed Economy Results

The results of Tables 8 and 9 indicate the potential explanatory power of the class of endogenous growth models developed—following the path of Uzawa (1965)—in recent work by Jones and Manuelli (1988), Lucas (1988b), and Rebelo (1987). In these models, the influence of policy on growth is governed by preferences—notably the intertemporal rate of substitution—and production possibilities. Hence, further research must focus on refining these specifications, particularly the latter.

Open Economy Experiments

With borrowing and lending possible at constant interest rates, as for a small open economy, policy in a single country may occasion changes in the desirable patterns of borrowing to support profiles of physical and capital accumulation.

In open economy versions of the environment discussed in the previous section, there are dramatic implications of borrowing and lending for growth and capital accumulation, as illustrated by Table 10. To maximize compatibility with the preceding analysis, we start the open economy in a

setting in which it would not trade in the absence of policy, calibrating it so that its domestic interest rate and growth rate are the same as the world's, i.e., R = 1.065 and γ_H = 1.02. In all other ways, the economy matches panel A of Table 9 (σ = 1 and $\alpha_1 = \alpha_2$ = 2/3). Then, we tax the economy's output of sector 1 or of both sectors 1 and 2, permitting it unrestricted borrowing and lending at the given world interest rate. A few percentage points of taxation are typically sufficient to shut down the accumulation of domestic human and physical capital reducing the growth of the economy to its minimum feasible level ($\gamma_H = 1-\delta_H$ = .988). Although few countries with substantial government intervention actually permit unrestricted access to international capital markets, these examples do indicate the potential power of these environments for explaining the "development trap," i.e., economies that appear to be stuck with low levels of national income and slow growth.

IV. Welfare Implications of Taxation

In this section we evaluate the welfare consequences of alternate policies within representative models drawn from the prior two sections. Our objective is to illustrate the general principle that there are larger welfare effects in endogenous growth models.

Method

The method that we employ is based on Lucas (1988a) and is given as follows. Suppose that there is a baseline consumption growth path given by $C_t = C_0\gamma^t$, where γ is the gross growth rate and C_0 is the period zero level of consumption. Now, consider an arbitrary alternative path $\{C_t'\}$. A utility equivalent path with growth rate γ, involves the constant $\tilde{C}_0$ that satisfies

$$U(\{\tilde{C}_0\gamma^t\}) = U(\{C_t'\}). \tag{IV.1}$$

Then, a comparison of the baseline path and the alternative path $\{C_t'\}$ can be reduced to a single number, the ratio $\tilde{C}_0/C_0$. This ratio provides the answer to the question, "at what fraction of initial consumption—growing at rate γ—would the individual just be indifferent between a constant growth path and the alternative path."

IV.1 A Linear Technology Example

The following simple economy provides an opportunity to illustrate our methodology for evaluating welfare implications of taxation, as well as providing a convenient benchmark for the more complex models considered below. Let production at date t depend only on the stock of capital,

$Y_t = A\,K_t$, and let capital evolve according to $K_{t+1} = (1-\delta_K)\,K_t + I_t$. The constraint on an individual's sources and uses of funds is just

$$C_t + I_t \leq (1-\tau)Y_t + T_t,$$

where τ is the tax rate and T is a lump sum transfer payment. In this simple environment, the after tax gross rate of return—which we call $R(\tau)$—is determined solely by technology and tax rates, $R(\tau)=(1-\tau)A + 1-\delta_K$. With a constant elasticity of intertemporal substitution utility function, this specification then implies that the growth rate of consumption is

$$\gamma(\tau) = C_{t+1}/C_t = [\beta R(\tau)]^{(1/\sigma)},$$

where β is the subjective discount factor. Under the assumption that the government rebates the proceeds of commodity taxation, it follows that that $T_t = \tau Y_t$, so that equilibrium accumulation is just $K_{t+1} = (1-\delta_K)\,K_t + AK_t - C_t = R(0)\,K_t - C_t$. This accumulation equation then implies that the initial consumption level satisfies $C_0 = [R(0)-\gamma(\tau)]K_0$, using basic present value conditions. Thus, the equations for $\gamma(\tau)$ and C_0 determine the time profile of consumption for any specification of the tax rate. Notably, this model implies that a permanent change in the tax rate implies an immediate shift in the level of the consumption path and a change in its rate of growth—there are no transitional dynamics.

In this context, then, the method works as follows. First, fix a baseline value of the tax rate τ and compute $\gamma(\tau)$. Second, choose a new value of the tax rate τ', and compute $\gamma(\tau')$ and $C_0(\tau')$. Third, find the constant $\bar{C}_0$ that provides utility equivalent to $U(\{C_0(\tau')\gamma(\tau')^t\})$ when

consumption is growing at the baseline rate $\gamma(\tau)$. Fourth, compute the ratio $\tilde{C}_0/C_0(\tau)$, as a measure of the cost or benefit of the tax variation.[13]

Table 11 provides some experiments with this simple model that provide background to interpreting our subsequent results. In this table, as in our subsequent analysis, we vary $1/\sigma$—the intertemporal elasticity of substitution—and tax wedges. In reading the table, one should recognize that for each value of σ, we chose β so that the economy without taxes displays the same growth rate of consumption (using $\gamma = [\beta R]^{(1/\sigma)}$).

Looking first at the effects of taxation on steady state growth rates (moving across one of the rows in panel A), we find that taxation reduces the growth rate. Looking down the columns, we find that this effect is more pronounced when individuals are more willing to substitute over time (i.e., when σ is small). Given the society's resource constraint ($C_0 = [R(0) - \gamma(\tau)]K_0$), lower growth is associated with a higher initial level of consumption. In panel C, we find that these effects are potentially large. For example, with $\sigma = 1$, there is a 35% increase in initial consumption—relative to the path with no taxes—when τ is increased from 0 to 10%. With relatively high rates of intertemporal substitution, zero gross investment is optimal so that the economy's growth rate is $-\delta = -.10$.

With lower growth due to taxation, welfare unambiguously declines in this economy. Panel B of Table 11 shows the percentage decline in the utility equivalent consumption path—relative to the path with no taxes—when a tax is imposed (this corresponds to the percentage decline in C_0/C_0 in the

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[13]As Ken Judd has pointed out to us, this measure of the welfare effects of taxation would not be appropriate if we were trying to address normative questions, such as the design of an optimal taxation system. In that case, the adequate measure of the welfare effects of taxation would be the marginal deadweight loss—see Judd (1987).

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terminology above). Generally, the welfare cost is higher when there is either more taxation (τ high) or greater substitution in consumption (σ low).

Under some restrictions on technology, the outcomes of our linear technology example will be identical to those of the two sector economy constructed in section III if both sectors are taxed at the same rate. Sufficient technology restrictions are (i) no point in time diminishing returns in human capital (Θ linear); and (ii) sectoral production functions that are Cobb-Douglas with identical shares (but with possibly different multiplicative constants). Thus, the linear technology example provides a benchmark case for the two sector endogenous growth economy.

IV.2 Taxation in the Neoclassical Model

The neoclassical model has been a workhorse of modern public finance, so that the influence of taxation on real activity within this environment is relatively well understood. The imposition of an output tax, for example, occasions a shift in the level of the steady state path—but not its slope—and sets in motion the transitional dynamics discussed in section II.

Table 12 provides a welfare analysis of an increase in the output/income tax rate from .20 to .30 under some alternative assumptions about intertemporal substitution in preferences. The rate of time preference (β) is calibrated so that the steady state real interest rate is 6.5% for each value of σ, so that varying σ has no influence on the steady state path. The remaining values of the model's parameters are those of the baseline economy constructed in section II ($A = 1$; $\delta_K = .10$; $\alpha = 2/3$; $\gamma_X = 1.02$; and $N = .2$).

In the steady state, capital falls by 18.2% and consumption fall by 3.6% due to the increase in the tax rate from 20% to 30%. As Judd (1987) and

Jorgenson and Yun (1988) have stressed, it is inappropriate to evaluate tax policies solely on the basis of these long run effects. This is highlighted in our analysis by the fact that the welfare costs in the neoclassical model would be independent of preferences if the steady state comparison were utilized.

Table 12 presents the results of the policy of raising the income tax rate from 20% to 30% on the welfare measure described above. For example, when $\sigma = 1$, the tax increase lowers the welfare measure by 1.6%. That is, the tax rate increase is equivalent—in utility terms—to an immediate 1.6% shift down in the steady state consumption path. When the intertemporal elasticity of substitution in consumption is increased (σ reduced), then there is an increase in the welfare cost of the tax increase—when $\sigma = 1/10$, it is 1.84%. Symmetrically, when σ is increased, the welfare costs falls—when $\sigma = 10$, it is .97%.

In all cases, the initial consumption level rises in response to the tax increase, so that the economy "works off" the capital stock through lower net investment and transitorily high levels of consumption. With low intertemporal substitution in consumption (high σ), there is a relatively small initial upward jump in consumption, since individuals seek to avoid temporally uneven consumption profiles. The initial upward jump in consumption is highest (roughly 20% of the initial steady state) when there is very high intertemporal substitution ($\sigma = 1/10$).

Relative to the example, the calibrated neoclassical model involves a much smaller welfare loss of taxation. For the example economy, with $\sigma = 1$, the effect of changing τ from .20 to .30 is a decline in the utility equivalent consumption path equal to 30.18% − 16.59% = 13.59%. For the neoclassical model, the effect is 1.60%. Fundamentally, this difference

reflects the fact that the long run growth rate is affected in the linear technology economy but not in the basic neoclassical model.

IV.3 Taxation in the Two-Sector Endogenous Growth Model

The two sector endogenous growth model that we explored in section III involves accumulation of physical capital and human capital, with the latter subject to a diminishing point in time investment technology. In this section, we provide an evaluation of the welfare cost of taxation within this model.

From section III, we know that the steady state rate of economic growth is generally affected by taxation in either sector. For simplicity, we wish to focus on evaluating public policies that induce an immediate shift in the steady state path in the two sector model, as in the example considered in section IV.1. In general, within endogenous growth models, changes in public policies occasion both a shift in the steady state path—both its level and growth rate—as well as setting off transitional dynamics as the economy adjusts toward an altered steady state ratio of physical to human capital. Transitional dynamics do not arise if the preferences, technologies and policy interventions are such that there is no required variation in this ratio. Thus, for the purpose of this section, we restrict the policy rules and technologies: (i) we require that both sectors are taxed at the same rate; and (ii) we require that the depreciation rates of the two capital goods are identical and that the production functions in the two sectors are the same up to a factor of proportionality. With this configuration of restrictions, we can then show that the introduction of diminishing point in time returns to human capital accumulation—necessary to a unique competitive decentralization of aggregate outcomes—does not overturn the comparison of

the endogenous growth and neoclassical models that we made in the previous sections.

Table 13 presents the results of these experiments. The economy is parameterized so that there is equal factor intensity in each sector ($\alpha_1 = \alpha_2 = 2/3$) and the depreciation rates are taken equal ($\delta_K = \delta_H = .10$). Further, as in section III, we assume modest diminishing point in time returns (parameterized by $\theta = .8$, as discussed in appendix A.) In comparison with table 11, the effect of the diminishing point in time investment technology is to mitigate the influence of taxation on growth rates. However, the influence of taxation continues to be important, both in the panel A implications for growth rates and the panel B implications for welfare.

Earlier, we saw that it was possible for taxation to move the example economy to a situation in which no gross investment was undertaken, i.e., the economy contracted at the rate $-\delta$. In the current analysis, this possibility will continue to arise but in more restricted circumstances due to the form of the human capital investment technology.

V. Conclusions

For a lengthy paper, the conclusions should be brief, so we simply list four basic lessons from the paper.

First, there is substantial cross country variation in average rates of growth of percapita income—which occurs without accompanying trends in interest rates, asset prices or factor shares—as noted by Kaldor more than 20 years ago. To us, this suggests that the growth process is potentially described by models in which there are endogenously determined differences in steady state growth rates.

Second, analysis of calibrated versions of the neoclassical model reveals that its transitional dynamics are inconsistent with the stylized facts of growth. Because of the presence of sharply diminishing returns to capital accumulation in these models, comparisons of early and later stages of development imply counterfactual trends in interest rates, asset prices or factor shares. The only way to rescue the neoclassical model is to introduce cross sectional differences in rates of exogenous "technical progress," which augments the productivity of labor, but this does not represent an *explanation* of differences in growth rates.

Third, following Uzawa (1965), Lucas (1988b) and Rebelo (1987), there are a variety of ways to make a comprehensive measure of "technical progress" endogenous in neoclassical analysis. Interpreting this comprehensive measure as social investment in "human capital" provides an important parallel to the work of Schultz (1961, 1981) on economic development. Our analysis uses this link to build some explicit microfoundations for a two sector model of endogenous economic growth. When we calibrate this growth model, we find that public policies can have quantitatively large influences on average rates of economic growth in economies that operate in isolation. Policies

display these effects—as in Schultz (1981)—because they influence private incentives for accumulation of physical and human capital. These incentive effects of taxation are reinforced in open economies that have access to international capital markets.

Fourth, since policies have the potential to influence the growth rate in models with endogenous long run growth, there is potentially a much larger quantitative influence of policies on welfare than in the neoclassical model where the growth rate is governed by the exogenous rate of technical progress. Some experiments comparing neoclassical and endogenous growth models suggest that this difference can be quantitatively important. It is relatively easy to generate situations in which countries stagnate or even regress for lengthy periods, if policies eliminate the incentives for growth that are provided by technology. This explanation of "no growth steady states" contrasts with that offered by Becker, Murphy and Tamura (1988) and Azariadis and Drazen (1988), where aspects of the technology give rise to multiple steady states so that economies with different initial conditions may converge to steady states with different rates of growth even in the absence of cross-country heterogeneity in public policy.

This paper demonstrates that the most basic class of models of endogenous economic growth—stemming from Uzawa (1965)—contains quantitatively important influences of public policy on steady state economic growth. The precise magnitudes of these incentive effects of taxation and analogous policies depends—as in any equilibrium framework—on the specification of preferences, technology and policy rules. As in other macroeconomic contexts, then, our analysis of growth models points to sets of microeconomic measurements that will prove valuable in determining the magnitudes of policy effects. Further, we find that the extent of access to international capital

markets substantially influences the impact of tax policy on economic growth. In summary, with the results of the present paper, we find new promise for the hypotheses of Schultz (1981) that incentive effects of policy can influence economic activity—taxation can readily lead to development traps and growth miracles. Models of endogenous economic growth thus provide new analytical paths for old problems in the economics of development.

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TABLE 1

GROWTH RATE OF PERCAPITA REAL GDP : 1950-1981

Country	*Mean*	*Standard Deviation*	*Number of Observations*
AFRICA			
ALGERIA	0.0243	0.0876	21
ANGOLA	-0.0129	0.1055	21
BENIN	-0.0006	0.0382	22
BOTSWANA	0.0755	0.0668	21
BURUNDI	-0.0109	0.0704	21
CAMEROON	0.0275	0.0310	21
CENTRAL AFRICAN REP.	-0.0078	0.0313	21
CHAD	-0.0249	0.0817	21
CONGO, PEOP. REP. OF	0.0239	0.0487	21
EGYPT, ARAB REP. OF	0.0311	0.0352	31
ETHIOPIA	0.0138	0.0250	31
GABON	0.0776	0.1174	21
GAMBIA, THE	0.0180	0.1602	21
GHANA	-0.0084	0.0625	26
GUINEA	-0.0008	0.0382	22
IVORY COAST	0.0271	0.0451	21
KENYA	0.0066	0.0533	31
LESOTHO	0.0500	0.0761	21
LIBERIA	0.0061	0.0509	21
MADAGASCAR	-0.0098	0.0328	21
MALAWI	0.0247	0.0439	28
MALI	-0.0079	0.0419	21
MAURITANIA	0.0112	0.0716	21
MAURITIUS	0.0112	0.0553	31
MOROCCO	0.0234	0.0520	31
MOZAMBIQUE	-0.0044	0.0617	21
NIGER	0.0199	0.0843	21
NIGERIA	0.0298	0.0736	31
RWANDA	0.0259	0.1075	21
SENEGAL	-0.0170	0.0504	21
SIERRA LEONE	0.0126	0.0458	21
SOMALIA	0.0009	0.0665	21
S. AFRICA	0.0192	0.0338	31
SUDAN	0.0130	0.0905	26
SWAZILAND	0.0541	0.0617	21
TANZANIA, UNITED REP	0.0225	0.0456	21
TOGO	0.0265	0.0545	21
TUNISIA	0.0439	0.0349	21
UGANDA	0.0034	0.0502	31

PPER VOLTA	0.0047	0.0790	21
AIRE	0.0104	0.0773	31
AMBIA	0.0055	0.1002	26
IMBABWE	0.0085	0.0490	28
ASIA			
FGHANISTAN	-0.0073	0.0519	21
ANGLADESH	0.0103	0.0590	22
URMA	0.0238	0.0571	31
ONG KONG	0.0741	0.0431	21
NDIA	0.0141	0.0427	31
RAN	0.0263	0.1025	26
RAQ	0.0160	0.1186	28
SRAEL	0.0355	0.0466	31
APAN	0.0653	0.0381	31
ORDAN	0.0286	0.1000	28
OREA, REP. OF	0.0467	0.0464	28
ALAYSIA	0.0411	0.0362	26
EPAL	0.0123	0.0407	21
AKISTAN	0.0189	0.0365	31
HILIPPINES	0.0275	0.0268	31
INGAPORE	0.0666	0.0387	21
RI LANKA	0.0089	0.0704	31
YRIAN ARAB REP.	0.0535	0.1034	21
AIWAN	0.0532	0.0283	31
HAILAND	0.0303	0.0433	31
EUROPE			
USTRIA	0.0414	0.0284	31
ELGIUM	0.0297	0.0240	31
YPRUS	0.0411	0.1072	31
ENMARK	0.0274	0.0328	31
INLAND	0.0361	0.0313	31
RANCE	0.0355	0.0187	31
ERMANY, FED. REP.	0.0422	0.0341	31
REECE	0.0464	0.0364	31
CELAND	0.0288	0.0526	31
RELAND	0.0266	0.0230	31
TALY	0.0389	0.0313	31
UXEMBOURG	0.0195	0.0389	31
ALTA	0.0566	0.0483	28
ETHERLANDS	0.0294	0.0344	31
ORWAY	0.0337	0.0199	31
ORTUGAL	0.0469	0.0507	31
PAIN	0.0415	0.0369	31
WEDEN	0.0257	0.0211	31
WITZERLAND	0.0246	0.0330	31
URKEY	0.0354	0.0451	31
NITED KINGDOM	0.0189	0.0218	31

NORTH & CENTRAL AMERICA			
BARBADOS	0.0350	0.0520	31
CANADA	0.0247	0.0286	31
COSTA RICA	0.0271	0.0440	31
DOMINICAN REP.	0.0254	0.0564	31
EL SALVADOR	0.0086	0.0489	31
GUATEMALA	0.0168	0.0216	31
HAITI	0.0085	0.0353	21
HONDURAS	0.0121	0.0265	31
JAMAICA	0.0211	0.0514	28
MEXICO	0.0301	0.0240	31
NICARAGUA	0.0210	0.0772	31
PANAMA	0.0276	0.0293	31
TRINIDAD AND TOBAGO	0.0383	0.0339	31
UNITED STATES	0.0190	0.0270	31
SOUTH AMERICA			
ARGENTINA	0.0141	0.0529	31
BOLIVIA	0.0109	0.0415	31
BRAZIL	0.0376	0.0341	31
CHILE	0.0187	0.0451	31
COLOMBIA	0.0224	0.0337	31
ECUADOR	0.0292	0.0352	31
GUYANA	0.0035	0.0617	31
PARAGUAY	0.0241	0.0369	31
PERU	0.0201	0.0308	31
SURINAM	0.0276	0.0737	21
URUGUAY	0.0122	0.0493	31
VENEZUELA	0.0130	0.0383	31
OCEANIA			
AUSTRALIA	0.0212	0.0304	31
FIJI	0.0267	0.0594	21
INDONESIA	0.0364	0.0426	21
NEW ZEALAND	0.0137	0.0316	31
PAPUA NEW GUINEA	0.0161	0.0522	21

Source: Summers and Heston (1984).

TABLE 2

THE RATE OF GROWTH OF GNP PERCAPITA
1870 - 1979: SUMMARY STATISTICS

Countries	Time Period	Average Growth Rate	Trend	R^2
Australia	1870-1979	1.1	2.1 E-2 (1.4 E-2)	.02
Austria	1870-1912	1.5	1.2 E-2 (2.9 E-2)	.00
	1920-1979	2.9	6.0 E-2 (10.3 E-2)	.01
Belgium	1870-1913	1.0	-.2 E-2 (1.7 E-2)	.00
	1949-1979	3.3	.8 E-2 (4.3 E-2)	.00
Canada	1870-1979	2.0	1.5 E-2 (2.7 E-2)	.00
Denmark	1870-1979	1.6	1.9 E-2 (1.3 E-2)	.02
Finland	1900-1979	2.5	5.0 E-2 (3.2 E-2)	.03
France	1870-1979	1.9	(a) 2.7 E-2 (1.9 E-2)	.02
Germany	1870-1979	2.5	3.7 E-2 (3.0 E-2)	.01
Italy	1870-1979	1.6	3.9 E-2 (1.8 E-2)	.04
Japan	1886-1944	1.7	-2.3 E-2 (4.6 E-2)	.00
	1948-1979	7.2	-14.9 E-2 (6.5 E-2)	.15
Netherlands	1900-1979	1.8	4.5 E-2 (4.4 E-2)	.01
Norway	1870-1979	2.1	2.8 E-2 (1.1 E-2)	.05
Sweden	1870-1979	2.3	(b) 1.1 E-2 (1.2 E-2)	.00
Switzerland	1925-1944	.9	-.2 E-2 (1.2 E-2)	.19
	1948-1979	2.2	-6.7 E-2 (6.2 E-2)	.04
United Kingdom	1870-1979	1.3	1.4 E-2 (1.0 E-2)	.02
USA	1870-1979	1.9	(a) .4 E-2 (1.6 E-2)	.00

Source: Maddison (1982). E-2 denotes 10^{-2}. Units are percentage points. Standard errors in parenthesis. Time periods dictated by data availability. (a) corrected for MA(1) residuals; (b) corrected for AR(1) residuals.

TABLE 3

HISTORICAL EVIDENCE ON LONG-TERM INTEREST RATES

Date	England	France	Dutch Republic Holland—	Spanish Netherlands— Belgium	Germany	Sweden	Spain	Switzerland	Italy	United States	Canada
	Minimum Rates on Best Credits by Half Centuries*										
13th century											
1st half				8.00							
2nd half		14.00		8.00					6 5/8		
14th century											
1st half				8.00					4 7/8		
2nd half				8.00					5 1/4		
15th century											
1st half		10.00		8.00			4.00		6.00		
2nd half		10.00		8.00	5.00		4.00		5.00		
16th century											
1st half	10.00	8 1/3	8 1/3	4.00	4.00				4.00		
2nd half	10.00	8 1/3	6 1/6	4.00	4.00				4.00		
17th century											
1st half	8.00	8 1/3	5.00								
2nd half	4.00	5.00	3.00								
18th century											
1st half	3.05	5.00	3.00		4.00			5.00	4.00		
2nd half	3.13	5.00	2.50		4.00			4.00	4.00		
19th century											
1st half	3.26	4.06	4.53	4.53	3.84					4.55	
2nd half	2.47	3.03	2.93	2.71	3.53	3.68				3.23	
20th century											
1st half	2.79	3.06	3.20	2.94	3.64	3.04		3.31		2.31	2.93

* Lowest decennial average where available; otherwise lowest reported rate. Lowest yield or yields are underlined for each time period. All yields in annual terms and expressed in percentage points.

Source: Homer: (1963)

TABLE 3 (Continued)

HISTORICAL EVIDENCE ON SHORT-TERM INTEREST RATES

Date	England	France	Dutch Republic Holland—	Spanish Netherlands— Belgium	Germany	Sweden	Switzerland	Italy	United States	Canada
	Minimum Rates on Best Credits by Half Centuries*									
13th century										
1st half				10.00				20.00		
2nd half		15.00		10.00				8.00		
14th century										
1st half		15.00		10.00				7.00		
2nd half		15.00		10.00				5.00		
15th century										
1st half	10.00			5.00	5.00			5.00		
2nd half	10.00			5.00	5.00			5.00		
16th century										
1st half		5.00		4.00	4.50			4.00		
2nd half		8.00		6.25	5.00			5.00		
17th century										
1st half	6.00		6.00							
2nd half	3.00[a]		1.75			6.00				
18th century										
1st half	3.00[b]	4.00	1.75			4.00				
2nd half	5.00[a]	4.00	2.00			3.00				
19th century										
1st half	3.57[b]	4.00[a]	2.87	3.71	3.90	4.00	4.11		7.99	
2nd half	2.09[b]	2.09[b]	2.04	2.29	2.97	4.17	3.35		4.51	
20th century										
1st half	0.83[b]	1.69[b]	1.26	1.83	2.18	2.80	1.33		0.87	1.90

* Lowest decennial average where available; otherwise lowest reported rate. Lowest yield or yields are underlined for each time period. All yields in annual terms and expressed in percentage points. [a] official discount rate. [b] free open market rate.
Source: Homer: (1963)

TABLE 4

ANNUAL REAL RATES OF RETURN: SUMMARY STATISTICS

US Securities, 1926 - 1981

Series	*Average Real Rate of Return*	*Trend*	*D-W*	R^2
Common Stocks	8.3	-.19 (.18)	2.00	.02
Small Stocks	14.9	-.06 (.31)	1.84	.00
Long Term Corporate Bonds*	.8	-.23 (.09)	1.94	.27
US Treasury Bills*	.01	-.00 (.008)	1.76	.40
Long Term Government Bonds	.08	-.22 (.07)	1.82	.17

Source: Ibbotson and Sinquefield (1982). Standard errors in parenthesis. D-W denotes the Durbin-Watson test. Units are percentage points.

* Corrected for first order autocorrelation.

Table 5A
Behavior of Real Interest Rates in the Neoclassical Model
Real Interest Rate 100 years ago—Cobb-Douglas Production Function

Fraction of Growth Due to Transitional Dynamics	γ_x	Baseline Model (%)	Depreciation Rate $\delta = 0$ (%)	Depreciation Rate $\delta = .25$	Labor Supply $N_0 = .36$ (%)	Capital Share $\alpha_k = .5$ (%)	Capital Share $\alpha_k = .9$	End of Period Real Interest Rate $r_T = 4\%$ (%)	End of Period Real Interest Rate $r_T = 9\%$
0%	2%	6.5	6.5	6.5	43.5	6.5	6.5	4.0	9.0
25%	1.5%	16.7	10.5	26.0	76.6	11.0	6.9	12.7	20.8
50%	1%	40.5	19.9	71.5	153.7	18.9	7.6	32.9	48.2
75%	.5%	119.4	51.0	222.0	409.1	36.2	8.5	99.8	139.0
100%	0%	798.5	318.5	1518.5	2609.2	105.5	10.5	676.0	921.0

Table 5B
Real Interest Rate (r_o) and Capital Share (α_{ko}) 100 years ago
CES Production Function with Elasticity of Substitution ρ

Fraction of Growth Due to Transitional Dynamics	γ_x	$\rho = .9$ r_0	$\rho = .9$ α_{k0}	$\rho = .5$ r_0	$\rho = .5$ α_{k0}	$\rho = 1.1$ r_0	$\rho = 1.1$ α_{k0}	$\rho = 1.25$ r_0	$\rho = 1.25$ α_{k0}
0%	2%	6.5	33.3	6.5	33.3	6.5	33.3	6.5	33.3
25%	1.5%	17.6	35.1	23.7	47.6	16.0	31.9	15.0	30.0
50%	1%	41.5	37.4	46.9	61.9	39.7	29.9	38.6	25.4
75%	.5%	106.8	40.5	76.2	76.2	136.6	26.8	180.2	18 [illegible]
100%	0%	430.7	46.3	111.6	90.5	2193.2	20.4	2993474.3	1.6

Table 6A
Transitional Dynamics, One-Sector Neoclassical Model

Parameterizations		Time Period (each period has 5 years) 1	2	3	4	5	6	7	8	9	10
1) BASELINE MODEL	Half life = 8 years										
	Average Growth of Capital	165.1	13.3	4.2	1.6	0.7	0.3	0.1	0.1	0.0	0.0
	Average Growth Rate of Output	38.4	4.2	1.4	0.5	0.2	0.1	0.0	0.0	0.0	0.0
	Average Real Interest Rate	129.2	15.7	9.4	7.6	7.0	6.7	6.6	6.6	6.5	6.5
2) LOW INTERTEMPORAL SUBSTITUTION (σ = 20)	Half life = 61 years										
	Average Growth of Capital	29.4	19.3	13.6	10.1	7.8	6.2	5.1	4.3	3.7	3.4
	Average Growth Rate of Output	9.0	6.1	4.3	3.3	2.5	2.0	1.7	1.4	1.2	1.1
	Averaage Real Interest Rate	550.5	257.3	149.2	99.0	71.5	54.8	43.8	36.1	30.4	26.0
3) STONE-GEARY UTILITY ($\bar{c}$ = .04)	Half life = 12 years										
	Average Growth Rate of Capital	104.1	35.4	9.3	3.6	1.5	0.7	0.3	0.1	0.1	0.0
	Averaage Growth Rate of Output	26.8	10.6	3.0	1.2	0.5	0.2	0.1	0.0	0.0	0.0
	Average Real Interest Rate	394.6	36.3	13.8	9.3	7.7	7.0	6.8	6.6	6.6	6.5
4) HIGH CAPITAL SHARE (α_k = .5)	Half life = 13 years										
	Average Growth Rate of Capital	60.4	16.3	7.2	3.7	2.1	1.2	0.7	0.4	0.2	0.1
	Average Growth Rate of Output	26.6	7.8	3.6	1.8	1.0	0.6	0.3	0.2	0.1	0.1
	Average Real Interest Rate	55.7	19.9	12.5	9.6	8.2	7.5	7.1	6.8	6.7	6.6
5) VERY HIGH CAPITAL SHARE (α_k = .9)	Half life = 80 years										
	Average Growth Rate of Capital	3.7	3.3	3.0	2.8	2.5	2.3	2.1	1.9	1.8	1.6
	Average Growth Rate of Output	3.3	3.0	2.7	2.5	2.3	2.1	1.9	1.7	1.6	1.5
	Average Real Interest Rate	10.3	10.0	9.7	9.4	9.1	8.9	8.7	8.5	8.3	8.2

Table 6B

Transitional Dynamics, Two-Sector Neoclassical Model

Parameterizations		Time Period (each period has 5 years) 1	2	3	4	5	6	7	8	9	10
1) LABOR SHARE Capital sector = .5 Consumption sector = .75	Half life = 11 years										
	Average Growth of Capital	66.3	15.7	6.4	3.0	1.5	0.8	0.4	0.2	0.1	0.1
	Average Growth Rate of Output	13.3	3.6	1.5	0.7	0.4	0.2	0.1	0.1	0.0	0.0
	Average Real Interest Rate	59.9	19.1	11.7	9.0	7.8	7.2	6.9	6.7	6.6	6.6
2) LABOR SHARE Capital sector = .5 Consumption sector = .25	Half life = 15 years										
	Average Growth Rate of Capital	54.3	16.6	8.0	4.4	2.6	1.6	1.0	0.7	0.4	0.3
	Average Growth Rate of Output	38.1	12.0	5.8	3.2	1.9	1.2	0.8	0.5	0.3	0.2
	Average Real Interest Rate	51.3	20.4	13.2	10.3	8.7	7.9	7.4	7.1	6.9	6.7

Each period has 5 years. All rates reported are the average over the five-year period in annual terms and expressed in percentage points.

Table 6C

Transitional Dynamics, Quadratic Adjustment Costs Model

Parameterizations		Time Period (each period has 5 years) 1	2	3	4	5	6	7	8	9	10
1) b = 32.2	Half life = 47										
	Average Growth Rate of Capital	45.0	22.8	14.2	9.8	7.2	5.5	4.3	3.4	2.7	2.2
	Average Growth Rate of Output	13.2	7.1	4.5	3.2	2.3	1.8	1.4	1.1	0.9	0.7
	Average Real Interest Rate	22.7	15.2	12.0	10.2	9.2	8.5	8.0	7.7	7.4	7.2
	Average Tobin's Q	13.4	7.6	5.2	4.0	3.2	2.7	2.3	2.0	1.8	1.7
2) b = 2.0	Half life = 14										
	Average Growth Rate of Capital	108.8	25.7	10.3	4.9	2.6	1.4	0.8	0.4	0.2	0.1
	Average Growth Rate of Output	27.8	7.9	3.3	1.6	0.8	0.5	0.3	0.1	0.1	0.0
	Average Real Interest Rate	37.6	16.5	11.0	8.8	7.7	7.2	6.9	6.7	6.6	6.6
	Average Tobin's Q	2.6	1.4	1.2	1.1	1.0	1.0	1.0	1.0	1.0	1.0

Each period has 5 years. All rates reported are the average over the five-year period in annual terms and expressed in percentage points.

Table 7
Transitional Dynamics, Open Economy with Adjustment Costs

Parameterizations		Time Period (each period has 5 years) 1	2	3	4	5	6	7	8	9	10
1) b = 32.2	Half life = 37										
	Average Growth Rate of Capital	64.1	22.6	12.5	8.1	5.7	4.3	3.3	2.6	2.0	1.6
	Average Growth Rate of Output	18.0	7.0	4.0	2.6	1.9	1.4	1.1	0.8	0.7	0.5
	Average Tobin's Q	22.4	8.3	5.0	3.6	2.8	2.4	2.0	1.8	1.7	1.5
2) b = 2.0	Half life = 9										
	Average Growth Rate of Capital	146.3	19.5	5.8	2.0	0.7	0.3	0.1	0.0	0.0	0.0
	Average Growth Rate of Output	35.0	6.1	1.9	0.7	0.2	0.1	0.0	0.0	0.0	0.0
	Average Tobin's Q	4.6	1.4	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Each period has 5 years. All rates reported are the average over the five-year period in annual terms and expressed in percentage points.

Table 8
Effects of Technology Parameters on Calibrated Steady State

A. Alternate Values of Labor's Share (α_2) with $\delta_H = \delta_k = .10$

Technology Parameters				Tax Rates		Investment Shares		Prices		Interest Rate	Growth Rate
A1	A2	α_1	α_2	τ_1	τ_2	s_i	s_i^*	p	w	R	γ_H
1.0000	0.0323	0.6667	0.0100	0	0	0.5911	0.3982	5.5061	0.9476	1.0650	1.0200
1.0000	0.0494	0.6667	0.1000	0	0	0.5816	0.3831	5.5061	0.9476	1.0650	1.0200
1.0000	0.0701	0.6667	0.2000	0	0	0.5693	0.3645	5.5061	0.9476	1.0650	1.0200
1.0000	0.0933	0.6667	0.3000	0	0	0.5548	0.3438	5.5061	0.9476	1.0650	1.0200
1.0000	0.1182	0.6667	0.4000	0	0	0.5373	0.3206	5.5061	0.9476	1.0650	1.0200
1.0000	0.1436	0.6667	0.5000	0	0	0.5158	0.2944	5.5061	0.9476	1.0650	1.0200
1.0000	0.1676	0.6667	0.6000	0	0	0.4890	0.2647	5.5061	0.9476	1.0650	1.0200
1.0000	0.1823	0.6667	0.6700	0	0	0.4657	0.2413	5.5061	0.9476	1.0650	1.0200
1.0000	0.1876	0.6667	0.7000	0	0	0.4543	0.2305	5.5061	0.9476	1.0650	1.0200
1.0000	0.2001	0.6667	0.8000	0	0	0.4077	0.1908	5.5061	0.9476	1.0650	1.0200
1.0000	0.2000	0.6667	0.9000	0	0	0.3421	0.1443	5.5061	0.9476	1.0650	1.0200
1.0000	0.1789	0.6667	0.9900	0	0	0.2546	0.0950	5.5061	0.9476	1.0650	1.0200

B. Alternate Values of Labor's Share (α_2) with $\delta_H = .0128$ and $\delta_k = .10$

Technology Parameters				Tax Rates		Investment Shares		Prices		Interest Rate	Growth Rate
A1	A2	α_1	α_2	τ_1	τ_2	s_i	s_i^*	p	w	R	γ_H
1.0000	0.0148	0.6667	0.0100	0	0	0.4445	0.3471	11.9949	0.9476	1.0650	1.0200
1.0000	0.0227	0.6667	0.1000	0	0	0.4334	0.3355	11.9949	0.9476	1.0650	1.0200
1.0000	0.0322	0.6667	0.2000	0	0	0.4199	0.3218	11.9949	0.9476	1.0650	1.0200
1.0000	0.0428	0.6667	0.3000	0	0	0.4052	0.3070	11.9949	0.9476	1.0650	1.0200
1.0000	0.0543	0.6667	0.4000	0	0	0.3890	0.2912	11.9949	0.9476	1.0650	1.0200
1.0000	0.0659	0.6667	0.5000	0	0	0.3710	0.2741	11.9949	0.9476	1.0650	1.0200
1.0000	0.0770	0.6667	0.6000	0	0	0.3511	0.2556	11.9949	0.9476	1.0650	1.0200
1.0000	0.0837	0.6667	0.6700	0	0	0.3357	0.2417	11.9949	0.9476	1.0650	1.0200
1.0000	0.0861	0.6667	0.7000	0	0	0.3287	0.2356	11.9949	0.9476	1.0650	1.0200
1.0000	0.0919	0.6667	0.8000	0	0	0.3036	0.2137	11.9949	0.9476	1.0650	1.0200
1.0000	0.0918	0.6667	0.9000	0	0	0.2751	0.1898	11.9949	0.9476	1.0650	1.0200
1.0000	0.0821	0.6667	0.9900	0	0	0.2459	0.1664	11.9949	0.9476	1.0650	1.0200

Effects of Taxation on Steady State Growth

A. Alternate Tax Rates with α_2 = .67 and σ = 1

Technology Parameters				Tax Rates		Investment Shares		Prices		Interest Rate	Growth Rate
A1	A2	α_1	α_2	τ_1	τ_2	s_1	s_1^*	p	w	R	γ_H
1.0000	0.0834	0.6667	0.6667	0.5000	0.5000	0.0969	0.1069	11.9949	0.3926	1.0202	0.9771
1.0000	0.0834	0.6667	0.6667	0.5000	0	0.1394	0.1268	5.9974	0.3560	1.0461	1.0019
1.0000	0.0834	0.6667	0.6667	0.4000	0.4000	0.1302	0.1325	11.9949	0.4984	1.0288	0.9853
1.0000	0.0834	0.6667	0.6667	0.4000	0	0.1762	0.1533	7.1969	0.4609	1.0506	1.0062
1.0000	0.0834	0.6667	0.6667	0.3000	0.3000	0.1694	0.1590	11.9949	0.6076	1.0377	0.9938
1.0000	0.0834	0.6667	0.6667	0.3000	0	0.2145	0.1782	8.3964	0.5731	1.0547	1.0101
1.0000	0.0834	0.6667	0.6667	0.2000	0.2000	0.2157	0.1863	11.9949	0.7191	1.0467	1.0025
1.0000	0.0834	0.6667	0.6667	0.2000	0	0.2541	0.2013	9.5959	0.6920	1.0584	1.0137
1.0000	0.0834	0.6667	0.6667	0.1000	0.1000	0.2706	0.2141	11.9949	0.8326	1.0558	1.0112
1.0000	0.0834	0.6667	0.6667	0.1000	0	0.2948	0.2227	10.7954	0.8170	1.0618	1.0170
1.0000	0.0834	0.6667	0.6667	0	0	0.3365	0.2424	11.9949	0.9476	1.0650	1.0200
1.0000	0.0834	0.6667	0.6667	-0.1000	-0.1000	0.4164	0.2712	11.9949	1.0638	1.0743	1.0289

B. Alternate Tax Rates with α_2 = .9 and σ = 1

Technology Parameters				Tax Rates		Investment Shares		Prices		Interest Rate	Growth Rate
A1	A2	α_1	α_2	τ_1	τ_2	s_1	s_1^*	p	w	R	γ_H
1.0000	0.0918	0.6667	0.9000	0.5000	0.5000	0.1071	0.1127	10.3864	0.3857	1.0245	0.9812
1.0000	0.0918	0.6667	0.9000	0.5000	0	0.1326	0.1121	4.7778	0.3424	1.0580	1.0133
1.0000	0.0918	0.6667	0.9000	0.4000	0.4000	0.1348	0.1327	10.8309	0.4914	1.0325	0.9889
1.0000	0.0918	0.6667	0.9000	0.4000	0	0.1606	0.1304	6.0871	0.4476	1.0598	1.0150
1.0000	0.0918	0.6667	0.9000	0.3000	0.3000	0.1648	0.1509	11.1967	0.6012	1.0406	0.9966
1.0000	0.0918	0.6667	0.9000	0.3000	0	0.1889	0.1472	7.4701	0.5613	1.0613	1.0165
1.0000	0.0918	0.6667	0.9000	0.2000	0.2000	0.1977	0.1667	11.5043	0.7141	1.0487	1.0044
1.0000	0.0918	0.6667	0.9000	0.2000	0	0.2175	0.1626	8.9194	0.6829	1.0627	1.0178
1.0000	0.0918	0.6667	0.9000	0.1000	0.1000	0.2340	0.1798	11.7671	0.8298	1.0569	1.0122
1.0000	0.0918	0.6667	0.9000	0.1000	0	0.2462	0.1768	10.4292	0.8118	1.0639	1.0189
1.0000	0.0918	0.6667	0.9000	0	0	0.2751	0.1898	11.9949	0.9476	1.0650	1.0200
1.0000	0.0918	0.6667	0.9000	-0.1000	-0.1000	0.3229	0.1965	12.1945	1.0672	1.0731	1.0278

C. Alternate Tax Rates with α_2 = .67 and σ = 5

Technology Parameters				Tax Rates		Investment Shares		Prices		Interest Rate	Growth Rate
A1	A2	α_1	α_2	τ_1	τ_2	s_1	s_1^*	p	w	R	γ_H
1.0000	0.0834	0.6667	0.6667	0.5000	0.5000	0.2051	0.1548	11.9949	0.3933	1.0197	1.0112
1.0000	0.0834	0.6667	0.6667	0.5000	0	0.1982	0.1591	5.9974	0.3563	1.0458	1.0163
1.0000	0.0834	0.6667	0.6667	0.4000	0.4000	0.2341	0.1759	11.9949	0.4992	1.0284	1.0129
1.0000	0.0834	0.6667	0.6667	0.4000	0	0.2274	0.1783	7.1969	0.4612	1.0504	1.0172
1.0000	0.0834	0.6667	0.6667	0.3000	0.3000	0.2611	0.1943	11.9949	0.6073	1.0378	1.0147
1.0000	0.0834	0.6667	0.6667	0.3000	0	0.2557	0.1960	8.3964	0.5734	1.0545	1.0180
1.0000	0.0834	0.6667	0.6667	0.2000	0.2000	0.2873	0.2120	11.9949	0.7197	1.0464	1.0164
1.0000	0.0834	0.6667	0.6667	0.2000	0	0.2833	0.2125	9.5959	0.6922	1.0583	1.0187
1.0000	0.0834	0.6667	0.6667	0.1000	0.1000	0.3122	0.2278	11.9949	0.8329	1.0557	1.0182
1.0000	0.0834	0.6667	0.6667	0.1000	0	0.3101	0.2279	10.7954	0.8171	1.0618	1.0194
1.0000	0.0834	0.6667	0.6667	0	0	0.3365	0.2424	11.9949	0.9476	1.0650	1.0200
1.0000	0.0834	0.6667	0.6667	-0.1000	-0.1000	0.3602	0.2561	11.9949	1.0633	1.0744	1.0218

Table 10
Effects of Taxation on Small Open Economy

Tax Rate τ_1	Tax Rate τ_2	Growth Rate γ_H
.050	.050	.9872*
.050	0	.9872*
.025	.025	.9872*
.025	0	.9923
.010	.010	.9881
.010	0	1.0080
0	0	1.0200

Economy is calibrated so that closed economy version is equivalent to panel A, Table 9, i.e., $A_1 = 1$, $A_2 = .0834$, $\alpha_1 = \alpha_2 = 2/3$, $\delta_K = .10$, $\delta_H = .0128$, and $\sigma = 1$. An asterisk indicates human capital investment is zero.

Table 11
Tax Effects on Growth in Example Economy
A. Growth of Consumption (γ)

σ \ τ	0	0.10	0.20	0.30
10.00	2.00	1.84	1.68	1.52
5.00	2.00	1.68	1.36	1.03
2.00	2.00	1.21	0.41	-0.40
1.00	2.00	0.42	-1.16	-2.74
0.50	2.00	-1.14	-4.22	-7.26
0.20	2.00	-5.66	-10.00	-10.00
0.10	2.00	-10.00	-10.00	-10.00

B. Welfare Effect

$$100\,[1 - (\tilde{C}_0/C_0)]$$

σ \ τ	0	0.10	0.20	0.30
10.00	0	0.82	4.71	35.23
5.00	0	1.54	7.94	28.46
2.00	0	3.27	13.29	30.38
1.00	0	5.16	16.59	30.18
0.50	0	7.05	17.77	27.48
0.20	0	8.22	-----	-----
0.10	0	----	-----	-----

C. Initial Consumption Effect

$$100\,[(C_0'/C_0) - 1]$$

σ \ τ	0	0.10	0.20	0.30
10.00	0	3.54	7.12	10.76
5.00	0	7.07	14.22	21.47
2.00	0	17.63	35.39	53.30
1.00	0	35.12	70.23	105.35
0.50	0	69.69	138.29	205.81
0.20	0	170.23	------	------
0.10	0	------	------	------

----- indicates economy contracts at rate $-\delta$. Hence, welfare and initial consumption effects are not calculated.

Table 12
Taxation in the Neoclassical Model
Increase in Tax Rate from τ = .20 to τ = .30

A. Steady State Effects

	c	% Decline	k	% Decline
τ = .20	.2049		.4109	
τ = .30	.1975	3.6	.3363	18.2

B. Full Transition Path Effects

Preference Parameter	Initial Consumption Level	% Decline in Utility Equivalent Consumption Path
σ = 10	.2080	.97
σ = 5	.2160	1.21
σ = 2	.2140	1.46
σ = 1	.2184	1.60
σ = 1/2	.2243	1.71
σ = 1/5	.2346	1.80
σ = 1/10	.2439	1.84

Table 13
Tax Effects on Growth in Two-Sector Economy
A. Growth of Consumption (γ)

σ \ τ	0	0.10	0.20	0.30
10.00	2.00	1.84	1.68	1.52
5.00	2.00	1.69	1.37	1.05
2.00	2.00	1.22	0.44	-0.36
1.00	2.00	0.46	-1.09	-2.64
0.50	2.00	-1.01	-3.97	-6.89
0.20	2.00	-4.87	-10.00	-10.00
0.10	2.00	-9.45	-10.00	-10.00

B. Welfare Effect
$100\ [1 - (\tilde{C}_0/C_0)]$

σ \ τ	0	0.10	0.20	0.30
10.00	0	0.88	4.68	27.42
5.00	0	1.58	7.81	26.96
2.00	0	3.26	13.06	29.72
1.00	0	5.12	16.40	29.90
0.50	0	7.02	17.79	27.72
0.20	0	8.44	-----	-----
0.10	0	8.53	-----	-----

C. Initial Consumption Effect
$100\ [(C_0'/C_0) - 1]$

σ \ τ	0	0.10	0.20	0.30
10.00	0	3.39	6.81	10.25
5.00	0	6.85	13.76	20.74
2.00	0	17.13	34.37	51.73
1.00	0	33.94	67.77	101.48
0.50	0	66.16	130.25	192.08
0.20	0	149.57	------	------
0.10	0	245.07	------	------

----- indicates economy contracts at rate $-\delta$. Hence, welfare and initial consumption effects are not calculated.

FIGURE 1

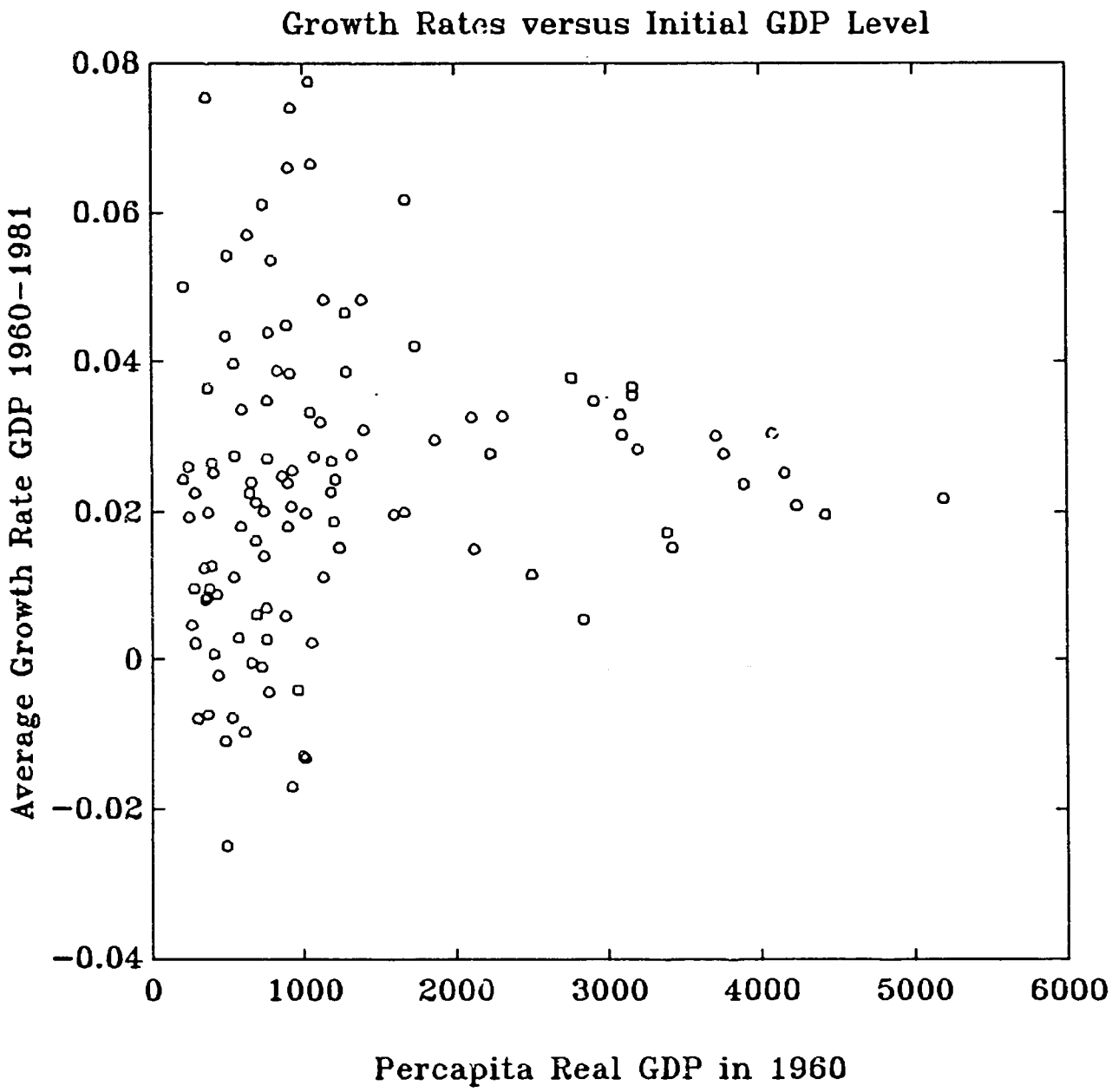

Growth Rates versus Initial GDP Level
Average Growth Rate GDP 1960-1981
0.08
0.06
0.04
0.02
0
-0.02
-0.04
0
1000
2000
3000
4000
5000
6000
Percapita Real GDP in 1960

FIGURE 2

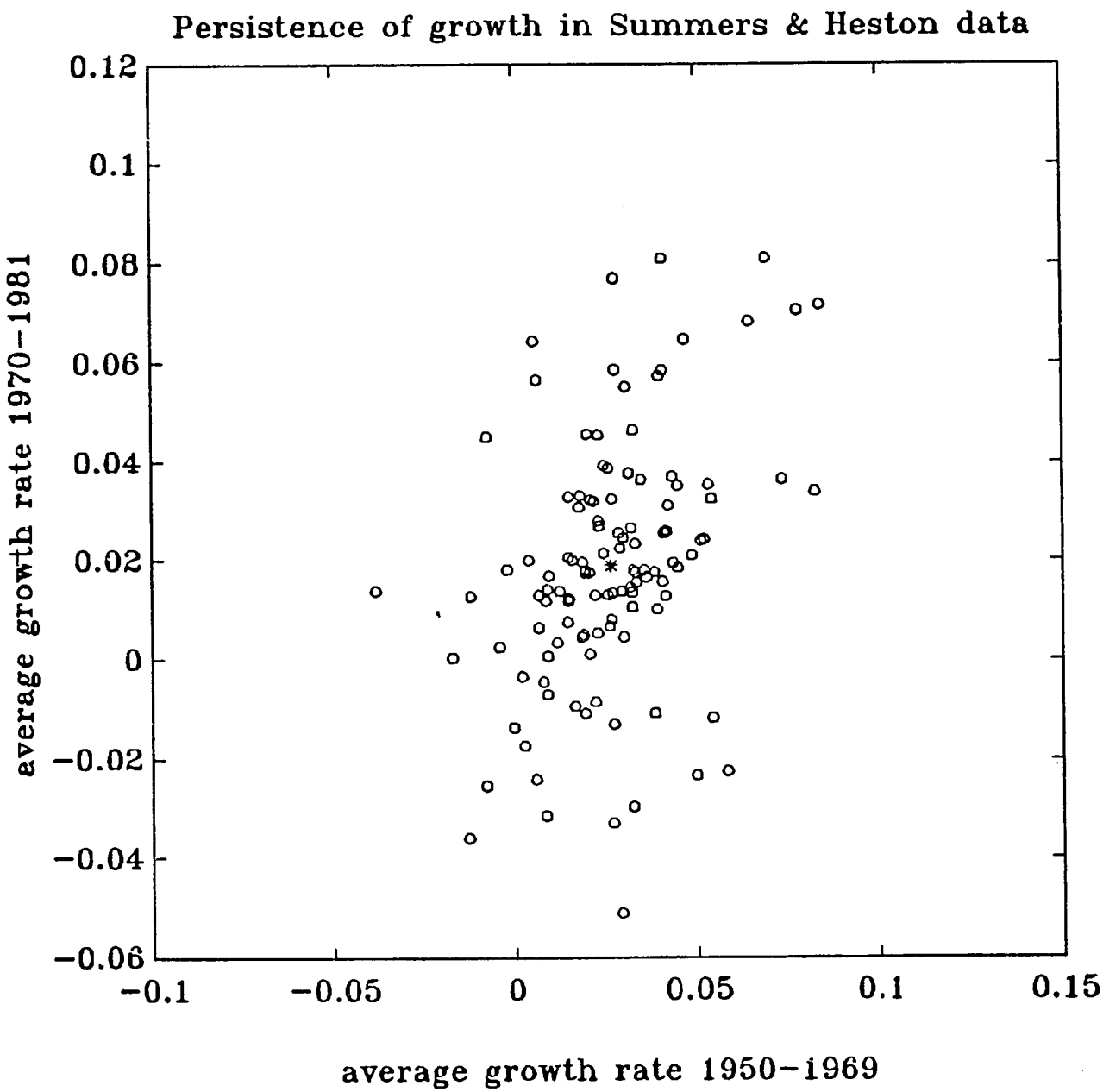

Persistence of growth in Summers & Heston data
0.12
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
average growth rate 1970−1981
−0.1
−0.05
0
0.05
0.1
0.15
average growth rate 1950−1969

FIGURE 3

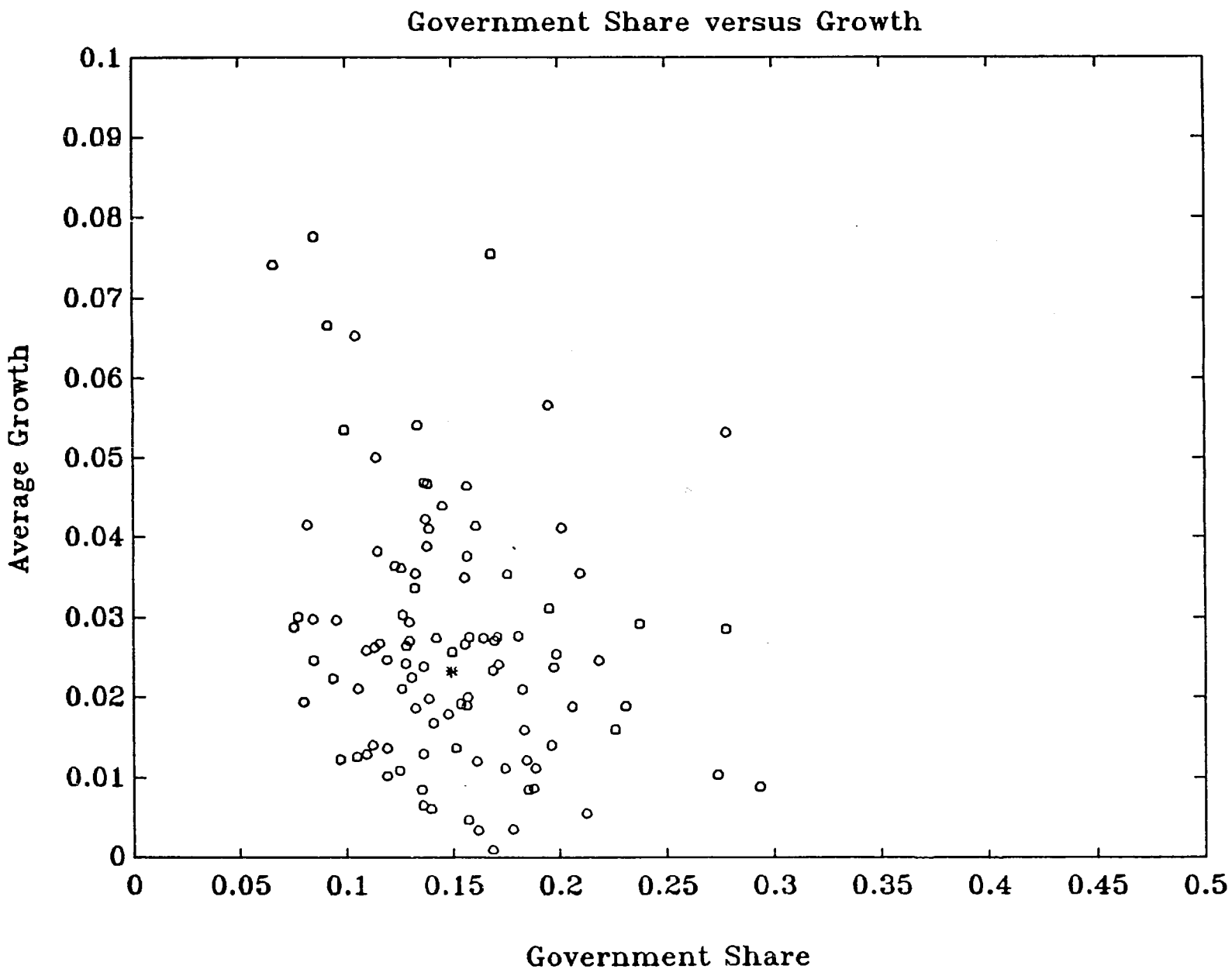

Government Share versus Growth
Average Growth
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Government Share

FIGURE 4

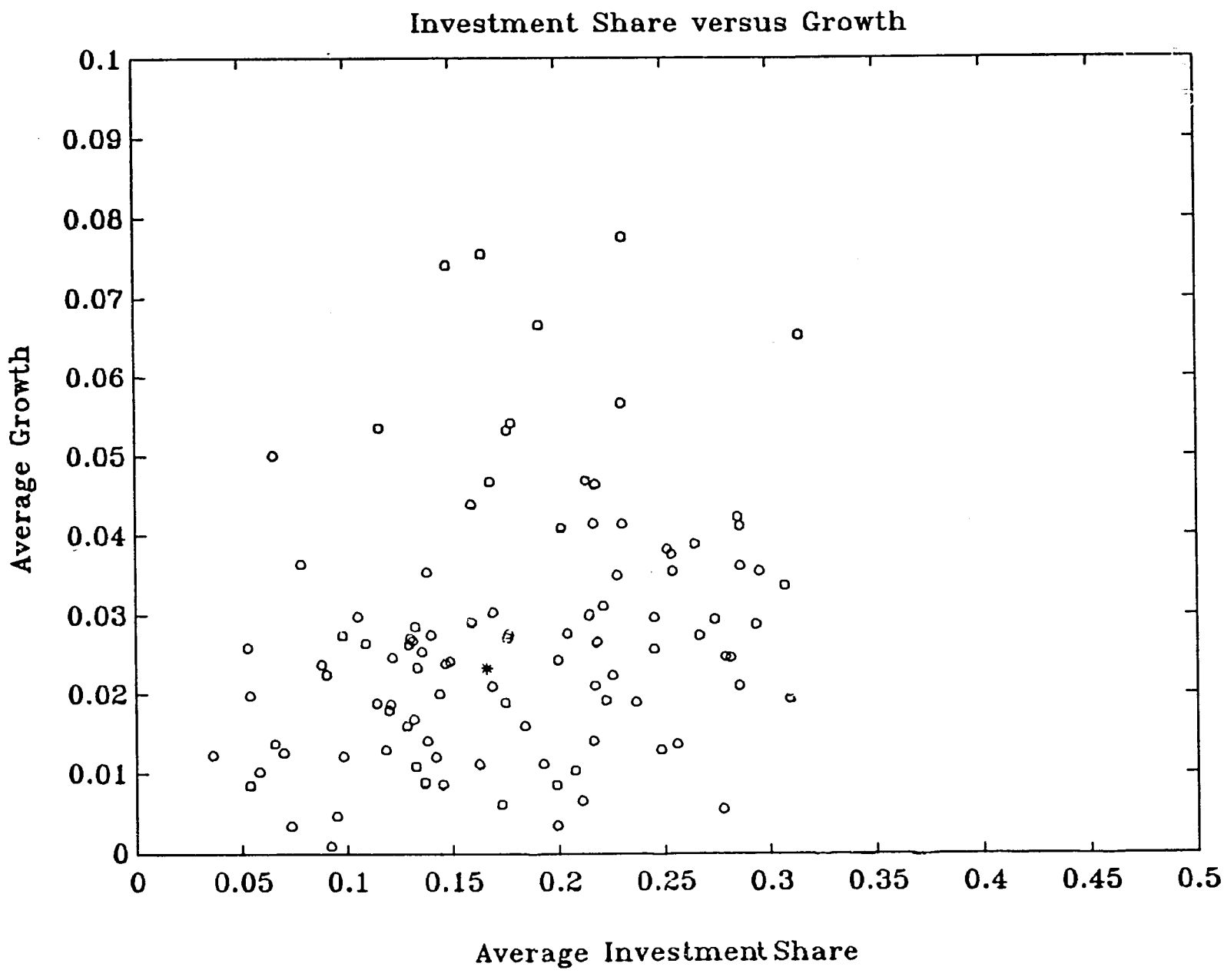
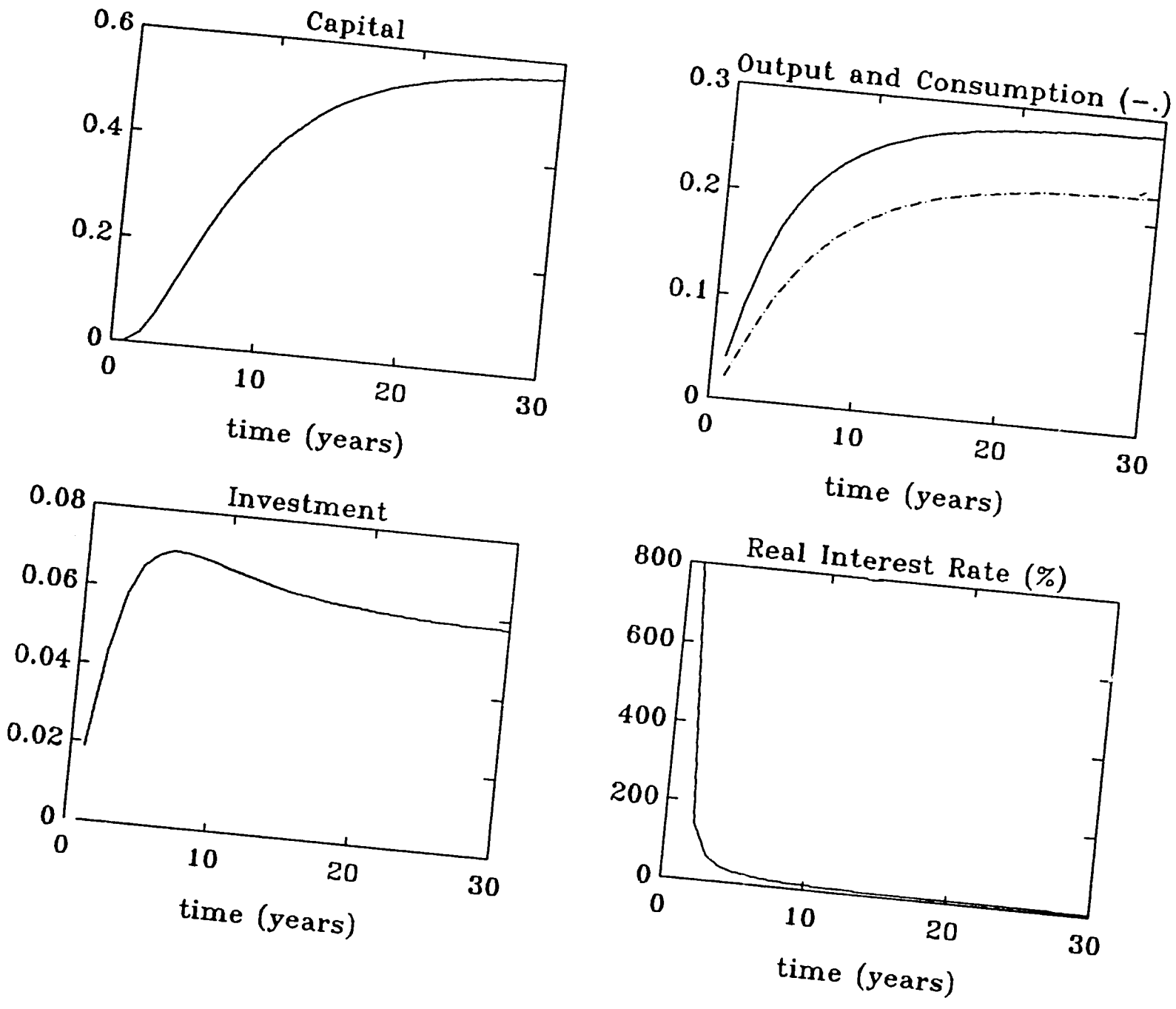

Investment Share versus Growth
Average Growth
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Average Investment Share

FIGURE 5


Capital
0.6
0.4
0.2
0
0
10
20
30
time (years)
Output and Consumption (-.)
0.3
0.2
0.1
0
0
10
20
30
time (years)
Investment
0.08
0.06
0.04
0.02
0
0
10
20
30
time (years)
Real Interest Rate (%)
800
600
400
200
0
0
10
20
30
time (years)

Appendix A

Properties of Human Capital Accumulation

The growth of human capital is given by

$$\frac{H_{t+1} - H_t}{H_t} = \Theta\left[\frac{I_t}{H_t}\right] - \delta_H,$$

where for the purpose of this appendix we consider only human capital investment and, thus, do not subscript the variable I. Here, we explore parameterizations of the Θ function, which is assumed to be increasing and concave. One natural property is that $\Theta(0) = 0$. That is, without investment in human capital, human capital grows at gross rate $\gamma_H = 1 - \delta_H$. A constant elasticity form for Θ involves

$$\Theta(\tfrac{I}{H}) = A[(\tfrac{I}{H}) + B]^{\theta} - C$$

where θ, A, B, and C are parameters to be determined.

The restriction that $\Theta()$ is increasing and concave implies $D\Theta > 0$ and $D^2\Theta < 0$, for $(I/H) > 0$.

$$D\Theta = A\theta[(I/H) + B]^{\theta-1}$$

$$D^2\Theta = A\theta(\theta-1)[(I/H) + B]^{\theta-2}$$

so that $A\theta > 0$ and $(\theta-1) < 0$. The restriction that $\Theta(0) = 0$ implies that

$$AB^{\theta} - C = 0.$$

Thus, to this point, we have required that $0 < \theta < 1$, $A > 0$ and that

$$\Theta(\tfrac{I}{H}) = A[\tfrac{I}{H} + B]^{\theta} - AB^{\theta}.$$

Restrictions from Slopes

Another restriction that can be imposed is that there are locally no "costs of adjustment" at some point. One possibility is that this is zero at $I/H = 0$ and another is that this is at $\Theta(I/H) = \delta_H$. In either case the requirement translates into $D\Theta = 1$, at the appropriate point. We consider these two cases in turn.

(a) requirement at $I/H = 0$.

$$D\Theta(0) = A\theta B^{\theta-1} = 1 \Rightarrow B = (A\theta)^{\frac{1}{1-\theta}}$$

$$\Rightarrow A(A\theta)^{\frac{\theta}{1-\theta}} = C \qquad \text{using the } \Theta(0) = 0 \text{ requirement}$$

$$\Rightarrow A^{\frac{1}{1-\theta}}\,\theta^{\frac{1}{1-\theta}} = C$$

so that the function $\Theta(.)$ takes the form

$$\Theta(\tfrac{I}{H}) = A\left[(\tfrac{I}{H}) + (A\theta)^{\frac{1}{1-\theta}}\right]^{\theta} - \left[A^{\frac{1}{1-\theta}}\ \theta^{\frac{1}{1-\theta}}\right]$$

(b) requirement at $\Theta(I/H) = \delta_H$.

$$\Theta(\tfrac{I}{H}) = \delta_H \Rightarrow A((\tfrac{I}{H})_r + B)^{\theta} = C + \delta_H.$$

$$D\Theta = A\theta((\tfrac{I}{H})_r + B)^{\theta-1} = 1$$

$$\Rightarrow A\theta(\frac{C + \delta_H}{A})^{\frac{\theta-1}{\theta}} = 1$$

$$\Rightarrow A^{1/\theta}\ \theta\ (C + \delta_H)^{\frac{\theta-1}{\theta}} = 1$$

$$(C + \delta_H) = [A^{1/\theta}\ \theta]^{\frac{\theta}{1-\theta}} = A^{\frac{1}{1-\theta}}\ \theta^{\frac{\theta}{1-\theta}}$$

so that the function takes the form

$$\Theta(\tfrac{I}{H}) = A\left[(\tfrac{I}{H}) + B\right]^{\theta} - A^{\frac{1}{1-\theta}}\ \theta^{\frac{\theta}{1-\theta}} + \delta_H$$

$$= A\left[(\tfrac{I}{H}) + \left[\frac{A^{\frac{1}{1-\theta}}\theta^{\frac{\theta}{1-\theta}} - \delta_H}{A}\right]^{1/\theta}\right]^{\theta} - A^{(\frac{1}{1-\theta})}\ \theta^{\frac{\theta}{1-\theta}} + \delta_H$$

$$= A\left[(\tfrac{I}{H}) + (A^{\frac{\theta}{1-\theta}}\ \theta^{\frac{\theta}{1-\theta}} - \delta_H)^{1/\theta}\right]^{\theta} - A^{\frac{1}{1-\theta}}\ \theta^{\frac{\theta}{1-\theta}} + \delta_H$$

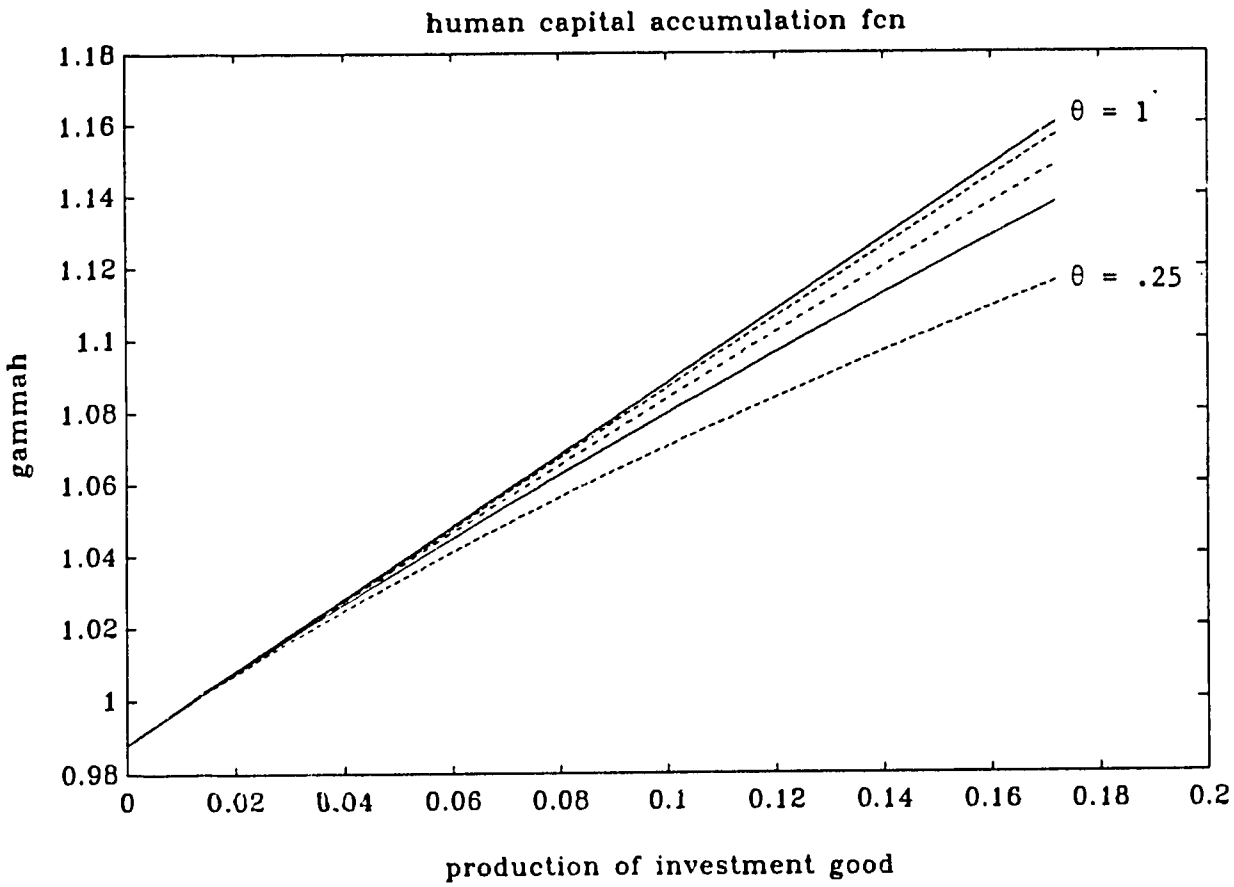
Note that the preceding functions coincide if $\delta_H = 0$. Experiments in this paper use a version of the former specification with A = 1

$$\Theta_1\left(\frac{I}{H}\right) = \left[\left(\frac{I}{H}\right) + \theta^{\frac{1}{1-\theta}}\right]^{\theta} - \theta^{\frac{\theta}{1-\theta}}$$

which are single parameter functions.

Figure A-1 provides a graph of this function for some alternative values of θ.

Figure A-1



Function Graphed for

$\theta = [1\ .9\ .8\ .7\ .5\ .25]$

Appendix B

Calibration of Two Sector Endogenous Growth Model

This appendix discusses the formal structure of the two-sector endogenous growth model outlined in the main text, as well as our procedures for calibrating its steady state and exploring policy implications.

The representative agent in this economy solves the dynamic optimization problem

$$\text{Max} \sum_{t=0}^{\infty} \beta^t \, u(C_t)$$

subject to the accumulation constraints

$$K_{t+1} = (1-\delta_K)K_t + I_{Kt}$$

$$H_{t+1} = \Theta(I_{Ht}/H_t)H_t + (1-\delta_H)H_t$$

the resource constraints

$$C_t + I_{Kt} \leq \Omega_1 F_1(K_{1t}, M_{1t}) + T_{1t}$$

$$I_{Ht} \leq \Omega_2 F_2(K_{2t}, M_{2t}) + T_{2t}$$

and the factor allocation constraints

$$M_{1t} + M_{2t} \leq NH_t$$

$$K_{1t} + K_{2t} \leq K_t$$

To analyze equilibrium behavior, we form the Lagrangian

$$\mathcal{L} = \sum_{t=0}^{\infty} \beta^t u(C_t)$$

$$+ \sum_{t=0}^{\infty} \tilde{\Lambda}_{1t}[\Omega_1 F_{1t} + T_{1t} + (1-\delta_K)K_t - K_{t+1} - C_t]$$

$$+ \sum_{t=0}^{\infty} \tilde{\Lambda}_{2t}[\Theta(\frac{\Omega_2 F_{2t}+T_{2t}}{H_t})H_t + (1-\delta_H)H_t - H_{t+1}]$$

$$+ \sum_{t=0}^{\infty} \tilde{Q}_{Kt}[K_t - K_{1t} - K_{2t}]$$

$$+ \sum_{t=0}^{\infty} \tilde{Q}_{Mt}[NH_t - M_{1t} - M_{2t}]$$

The efficiency conditions take the following forms. For consumption, we have the familiar requirement that

$$\beta^t Du(C_t) = \tilde{\Lambda}_{1t}.$$

For the cross-sectoral allocations of factor stocks, we have the four conditions

$$\tilde{\Lambda}_{1t}\Omega_1 D_1 F_1(K_{1t}, M_{1t}) = \tilde{Q}_{Kt}$$

$$\tilde{\Lambda}_{1t}\Omega_1 D_2 F_1(K_{1t}, M_{1t}) = \tilde{Q}_{MT}$$

$$\tilde{\Lambda}_{2t} D\Theta_t \Omega_2 D_1 F_2(K_{2t}, M_{2t}) = \tilde{Q}_{Kt}$$

$$\tilde{\Lambda}_{2t} D\Theta_t \Omega_2 D_2 F_2(K_{2t}, M_{2t}) = \tilde{Q}_{Mt}$$

For the efficient evolution of capital stocks, we have the two shadow price requirements

$$\tilde{\Lambda}_{1t} = \tilde{\Lambda}_{1,t+1}(1-\delta_K) + Q_{K,t+1}$$

$$\tilde{\Lambda}_{2t} = \tilde{\Lambda}_{2,T+1}(1-\delta_H) + Q_{1t,T+1}N + \Lambda_{2,T+1}[\Theta_{t+1} - D\Theta_{t+1}(\frac{\Omega_2 F_{2,t+1} + T_{2,t+1}}{H_{t+1}})]$$

and the transversality conditions

$$\lim_{t\to\infty} \tilde{\Lambda}_{1t} K_{t+1}$$

$$\lim_{t\to\infty} \tilde{\Lambda}_{2t} H_{t+1}$$

Finally, we have the four resource constraints

$$K_{t+1} = \Omega_1 F_{1t} + T_{1t} + (1-\delta_K)K_t - C_t$$

$$H_{t+1} = \Theta(\frac{\Omega_2 F_{2t} + T_{2t}}{H_t})H_t + (1-\delta_H)H_t$$

$$K_t = K_{1t} + K_{2t}$$

$$NH_t = M_{1t} + M_{2t}$$

Steady State Requirements

Consolidating the preceding conditions, we find that the steady state is described by

(SS1) $$\beta(\gamma_H)^{-\sigma} = 1/(1+r).$$

(SS2) $$(1+r) = (1-\delta_K) + \Omega_1 D_1 F_1(K_1/M_1,\ 1)$$

(SS3) $$(1+r) = [(1-\delta_H) + N\ D\Theta\ \Omega_2 D_2 F_2 + \Theta - (F_2/H)\ D\Theta]$$

(SS4) $$\frac{D_1 F_1(K_1/M_1,\ 1)}{D_2 F_1(K_1/M_1,\ 1)} = \frac{D_1 F_2(K_2/M_2,\ 1)}{D_2 F_2(K_2/M_2,\ 1)}$$

(SS5) $$1 = \frac{M_1}{NH} + \frac{M_2}{NH}$$

(SS6) $$\frac{K}{NH} = (\frac{K_1}{M_1})(\frac{M_1}{NH}) + (\frac{K_2}{M_2})(\frac{M_2}{NH})$$

(SS7) $$\gamma_H = \Theta(I_E/H) + 1-\delta_H$$

(SS8) $$I_E/H = F_2(\frac{K_2}{M_2},\ 1)\ \frac{M_2}{H}$$

(SS9) $$\left(\frac{Y}{NH}\right) = F_1(K_1/M_1,\ 1)\left(\frac{M_1}{NH}\right)$$

(SS10) $$\frac{C}{NH} = \frac{Y}{NH} - (\gamma_H + 1-\delta_K)\frac{K}{NH}$$

This system is 10 equations in the 10 unknowns γ_H, $(1+r)$, (K_1/M_1), (K_2/M_2), (M_1/NH), (K/NH), (I_E/H), (Y/NH) and (C/NH).

Calibration

For the purpose of determining the parameters of the steady state to match observed average growth and real interest rates, we proceed as follows. First, we postulate CES forms for the F_1 and F_2 functions, so that F_i

$$F_i(K_i,\ M_i;\ A_i,\ \alpha_i,\ \rho_i) = A_i[(1-\alpha_i)K_i^{-\rho_i} + \alpha_i M_i^{-\rho_i}]^{-1/\rho_i}$$

Then, we compute the steady state according to the following algorithm:

Step 1: Given $A_1 = 1$, α_1, and ρ_1, invert $(1+r) = D_1F_1(K_1/M_1,1) + 1-\delta_K$ to obtain steady state K_1/M_1 ratio using (SS2).

Step 2: Given α_1, α_2, ρ_1 and ρ_2 calculate K_2/M_2 from requirement that marginal rates of transformation are equated in the two sectors, using (SS4).

Step 3: Given the parameters of Θ function—the coefficients developed in Appendix A (i.e., θ and A_3)—compute (I_E/H) consistent with specified γ_H using (SS7).

Step 4: Given the results of the preceding steps, (SS3) permits—with specification of Ω_2—solution for the parameter A_2

$$A_2 = \frac{r+\delta_H - [\Theta(I_E/H) - D\Theta(I_E/H)(I_E/H)]}{ND\Theta(I_E/H)\Omega_2[D_2F_2(K_2/M_2,\ 1)/A_2]}$$

Step 5: Use (SS8) to compute the fraction of time in efficiency units allocated to investment in human capital, given previously determined (I_E/H) and (K_2/M_2) with specified N.

$$(M_2/NH) = I_E/[F_2(\frac{K_2}{M_2},1)]$$

Step 6: Compute $M_1/NH = 1-(M_2/NH)$, using (SS5).

Step 7: Compute $\frac{Y}{NH} = (\frac{Y}{M1})(\frac{M_1}{NH}) = F_2[(\frac{K_1}{M_1}),\ 1;\ A_1,\ \alpha_1,\ \rho_1]\bullet(\frac{M_1}{NH})$, using (SS8) and the results above.

Step 8: Compute $\frac{K}{NH} = (\frac{K_1}{M_1}\frac{M_1}{NH} + \frac{K_2}{M_2}\frac{M_2}{NH})$, using (SS6) and the results above.

Step 9: Compute $\frac{C}{NH} = \frac{Y}{NH} - \gamma_H\frac{K}{NH} + (1-\delta_K)\frac{K}{NH}$, using (SS9) and the results above.

Step 10: Compute $\beta = \gamma_H^{\sigma}/(1+r)$ using (SS1) and the results above.

A Modern Vision of the Growth Process

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and

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Ruminations and comments on Robert G. King and Sergio T. Rebelo, "Public Policy and Economic Growth: Developing Neoclassical Implications" Conference on the Problem of Development, Buffalo, May 1988.

4660

The frame of reference given to me as a discussant and the broad scope of the King-Rebelo paper both lead me to want to share with readers a vision of the growth process. I do not really think of this vision as being my own; rather it is the way in which I would express what I consider the "consensus view" of a considerable number of professional economists with wide experience in developing countries.

First, the growth process is extremely complex; there are many "known" sources of growth. Second, our understanding has been much enhanced by the neoclassical growth model

(1) $\Delta Y = \bar{w}\Delta L + \bar{\rho}\Delta K + R.$

Here R is the Solow-Denison residual. I take it to be a recognized fact that most of the cross country variation in the growth rate ($\Delta Y/Y$) comes from varition in the residual (R/Y). This is also true of the variation of ($\Delta Y/Y$) over time in a single country.

Third, additional subtlety and understanding are introduced with a disaggregated version of equation (1) is used

(2) $\Delta Y = \sum \bar{w}_i \, \Delta L_i + \sum \bar{\rho}_j \, \Delta K_j + R'$

Here, different qualities of labor have different $\bar{w}_i$. Investment in human capital entails shifting labor from one category to the other. Any impact on human capital investment that is reflected in market earnings will be captured in the first term ($\sum \bar{w}_i \, \Delta L_i$) of equation (2). The new residual R' is free of any such "influence." The adroit choice of categories for labor and capital can also cause reallocations of resources across industries to be captured in the

first two terms of (2). For example, corporate capital has a high $\bar{\rho}_j$ because of corporation income taxes, housing capital has a low $\bar{\rho}_j$ because of explicit and implicit subsidies. Reallocations of capital among such activities can make positive or negative contributions to growth; these will be caught in the $\sum\bar{\rho}_j\ \Delta K_j$ term of (2), not in R'.

I think of (2) as the modern neoclassical decomposition of growth. I use the term <u>attribution</u> to describe the procedure. It <u>attributes</u> a marginal contribution of $\bar{w}_i$ to each ΔL_i, and a marginal contribution of $\bar{\rho}_j$ to each ΔK_j If $\bar{w}_i$ is high because of labor union monopolies, so be it...the attribution would still be precisely correct if the users of that labor acted as price takers. The attribution of $\bar{w}_i$ to each category of labor is inexact to the degree that labor monopsony a product monopoly characterizes the users of that labor in sector i. In this case $\bar{w}_i$ would tend systematically to understate the (marginal) contribution of ΔL_i to ΔY.

As a practical empirical exercise, think of measuring $\bar{w}_i$ and ΔL_i for as many categories of labor and of measuring the perceived real return to capital $\bar{p}_j$ and the increment of capital stock ΔK_j for as many categories of capital as one deems useful. As far as choosing categories for capital are concerned, the most significant limitation is the need for data on investment for each such category, time series on real capital stock can then be generated by perpetual inventory techniques, and rates of real return $\bar{\rho}_j$ can accordingly be estimated. One can keep in mind, then, a vision of the growth process in which we attribute to each ΔL_i the going wage for that particular category of labor in that particular occupation and/or industry and in which we attribute to each increment of capital stock ΔK_j its corresponding $\bar{\rho}_j$, measured as suggested

above.

All this will leave a residual R′ ($= \Delta Y - \sum \bar{w}_i \, \Delta L_i - \sum \bar{p}_j \, \Delta K_j$). The one thing we can presume about R′ is that it does not measure the ordinary marginal productivity of factors of production. It comes from other sources, for which the term technical advance is, I think, a good catch-all

Many economists are not aware that R′ has a "dual" representation. To show this, let individual outputs be denoted by X_j and individual factors (including both labor and capital categories) by F_i. Letting their respective prices be P_j and W_i, we have a definition of national output Y as

$$(3) \quad Y = \sum X_j P_j = \sum F_i \, W_i .$$

The term $\sum X_j P_j$ adds up the value added of all activities j, while the term $\sum F_i W_i$ captures total product as the sum of the individual rewards earned by the different categories of labor and capital.

Now take the differential of expression (3). This yields:

$$(4) \quad \sum X_j \, \Delta P_j + \sum P_j \, \Delta X_j = \sum F_i \, \Delta W_i + \sum W_i \, \Delta F_i .$$

Rearranging terms, this gives us

$$(5) \quad \underbrace{\sum P_j \, \Delta X_j - \sum W_i \, \Delta F_i}_{=R'} = \underbrace{\sum F_i \, \Delta W_i - \sum X_j \, \Delta P_j}_{=R'}$$

The left hand side of (5) is the ordinary definition of R′ (change in output valued at "last period" prices minus change in factor inputs, also valued at "last period's" prices). The right hand side of (5) has to give us the same answer. It is the "dual" representation of R′ and is equal to the amount by

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which the weighted sum of factor price increases exceeds the weighted sum of output price increases. It is thus a measure of reduction in output prices relative to factor costs.

I truly appreciate this "dual" representation of R′ because it brings out very clearly how any and everything that reduces real costs per unit of output contributes to economic growth. Eliminating unnecessary motion in an assembly line, buying a better broom that sweeps a larger area in the same time, finding a use (as final product) for something that was previously thrown away as waste--all these contribute to growth just as surely as did the invention of hybrid corn or of laser beams.

A second important lesson from the "dual" representation of R′ is that on the whole it is a measure of consumer benefit. This is certainly true to the extent that factor markets really function across sectors and industries. Any one innovation in *any* one sector will not normally produce rises in the equilibrium rewards of its factors. Its owners might gain in the short to middle run, with returns per dollar of capital rising while product prices and wages remain relatively constant. But if competition prevails, returns to capital will over time be driven back to normal; ultimately, the reflection of the innovation will be a reduced real price to the consumer.

Looking around in the real world, we find dramatic evidence that consumers gain from technological improvements. Each decade seems to have its own standout activity--first automobiles, then tires, then plastics, then chemicals and pharmaceuticals, then telecommunications, then computers. In each case the bulk of the benefit came by way of a reduced real price to the consumer. Think of it this way; each important innovation in each industry has only a small impact on economy-wide real wages; but it has a big impact in reducing the real

cost of the product. The actual rise in real wages (for given skills) in an economy tends to reflect the "average" rate of tehcnical advance (R'/Y). Services (like haircuts and taxi rides) with little technical advance tend to have secularly rising real prices, while those (like computers and hi-fi sets in recent years) with greater than average technical advance tend to fall in relative price.

I see the process as one in which the reduction in relative price of the product is the individual consequence of just about every technical advance. The rise in real factor rewards is a broader market phenomenon, and tends to reflect the average rate of technical advance for the economy as a whole.

Yet another lesson from the "dual" representation of R' is that it is fruitless to search for a "full" attribution of economic growth to the different factors of production. It is vain to hope that we will be able to reduce the residual to zero. If not vain, then certainly pessimistic, for an R' of zero would mean that consumers have ceased to benefit from economic growth, that real wages have ceased to rise (except for upgrading through investment in human capital). Such would not be a happy scene, nor one that represents an extrapolation of past experience.

A final lesson concerning (R'/Y)--that can be derived from either of its two representations--is that it varies greatly across industries and sectors. Kendrick's classic study of technological advance by industry showed vast differences across industries within each decade and across decades within each industry. Comparisons across countries lead to similar conclusions. High growth nearly always reflects a high (R'/Y), but (R'/Y) is not steady and predictable. If we think in terms of a growth process described by $Y = L^{\alpha}K^{(1-\alpha)}e^{\lambda t}$, we naturally tend to view growth as steady and generalized,

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working, in principle, throughout the economy. My analogy here is with yeast in causing bread to rise, or with air in a balloon. The much better analogy, given the evidence just referred to, is with mushrooms. Productivity growth may occur here, there, or anywhere. It is hard to predict where the rate will be high or low. Policywise, the best we can do is provide a favorable environment--temperature, ventilation, darkness, and humidity in the case of growing mushrooms; tax and trade, credit and monetary policies that are robust and allocationally relatively neutral in the case of promoting the growth of total factor productivity.

This vision of the growth process fits the facts of most cases of exceptional growth (the exceptions are cases where major world price changes--like the oil price booms--were the cause of a country's prosperity). Most particularly, it fits the cases of spectacular growth by the East Asian NICs--Hong Kong, Singapore, Taiwan and Korea. Perhaps the most notable aspect of their growth is the unexpected things they ended up producing.

Let me try to summarize a vision of the growth process that fits with the above observations and with the bulk of our experience:

1. Many factors combine to produce episodes of outstanding growth, [Spain 1961-73, Panama 1960-73, Greece 1963-73, Mexico 1957-72, Brazil 1968-76, Indonesia 1968-81, Malaysia 1971-84, Guatemala 1968-78, Pakistan 1978-86, Portugal 1960-73]. The key question is when does a country "get it all together," or perhaps get enough of it together to produce a spurt of extraordinary growth.
2. Human capital investment is important. Part of getting it all together is having good managers, a qualified labor force with a wide range of skills, etc. But, as shown at length above, human capital

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investment works through $\sum \bar{w}_i \Delta L_i$, not through R'. Insofar as the truly successful growth episodes are characterized by high (R'/Y), they seem to require important contributions above and beyond human capital investment.

3. Success is fragile. Many countries fall back after episodes of highly successful growth. Argentina, Brazil, Guatemala, Mexico, and Portugal all provide good examples.

4. Their relative success at "getting it all together" determines, among other things, how fast backward countries catch up--i.e., approach the technological and productivity frontier. The idea of one production function applying in all countries just does not fit the facts. A better approximation is the assumption that each country even better, each enterprise--has its own production function (along which it works at any given time). That production function shifts through time, hopefully coming closer to the one that defines the world technological frontier.

5. It is wrong to think that somehow human capital investment produces externalities. The great growth spurts in Taiwan and Japan were not a reflection of such a rapid spurt in human capital. Rather, it was in other aspects, other facets of policy that they were able generally to "get their act together."

6. It is useful to make mental experiments like shifting Indian taxidrivers to New York, or Guatemalan housemaids to Los Angeles, or Philippine nurses and Argentine doctors to Chicago. In the new environment, their productivity rivals that of natives; their "human capital" is just as good as that of U.S. nationals.

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7. The pace with which a country moves from its present interior point to the world technological frontier is not plausibly predictable. It really does not pay for economists to try to endogenize this time path. Nevertheless we must recognize that for the biggest spurts of growth that we have observed over recent decades, the name of the game is "closing the gap"--i.e., bringing the country's production function in a given line of activity rapidly closer to that would technological frontier.

With this vision of the world I now turn to some of King and Rebelo's questions (p. 4).

1. Q Why is sustained growth in per capita income feasible?

   Ans Because technical advance is not all eaten up in reward to innovators for their human capital. If it were we would still have growth in output per head but we would have no residual (R'). With no residual there would be no tendency for real wages of each category of labor (L_i) to rise secularly.

2. Q Is the vision of the world capable of generating the pattern of cross-country diversity of growth that we observe?

   Ans We have different production functions everywhere. These differences are important in explaining cross-country variations in income per capita. Likewise, the major differences in growth rates among developing countries are in the speed with which they approach the full exploitation of existing knowledge (the world technological frontier).

3. Q How does this vision predict the behavior over time of the growth rate of output and of the real interest rate?

Ans The real interest rate will, with capital mobility, tend to the world level. However, vast and sustained differences in real interest rates can and do exist across countries due to barriers to capital mobility and (importantly) to differences in perceived risk.

LDC's can best promote growth by providing a good and stable (reliable) policy environment. Above all they should not impede the sensible modernization of each industry as it "gets its act together."

The vision would predict that the best LDC's will always or nearly always have greater growth than the countries at the world frontier. The worst LDC's have in the past grown much less than the frontier, but on the whole this has been the result of bad policies. There seems no need for even the worst of them to grow slower than the frontier countries.

4. Q What implications for (potentially) observable variables allow us to distinguish this vision from competing models?

Ans The question is not too apt, but nonetheless, we can say that most competing models tend to be too partial--emphasizing only one or two or three of the many facets of growth. It takes very little to show that R' is real, and that any approach that says R' is unimportant is inconsistent with the data. Similarly, any approach that relies primarily on human capital investment to explain all

growth runs quickly into contradictions with the data. Also any approach which places many different countries on the same production frontier can easily be disproved. Our vision is more general, and has in part, been built up by the experiences of confronting simpler hypotheses with the data and finding, simply put, that they do not fit.

5. I would add a question about implicit dynamics in place of King-Rebelo's grossly overspecific question 5.

Ans The vision being put forward has no implied dynamics, in the sense that it is not able to predict the speed with which a country approaches the technological frontier. In terms of the vision itself, it is naive to think that there should be such an implicit dynamics.

Some specific observations on the paper.

p.7 The tendency for periods of high and low growth to be persistent is established, with an R of .39. That means $R^2 = .15$. Only 15 percent of the variation among growth rates is explained by earlier period rates. I believe even less of the variation in (R'/Y) across countries would be explained by its earlier-period value.

p.8 The authors note that in the Summers-Heston data the share of government is negatively correlated with growth. No correlation is observed in the 1950-68 period. The negative relation stems from 1970-81. Observation: there was much less variation in (G/Y) in the earlier period. Recent decades have witnessed a worldwide growth of the government sector, much of it ill-considered and with a negative effect on output.

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p.12 The implied dynamics of transformed capital is not particularly meaningful to explain real-world observations. Reason: the model is one of a closed economy. International capital movements are major sources of variation in investment rates across LDCs.

p.14 Similarly, lifetime utility functions are not the key to any relevant observable real interest rate, at least in the developing countries. The world interest rate is the key parameter here, together with the specific reasons why the interest rate of any particular LDC will diverge from the world rate.

pp 14-16 Real interest rate implications at the top of page 15 are absurd. The methodology yields high real interest rates because it is putting LDCs on the same isoquants as advanced countries. Once it is recognized that the LDCs operate with inferior techniques, the paradox of such high implied rates of return can easily be eliminated.

pp. 18 The possibility of different constant terms in the production function is mentioned here. The authors say this "only works in the absence of technological progress." Not so in our vision of the growth process. For LDCs we do not even need exogenous progress at the frontier (though our vision contemplates it). The important thing for LDCs is the closing of the technological gap. I would say as an empirical statement that can be contradicted or verified that "growing economies take (more) advantage of existing possibilities (i.e., can be demonstrated to be closing the technological gap), while stagnant economies do not." The truly hopeless cases even seem to forget what they once appeared to know.

p.18 Naively, the authors state "it is clear from the discussion above that economic policy can have at most transitory effects since in the long run

the economy's growth will always be γ_x-1." This is surely true within their model. But in our alternative vision of the world, the most important differences in LDC growth rates arise because different countries close the technological gap at different rates.

p.21 Increasing returns fit into our vision of the growth process. In this case the attribution of growth using observed $\bar{w}_i$ and $\bar{\rho}_j$ understates the actual marginal productivity of factors. The difference between true marginal productivity and $\bar{w}_i$ would end up as a potentially measurable $[\sum(MP_i-\bar{w}_i)\Delta L_i]$ part of the residual, R'.

p.21 bottom Why rule out shifting technology when it is so clearly of the essence of the process. Where would Singapore be without Lee Kwong Yew? Where would Taiwan be without TC Liu and SC Tsiang? These are the people that helped those countries get their act together, and modernize like mad.

May 1988

COMMENTS ON KING AND REBELO.

Stanley Fischer[1]

With a substantial body of work on the new growth theory in hand--much of it in this volume--King and Rebelo aim to begin evaluating these models by matching their predictions to the time-series and cross-sectional growth experiences of a large number of countries. In so doing they also provide a useful exposition and classification of the new models.

1. The Stylized Facts.

Early papers in the new growth theory were motivated by dissatisfaction over two results obtained in the Solow growth model and Ramsey-style optimal growth formulations. First, in the Solow model the steady state growth rate is determined solely by population growth and exogenous technical progress, and is invariant to policy and preferences. Of course the level of output in these models and the speed of adjustment towards the steady state are affected by policy and preferences. Second, in the standard models, countries with identical technologies and tastes should eventually converge to the same level of income. This is a problem because the appearance of convergence certainly does not jump out of the data.

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[1]The World Bank, MIT, and NBER. These are comments on the paper "Public Policy and Economic Growth: Developing Neoclassical Implications" by Robert King and Sergio Rebelo, presented at the First International Conference of the Institute for the Study of Free Enterprise Systems, SUNY at Buffalo, May 27-29 1988.

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Models that do not exhibit these properties can be constructed by assuming either increasing returns to scale, or that there are constant returns to scale in reproducible factors of production (including human capital).

King and Rebelo provide other observations that should be accounted for by any theory of growth. These are mostly Kaldor's stylized facts: the interest rate is constant; the share of labor is constant; the capital output ratio is constant. In addition they show that growth rates in sixteen industrialized countries in the last century have not been decreasing--as they would be if countries were approaching a steady state from below.

This paper, as many others, uses individual economies as the units of observation in studying theories developed for a closed economy. This is not legitimate in a world with foreign trade. With capital mobility and costs of adjusting the capital stock, the real interest rate can be equalized worldwide even though capital-output ratios may differ widely. It is possible that evidence on different approaches to growth can be gleaned from differences in regional growth performance within a given country. Probably there are lessons to be learned from the experience of both Hawaii and Puerto Rico as they came increasingly into the U.S. economy.

Some of the facts are indeed only stylized. For instance, Table 3 suggests that at least over very long periods interest rates have decreased. Similarly, it is true that over long periods the share of labor in income has been increasing: over the last few centuries the share of labor has increased at the expense of rents; during this century the share of labor

has been rising at the expense of capital. Further, there are not sixteen independent observations showing that the growth rate of income has been rising in the past century. The countries examined in Table 2 operate in the same international environment in which growth is transmitted among countries: what the data show is that the world economy grew more rapidly in the 1950-1973 period than earlier. Of course, there is no question that modern growth rates exceed those that must have prevailed in most of the world in the past two centuries.

Tempting as it is to turn to the very long run of centuries and millenia in discussing growth, some discipline in the demands made on any theory is needed. Questions about growth in pharaonic Egypt, classical Greece or medieval Europe are fascinating, should be raised, and may well throw light on the sources of growth. But even if those eras are ignored, it would be a considerable achievement to explain a significant part of the time series and cross-sectional growth experience of the last fifty to one hundred years. This makes the Kaldor stylized facts more relevant than the critical comments of the preceding paragraph and some comments made at the conference suggest.

2. Properties of the Ramsey-Solow Model.

In addition to providing the facts, King and Rebelo simulate optimal growth models to show that they are inconsistent with the facts. The most interesting aspect of these simulations (Table 5) is that the approach to the steady state is very rapid for the baseline case. Before taking these results at face value, we examine the results in Table 5. The most striking fact is that capital accumulates at an extraordinary rate in the first few

years of the program (except in the bottom row, where capital's share in output is very high).

These extraordinary rates of capital accumulation probably imply saving rates that have never been seen in practice. It is possible that this feature of the results would disappear if rapid adjustment of the capital stock were costly. Such a result could be obtained using either a two-sector model or an adjustment cost model. In the two-sector model, the relative price of capital would under the usual factor intensity assumption be declining as capital accumulated--and this is a stylized fact that is probably true.

If the transitional dynamics are very rapid, and if the standard neoclassical models are our null hypothesis, then we should be close to the steady state most of the time. That appears to justify King and Rebelo's concentration on the steady state properties of the models. However, we need not abandon the existing models until it is shown that stochastic versions of the Ramsey-Solow model with technical change are inconsistent with the facts. Furthermore such models are most of the time not at the steady state, therefore most of the time policy matters for the growth rate of output. An exercise of the Kydland-Prescott type that allows the growth path to be driven by stochastic technical progress could show that stochastic versions of the Ramsey-Solow model do quite well at explaining the facts.

3. <u>The New Models</u>.

The new models surveyed by King and Rebelo in any case make a contribution to formalizing and understanding the growth process. The main

emphasis in their exposition is on models that endogenize human capital formation. There is no question this is an important part of the growth process that should be included in serious models of growth. Similarly the increasing returns to scale assumption is worth pursuing.

How important are these extensions? Denison has attempted to quantify both contributions to growth. His estimates are that economies of scale account for 0.36% of growth out of a total growth rate of U.S. national income of 3.33% from 1929 to 1969; and education for 0.41% of growth[2]. Thus between them the extensions to increasing returns and human capital formation address factors that by Denison's estimates account for nearly one quarter of annual growth. No doubt the Denison estimates are highly imperfect, but they do suggest that the King-Rebelo paper addresses important sources of growth.

4. The Missing Factor: Technology.

Perhaps Solow in his theoretical and empirical work laid too much stress on technology. But it is strange that King and Rebelo attempt in this paper to confront the facts about growth without explicitly incorporating technological progress. From discussion of the paper at the conference, it appears that the authors regard the model of the accumulation of human capital as representing the accumulation of knowledge. It is hard to see why. In his paper for this conference, Paul Romer successfully distinguishes the two concepts. This is the more promising route to take.

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[2]Edward F. Denison, Accounting for United States Economic Growth 1929-1969. Washington, DC: Brookings Institution, p127.

Why? Because it is impossible to believe that technological progress is not the major source of the long-term growth in per capita income. Whether one looks at the long-run perspective, seeing modern growth beginning with industrialization and the ability of agriculture to support ever-increasing urban populations, or at the short-run, where Schumpeterian bursts of development consequent on the diffusion and development of new technologies can be seen to drive growth, it is difficult not to place technology near the center of the growth process. No doubt it would be desirable to endogenize technical progress, but that is different from leaving it out, as this version of the paper appears to.

In considering the role of technology in growth, it is necssary to emphasize the differences in growth rates that can be obtained by advancing rapidly towards the world's technological frontier, and those that can be obtained by pushing out the existing frontier. All the miracle growers of the post-World War II period--Brazil, Germany, Japan, Israel, Korea and others--grew rapidly from well within the frontier. Even Japan is now growing at only half the rate of two decades ago.

5. <u>The Real World</u>.

Here are a few observations about growth from the perspective of the World Bank. First, it does seem to be true that outward-oriented economies do well--among the examples are Korea, Taiwan, Thailand, Singapore, Chile. Researchers have not yet looked carefully enough for countries that were outwards oriented and grew slowly, and for countries that were inwards oriented and grew fast.

Second, we now unfortunately have in the case of Africa many countries that have suffered negative growth over prolonged periods. The evidence from these countries may be very useful in evaluating growth theories.

Third, the data are probably very weak. This is not only for the conceptual reasons discussed and corrected by Heston, Summers et al. There are also simple measurement problems, which suggest to close observers that the data may be very far off their true values.

6. Summary.

Where do the new theories take us? We used to believe that we could explain about one half of the time series variance in growth in the U.S. Perhaps after incorporating the elements emphasized by the new theory, we will get up to two-thirds of the variance. Whether the new theories will do very much to explain the cross-sectional variance in growth rates remains to be seen. No doubt factors that are difficult to evaluate and measure--such as social capital, the organization of government, honesty, the public and private institutional structure--play a major role in accounting for cross-sectional differences in growth rates.

August 11, 1988

TAX REFORM AND U.S. ECONOMIC GROWTH

by

Dale W. Jorgenson and Kun-Young Yun

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1. Introduction

The purpose of this paper is to evaluate the impact of the Tax Reform Act of 1986 on U.S. economic growth. We also analyze the potential impact of proposals for tax reform that figured prominently in the debate leading up to the the 1986 tax reform. We consider proposals advanced by the Department of the Treasury and by President Ronald Reagan in detail, since these proposals were instrumental in shaping the final legislation.[1] Second, we assess the potential impact of a number of hypothetical tax reform proposals that embody notions of neutrality in the treatment of different kinds of income. The results of this analysis are useful in suggesting fruitful directions for future tax reform.

Harberger (1962, 1966) has argued that the U.S. tax system leads to a loss in efficiency in the allocation of resources, since it fails to impose a uniform tax rate on the capital used in competing economic activities. There have been wide gaps between the rates of return on investment before and *after* taxes for assets in employed in different sectors and among assets in different durability categories. However, the argument that the efficiency of capital allocation requires a uniform tax rate holds only under the restrictive assumption that the allocation of capital is separable from the allocation of other resources in production and consumption. In a more general setting, the uniformity of tax treatment of different kinds of income from capital is neither necessary nor sufficient for efficient resource allocation.[2]

[1] The Tax Reform Act of 1986 was enacted into law on October 22, 1986 and took effect on January 1, 1987. The Treasury proposal was presented in November 1984 and the President's proposal in May 1985. A detailed description of the Tax Reform Act of 1986 is given by the Joint Committee on Taxation (1986). The economic impact of the 1986 tax reform has been analyzed by the Office of Tax Analysis of the U.S. Department of the Treasury (1987) and in the symposium edited by Henry Aaron (1987).

[2] For example, in Section 4 below we find that the equalization of tax rates on corporate and noncorporate capital considered by Harberger (1966) actually reduces efficiency. However, we show that symmetrical tax treatment of income from business and household assets is a very promising avenue for tax reform.

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Harberger's analysis of the impact of tax policy on the efficiency of capital allocation is limited to the allocation of a given capital stock.[3] However, saving behavior may be affected by changes in tax policy, so that the capital stock must be determined endogenously in order to assess the economic impact of tax reform.[4] In addition, the notion of efficiency in the allocation of resources must be extended to encompass intertemporal allocations. The absence of tax distortions in the intertemporal allocation of resources requires that income from capital should not be taxed at all. A possible approach to eliminating taxes on capital income is to replace corporate and individual income taxes on capital with taxes on labor income. An alternative approach is to replace income taxes by a tax on consumption expenditures.[5]

The argument for eliminating capital income taxes ignores the fact that distortions in resource allocation resulting from these taxes must be replaced by other tax induced distortions. For example, labor income accounts for roughly sixty percent of U.S. private national income and a very substantial proportion of U.S. tax revenues. The taxation of labor income has received much less attention than the taxation of capital income. However, it is well established that, even though the price elasticity of labor supply is very low, there is a substantial substitution effect that is similar in magnitude but opposite in sign to the income effect of a change in the wage rate.[6] It is the substitution effect, not the total price effect, that is relevant to the impact of a tax on labor income on economic efficiency. The taxation of labor income has important implications for economic efficiency through its effects on the choice between labor and leisure.

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[3] Harberger's general equilibrium approach to the analysis of tax policy has been greatly further developed by Ballard, Fullerton, Shoven, and Whalley (1985). The economic impact of the Tax Reform Act of 1986 has been analyzed, using an extension of this model, by Fullerton, Henderson, and Mackie (1987). A recent survey of the literature on applied general equilibrium models for tax policy analysis is provided by Whalley (1988).

[4] The literature on the effect of taxation on saving is reviewed by Sandmo (1985) and Summers (1984). The impact of the Tax Reform Act of 1986 on saving behavior is analyzed by Hausman and Poterba (1987).

[5] Proposals for implementation of a consumption tax in the United States are discussed by the U.S. Department of the Treasury (1977), Hall and Rabushka (1983), and Bradford (1986). Arguments against a consumption tax are presented by the U.S. Department of the Treasury (1984), Vol. 3.

[6] The elasticity of labor supply and its implications for tax policy are discussed by Hausman (1981, 1985). The impact of the Tax Reform Act of 1986 on labor supply is analyzed by Hausman and Poterba (1987).

Major tax legislation like the Tax Reform Act of 1986 can produce substantial alterations in the rate of accumulation of capital and the allocation of capital among sectors and different types of assets. An assessment of the impact of tax reform depends not only on the changes in tax policy but also on the elasticities of substitution along all the relevant margins. The intertemporal margin, involving the allocation of resources between present and future consumption, is essential to the evaluation of the consequences of a tax reform involving changes in the the treatment of income from capital. We conclude that a fully dynamic model of the economy is required for measuring the impact of the tax reform on economic welfare.

In order to evaluate the economic impact of alternative tax reform proposals -- the Treasury proposal, the President's proposal, and the Tax Reform Act of 1986 -- we employ a dynamic general equilibrium model. This model provides a highly schematic representation of the U.S. economy. A single representative producer employs capital and labor services to produce outputs of consumption and investment goods. We have simplified the representation of technology by introducing a single stock of capital at each point of time. This capital is perfectly malleable and is allocated so as to equalize after tax rates of return to equity in the corporate, noncorporate, and household sectors.

Our model also incorporates a representative consumer that supplies labor services, demands consumption goods, and makes choices between consumption and saving. This model of consumer behavior is based on an intertemporally additive utility function that depends on levels of full consumption in all time periods. Full consumption is an aggregate of consumption goods, household capital services, and leisure. To simplify the representation of preferences we endow the representative consumer with an infinite lifetime and perfect foresight about future prices. We have fitted econometric models of producer and consumer behavior to data for the U.S. economy covering the period 1947-1986.[7]

[7] See Jorgenson and Yun (1986a) for a discussion of the model and Jorgenson and Yun (1986b) for an application to earlier changes in tax policy. The results presented in these papers are based on econometric models fitted to data covering the period 1955-1980. An alternative approach to dynamic general equilibrium modeling of U.S. tax policy is presented by Auerbach and Kotlikoff (1987).

In our model the equilibrium of the U.S. economy is characterized by an intertemporal price system that clears the markets for all four commodity groups included in the model -- labor and capital services and consumption and investment goods. Equilibrium at each point of time links the past and the future through markets for investment goods and capital services. Assets are accumulated as a result of past investments, while the price of an asset must be equal to the present value of future capital services. The time path of consumption must satisfy the conditions for intertemporal optimality of the household sector under perfect foresight.[8] Similarly, the time path of investment must satisfy requirements for the accumulation of assets by both business and household sectors.

The government sector of the U.S. economy raises revenues through taxes on income from capital and labor services. Corporate capital income is taxed at both corporate and individual levels, noncorporate capital income is taxed only at the individual level, and household capital income is not subject to income taxation. In addition, the government sector imposes sales taxes on the production of consumption and investment goods and property taxes on assets held by the business and household sectors. Taxes insert wedges between demand and supply prices for investment and consumption goods and for capital and labor services. These tax wedges distort private decisions and lead to losses in efficiency.

In order to evaluate alternative tax policies, we first consider the intertemporal equilibrium associated with each policy. Under perfect foresight there is a unique transition path to balanced growth equilibrium corresponding to any tax policy and any initial level of capital. The growth path of the U.S. economy consists of a plan for consumption of goods and leisure at every point of time by the representative consumer and a plan for production of investment and consumption goods from capital and labor services at every point of time by the representative producer. These plans are brought into consistency by the intertemporal price system.

Associated with each tax policy and the corresponding intertemporal equilibrium is a

[8] Perfect foresight models of tax incidence have been presented by Hall (1971), Chamley (1981), Judd (1987), and many others.

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level of welfare for the representative consumer. This level of welfare can be interpreted as a measure of economic efficiency corresponding to the potential level of welfare for society as a whole. The actual level of welfare also depends on the distribution of welfare among consuming units. To evaluate changes in tax policy in terms of efficiency we translate changes in potential welfare into an equivalent change in private national wealth. We first consider the time path of the price of full consumption associated with current tax policy. We then evaluate the difference in wealth required to attain levels of potential welfare before and after the change in tax policy at prices prevailing before the policy change.

The plan of this paper is as follows. In Section 2, we summarize the 1986 tax reform, the Treasury proposal, and the President's proposal in terms of changes in tax rates, the treatment of deductions from income for tax purposes, the availability of tax credits, and provisions for indexing taxable income for inflation. In Section 3, we analyze the tax burdens on capital income under four alternative tax policy regimes: the tax law in effect prior to the 1986 tax reform, the Treasury proposal, the President's proposal and the Tax Reform Act of 1986. We utilize the concept of an effective tax rate, which summarizes the statutory tax rates and the provisions of a given tax law that affect the definition of taxable income. We also employ the notion of a tax wedge, defined in terms of differences in tax burdens imposed on different types of income.

In Section 4 of the paper we analyze the impact of each of the alternative tax policies on U.S. economic growth. We evaluate the effects of changes in tax policy on economic efficiency by measuring the corresponding changes in potential economic welfare. The reference level of welfare, which serves as the basis of comparison among alternative tax policies, is the level attainable by the U.S. economy under the tax law in effect prior to the 1986 tax reform. We also analyze the losses in efficiency associated with tax wedges between different kinds of capital income. These tax wedges are the consequences of the corporate and personal income taxes, property taxes, and sales taxes on investment goods.

Section 5 provides a summary of the paper and presents our main conclusions. Our con-

clusions are, first, that much of the potential gain in welfare from the 1986 tax reform was dissipated through failure to index the income tax base for inflation. At rates of inflation near zero the loss is not substantial. However, at moderate rates of inflation like those prevailing for the past decade, the loss is highly significant. Second, the greatest welfare gains would have resulted from integrating the income from household assets into the tax base while reducing the tax rates on capital income in the business sector. This approach to tax policy played a minor role in the debates leading up to the Tax Reform Act of 1986. Third, the potential welfare gains from an income based tax system, reconstructed along these lines, would have exceeded those from a consumption based tax system.

2. The 1986 Tax Reform

When the Reagan Administration took office in 1981, there was widespread concern about the slowdown in U.S. economic growth. Federal tax policy was viewed by the new Administration as a major barrier to improved economic performance. Tax reform proposals by the Administration received overwhelming support from the Congress with the enactment of the Economic Recovery Tax Act (ERTA) of 1981.[9] The 1981 Tax Act combined sizable enhancements in investment incentives with substantial reductions in statutory tax rates for individuals and corporations.

The 1981 Tax Act introduced multi-year cuts in statutory tax rates at both individual and corporate levels with the aim of improving incentives "to work, save, and invest, consistent with the goal of eliminating the Federal budget deficit by 1984."[10] Prior to the 1981 Tax Act statutory tax rates under the individual income tax ranged from 14 to 70 percent of taxable income over fourteen tax brackets. However, important categories of income were excluded from the tax base. For example, only 40 percent of capital gains were included in income for tax purposes, so that the top rate for capital gains taxation was only 28 percent. There were four statutory tax brackets for corporate income with a top rate of 46 percent.

The 1981 Tax Act cut the statutory tax rates for individuals by 23 percent over the years 1982-84 -- 10 percent in 1982, another 10 percent in 1983, and a final five percent in 1984.[11] As a consequence of the multi-year reductions in statutory tax rates, the range of marginal tax rates for individuals was narrowed from 14-70 percent of taxable income to 11-50 percent. The 1981 Act also reduced corporate tax rates for the lowest two income brackets from 17 to 15 percent and from 20 to 18 percent over the years 1982-83.

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[9] We have analyzed the impact of the 1981 Tax Act on U.S. economic growth in a previous paper. See Jorgenson and Yun (1986b), esp. pp. 365-370.

[10] Joint Committee on Taxation (1981).

[11] The total tax cut was 0.1 + (0.1)(1.0-0.1) + (0.05)[1-(0.1)(1-0.1)] = 0.23.

2.1. The 1986 Tax Law

In describing the key features of the Tax Reform Act of 1986, we find it useful to begin with a description of the pre-existing tax law in order to provide a basis for comparison. We refer to this law as the Tax Law of 1986, since it remained in force until the end of calendar 1986. To provide additional perspective on the objectives of the 1986 tax reform, we also characterize two alternative tax reform proposals presented by the Department of the Treasury and the President. We summarize the statutory tax rates under the 1986 Tax Law, the Treasury and President's proposals, and the 1986 Tax Act in Table 1. We summarize the

(Table 1 goes about here)

definition of income for tax purposes in Table 2.

(Table 2 goes about here)

The first column in Table 1 gives average marginal tax rates for different types of income under the 1986 Tax Law for zero, six, and 10 percent annual inflation rates. The tax rate on each type of income is a weighted average of marginal tax rates paid by taxpayers in all income tax brackets. Average tax rates on different types of income reflect differences in the distribution of each type of income over the tax brackets. We present rates for income in the form of dividends and other distributions on corporate and noncorporate equity, for capital gains accruing on corporate and noncorporate equity, and for interest on corporate, noncorporate, household, and government debt.[12]

We also give the average marginal tax rate on labor income, the average marginal tax rate on income under the corporate income tax, and the average tax rate under the individual income tax. All tax rates include taxes levied at both Federal and state and local levels and take into account the deductibility of state and local taxes at the Federal level. In projecting U.S. economic growth under the 1986 Tax Law we take the average marginal tax rates on each type of income and the average individual income tax rate as fixed. Tax revenues received by

[12] These tax rates are based on detailed simulations of the Office of Tax Analysis Individual Income Tax Model presented by Cilke and Wyscarver (1987).

the government are generated by applying these tax rates to streams of income generated endogenously within our model of U.S. economic growth.

Prior to the 1981 Tax Act, the time period for capital cost recovery was based on the "useful life" of an asset. Under the 1981 Tax Act useful lifetimes were replaced by a highly simplified system of "tax lifetimes". The purpose of the new system was to reduce the burden of taxation on income from capital with the aim of promoting a higher level of capital formation. Tax lifetimes were considerably shorter than the corresponding useful lives and resulted in more rapid recovery of capital costs. Investment outlays on producers' durable equipment could be recovered over a five year tax lifetime. A three year lifetime was applied to automobiles, light trucks, special tools, and property used in connection with research and experimentation. Lifetimes of 10 and 15 years were employed for public utility property. Structures were also assigned a tax lifetime of 15 years.

The 1981 Tax Act provided three statutory schedules for capital consumption allowances for each category of investment expenditures on producers' durables: the first for property placed in service during the years 1981-84, the second for property placed in service in 1985, and the third for property placed in service after 1985. These three schedules provided for a gradual increase in the rates at which capital costs could be recovered. For structures the 1981 Tax Act provided a single schedule for capital cost recovery.

Prior to the 1981 Tax Act, a 10 percent investment tax credit was allowed for assets with a useful life of seven years or more. Two-thirds of the regular credit was allowed for assets with a useful life of five to six years and one-third of the credit for assets with a useful life of three to four years. The 1981 Tax Act made the investment tax credit more generous by allowing the 10 percent credit for assets with five-year, 10-year, 15-year tax lifetimes. The tax credit was applied to tangible property included in buildings such as elevators, but the structural components of buildings were excluded. The 1981 Tax Act permitted 60 percent of the regular credit for assets with a tax lifetime of three years. In addition to shortening capital recovery periods and liberalizing the investment tax credit, the 1981 Tax Act reduced the bur-

den of taxation on capital by lowering individual income tax rates and introducing so-called "safe harbor" leasing rules.

The 1981 Tax Act involved tax reductions across the board and created the prospect of rising Federal deficits. Only one year after the 1981 Tax Act the Congress passed the Tax Equity and Fiscal Responsibility Act of 1982 (TEFRA), which repealed the provisions of the 1981 Act for phasing in a more accelerated cost recovery system for property placed in service in 1985 and after. In addition, the 1982 Tax Act reduced the capital cost to be amortized over the tax lifetime of the asset by 50 percent of the investment tax credit. After a transitional period, the 1982 Tax Act repealed the safe harbor leasing provisions on January 1, 1984. In Table 3 we present economic depreciation rates for each of fifty-one classes

(Table 3 goes about here)

of assets distinguished in the U.S. national income and product accounts. We also give statutory rates of the investment tax credit and tax lifetimes under 1986 Tax Law, the Treasury and President's proposals, and the Tax Reform Act of 1986.[13] In Panel 1 of Table 4 we present average rates of the investment tax

(Table 4 goes about here)

credit and the present values of capital consumption allowances for short-lived and long-lived business assets under the 1986 Tax Law, prior to the enactment of the Tax Reform Act of 1986. Short-lived assets include all types of producers' durable equipment employed in the business sector. Long-lived assets include residential and nonresidential structures, land, and inventories.

2.2. The Treasury Proposal

The tax reforms of the early 1980's substantially reduced the burden of taxation on capital income. However, these reforms also introduced important non-neutralities in the taxa-

[13] The statutory rates of the investment tax credit and the tax lifetimes are based on the estimates of Fullerton, Gillette, and Mackie (1987).

tion of income from different sources. Differences in the tax treatment of different types of assets gave rise to concerns in Congress about the fairness of the tax system and the impact of tax induced distortions on the efficiency of capital allocation. In the State of the Union Address in January 1984 President Reagan announced that he had requested a plan for further tax reform from the Department of the Treasury.

In November 1984 the Treasury Department presented a tax reform plan that become known as the Treasury proposal. A principal objective of the Treasury plan was to reduce statutory tax rates at both individual and corporate levels. However, the Treasury plan was intended to be "revenue neutral," so as to produce the same revenue as the existing tax system.[14] Lower statutory tax rates were to be offset by eliminating a wide range of tax preferences, greatly broadening the tax base. In addition, the plan had the objective of introducing greater neutrality in the tax treatment of different types of assets. The Treasury proposed to offset the decreased progressivity of the rate structure by curtailing tax preferences heavily used by high income taxpayers and reducing the tax burden for low income earners through increased personal exemptions and zero bracket amounts for household heads.

Under the 1986 Tax Law the rate structure for the individual income tax consisted of fourteen separate tax brackets with statutory tax rates ranging from 11-50 percent of taxable income. Corporate income was taxed under a graduated rate structure with a top rate of 46 percent. The Treasury plan proposed to replace the fourteen individual income tax brackets with three broader brackets. Individual income was to be taxed at statutory rates of 15, 25 and 35 percent. The reduction of statutory income tax rates was expected to lower the average marginal tax rate of individuals by 20 percent and the average individual tax rate by 8.5 percent.

Table 1 shows the effects of the Treasury plan on average marginal tax rates. Under the

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[14] See U.S. Department of the Treasury (1984). The Treasury plan and its relationship to the Tax Reform Act of 1986 are discussed in detail by McLure and Zodrow (1987). McLure and Zodrow note that the definition of revenue neutrality did not take into account changes in the tax base. In the simulations of U.S. economic growth presented below we consider the impact of these changes on government revenues.

central assumption of six percent inflation the average marginal tax rate on income from equity was to be reduced by 11.6 percent – from 25.59 to 22.61 percent –and the corresponding average marginal tax rate on interest from corporate bonds was to be reduced by 16.1 percent -- from 17.30 to 14.52 percent. Finally, the average marginal tax rate on labor income was to be reduced by 15.3 percent – from 29.67 to 25.12 percent. Given the constraint that the tax reform proposed by the Treasury was to be revenue neutral, reductions in average marginal tax rates were to be offset by broadening the definition of taxable income at both individual and corporate levels.

Broadening of the income tax base under the Treasury proposal would have been achieved by wholesale elimination of tax preferences for individuals and corporations. For example, the deduction for state and local income taxes would have been repealed and other state and local taxes would have been deductible only to the extent that they were incurred in income generating activity. Property taxes on owner-occupied residential real estate would not have been deductible. Other proposed changes included the taxation of unemployment compensation, curtailment of the tax deductions for mortgage and other personal interest expenses, elimination of accelerated capital cost recovery, abolition of the investment tax credit, taxation of interest on private purpose municipal bonds, accrual basis taxation of earnings on life insurance policies, recovery of intangible drilling costs in the production of petroleum and natural gas through amortization rather than immediate expensing, and many others.

The Treasury proposal included extensive provisions for indexing income and deductions from income for tax purposes for inflation. This proposal would have retained the indexing of tax brackets, personal exemptions, and zero bracket amounts from the 1981 Tax Act for to prevent the upward creep of tax brackets as a consequence of inflation. In addition, the proposal would have indexed capital gains, interest expenses, interest income, FIFO inventory accounting, and capital cost recovery.[15] Prior to the tax reform of 1986, a 60 percent

[15] Deduction of mortgage and other personal interest would not have been indexed under the Treasury proposal. Indexing of interest income and interest expenses would have been based on the assumptions

exclusion of net capital gains was allowed as an adjustment of realized capital gains for inflation during the holding period of an asset. With the indexing of capital gains the 60 percent exclusion could no longer be justified as an adjustment for inflation and would have been eliminated under the Treasury proposal.

In order to provide relief from multiple taxation of dividend income, the Treasury proposal would have allowed a 50 percent deduction of dividends from corporate income, as defined for tax purposes. In addition, the proposal would have completely eliminated multiple taxation for intercorporate dividends by excluding 50 percent of dividends received by corporations from taxable income. On the average about 40-50 percent of after tax corporate profits are distributed to the shareholders in the form of dividends, so that these provisions would have significantly reduced the tax burden on corporate equity. Column 2 of Table 2 summarizes the key provisions of the Treasury proposal.

Utilization of the economic concept of income as the base for income taxation requires that capital cost recovery must coincide with economic depreciation. To achieve this objective the Treasury proposal would have classified producers' durable equipment into five-, eight-, 12-, 17-, and 25-year property and structures into two categories with tax lives of 38 and 63 years. The corresponding annual rates of depreciation were 0.32, 0.24, 0.18, 0.12, and 0.8 for producers' durables and 0.05 and 0.03 for structures, respectively. In addition, the Treasury proposal would have indexed capital cost recovery for inflation. Panels 1 and 2 of Table 4 show that capital cost recovery under the Treasury proposal would have been more favorable than under the 1986 Tax Law for both short-lived and long-lived assets at a high rate of inflation; the reverse is true at a low rate of inflation.[16]

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that the real interest rate is constant at six percent per year and that inflation raises the rate of inflation point for point. To the extent that the actual real rate of interest deviates from six percent, the indexing would have been incomplete.

[16] In this calculation, we have assumed that inflation rate increases the nominal interest rate point for point. Thus, the after tax real interest rate would have declined with inflation and the present value of capital consumption allowances would have increased with inflation under the Treasury proposal.

2.3. The President's Proposal

The Treasury tax reform plan resulted in a great public outcry, especially among taxpayers would would have been adversely affected by the elimination of tax preferences. However, the rate reductions in the proposal attracted widespread approval and considerable public support. The Reagan Administration did not endorse the Treasury plan, but set the Treasury staff to work on a revised proposal, duly delivered in May 1985.[17] The second Treasury tax reform plan was endorsed by the Administration and become known as the President's proposal. Not surprisingly, this proposal combined substantial reduction in tax rates at both individual and corporate levels with base broadening through the elimination of tax preferences.

The President's proposal would have followed the Treasury proposal by taxing individual income in only three tax brackets with statutory rates of 15, 25, and 35 percent. The President's proposal would also have raised personal exemptions and zero bracket amounts in order to compensate low income taxpayers for the loss in progressivity of the tax structure. The President's proposal would have maintained the favorable treatment of long term capital gains under the 1986 Tax Law, but would have reduced the proportion of capital gains excluded from income from 60 to 50 percent. In addition, beginning in 1991 taxpayers would have had the option of electing exclusion of 50 percent of capital gains from income for tax purposes or 100 percent inclusion of capital gains with complete indexing.

Under the President's proposal the corporate tax rate would have been graduated up to a top rate of 33 percent and corporate capital gains would have been taxed at a lower rate of 28 percent, as under the 1986 Tax Law. Table 1 shows the impact of the proposal on average marginal tax rates. These changes would have lowered the average marginal tax rates at the individual level by 19 percent and the average individual tax rate by seven percent. We find that average marginal tax rates under the Treasury and President's proposals are similar,

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[17] See U.S. Department of the Treasury (1985). The provisions of the Treasury proposal, the President's proposal, and the 1986 Tax Law are compared in Chart 18, pp. 26-30.

except that the tax rates on interest and labor income would have been slightly higher under the President's proposal.[18]

Like the Treasury proposal, the President's proposal was intended to produce the same tax revenue as the 1986 Tax Law. In order to offset the sharply lower statutory tax rates, the tax base would have been broadened by curtailing or eliminating tax preferences at both individual and corporate levels. In addition, many preferences favoring high income taxpayers would have been limited or abolished on grounds of fairness. Important changes in the list of tax preferences would have included the repeal of the investment tax credit, repeal of the deductibility of state and local income taxes, and accrual based taxation of earnings on life insurance policies.

Unlike the Treasury proposal, however, the President's proposal would not have indexed interest income and expenses. When combined with the option of indexing capital gains, this feature of the proposal would have reduced the cost of capital for projects with debt financing. Another implication of the deduction of nominal interest expenses is apparent in Panel 3 of Table 4; the present value of capital consumption allowances for short-lived assets is slightly greater than unity when inflation is six or 10 percent per year. Under our assumption that an increase in the rate of inflation would result in a point for point increase in the nominal rate of interest the after tax real interest rate becomes negative above a certain inflation rate.[19] The present value for long-lived assets in Panel 3 of Table 4 is smaller than unity only because our category of long-lived assets includes land and inventories as well as depreciable assets.

In order to alleviate multiple taxation of income from corporate equity, the President's proposal would have allowed a deduction of 10 percent of dividends paid from corporate

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[18] In Table 1 we assume that the taxpayers would elect to be taxed on real capital gains when inflation is zero and 50 percent of nominal capital gains when inflation is six or 10 percent.

[19] The after tax real interest rate is $(1-TQ)(i_0 + \pi) - \pi$, where i_0 is the real interest rate, π is the rate of inflation, and TQ is the corporate tax rate. The after tax real interest rate is negative for an inflation rate above $\frac{(1-TQ)i_0}{TQ}$.

income. Double taxation of intercorporate dividends would have been eliminated by excluding 90 percent of dividends received by corporations from taxable income. The President's proposal would have had the same effect as the Treasury proposal on the double taxation of intercorporate dividends, but would have had less impact on double taxation at corporate and individual levels. Column 3 of Table 2 summarizes the specific provisions of the President's proposal pertaining to taxation of income from capital.

The President's proposal would have replaced the Accelerated Cost Recovery System(ACRS) of the 1981 Tax Law with a new Capital Cost Recovery System (CCRS). An important difference from the Treasury proposal is that CCRS would have permitted accelerated capital cost recovery in order to provide systematic incentives for investment that are neutral across asset classes. Producers' durable equipment would have been classified into four-, five-, six-, seven-, and 10-year capital cost recovery classes. Structures would have been assigned to a 28-year class. Second, capital cost recovery under CCRS would have been indexed against inflation. This is one of the most important ideas carried over from the Treasury proposal.

2.4. The Tax Reform Act of 1986

The lengthy debate over tax reform was brought to a conclusion on October 22, 1986, by enactment of the Tax Reform Act of 1986. The main provisions of the new tax law took effect on January 1, 1987.[20] The 1986 Tax Act preserved many features of the Treasury and President's proposals. The final legislation resulted in sharply lower tax rates for both individuals and corporations. The highest statutory tax rate for individuals was lowered from 50 to 28 percent.[21] The corresponding rate for corporations was lowered from 46 to 34 percent. The substantial reductions in tax rates were offset by sharp cutbacks in tax preferences for both

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[20] The Tax Reform Act of 1986 is described by the Joint Committee on Taxation (1986). The economic impact of the 1986 tax reform is discussed in detail by Musgrave (1987) and Pechman (1987).

[21] Due to the phase-out of the 15 percent tax bracket and the personal and dependents' exemptions for high income taxpayers, the top marginal rate is as high as 33 percent for certain ranges of taxable income. Statutory tax rates under the 1986 Tax Act were higher for the transitional year 1987.

individuals and corporations.

Table 1 shows that the tax reform reduced average marginal tax rates on various types of income in approximately the same proportion as the Treasury and President's proposals. For example, if the annual rate of inflation is assumed to be six percent, the average marginal tax rate on individual income from equity is reduced by 20.6 percent -- from 25.59 to 20.33 -- and the average marginal tax rate on interest inc . from corporate debt is reduced by 17.1 percent -- from 17.30 to 14.34 percent. The reduction in the corporate income tax rate by 24.3 percent -- from 50.84 to 38.47 percent -- is even more dramatic. By contrast the average marginal tax rate on labor income is reduced by only 15.2 percent -- from 29.67 to 25.17 percent.

The magnitude of the 1986 reductions in statutory tax rates for individuals and corporations is very large. It is not surprising that the base for income taxation at both individual and corporate levels had to be broadened very substantially in order to achieve revenue neutrality. Under the 1986 Tax Law individuals, estates, and trusts were eligible for a 60 percent exclusion of realized net capital gains from taxable income. Corporations were taxed on capital gains at a rate of 28 percent, which was lower than the statutory corporate tax rate. Under the Tax Reform Act of 1986, the 60 percent exclusion of capital gains from taxable income at the individual level was repealed and all corporate capital gains, whether long term or short term, are taxed at the statutory corporate tax rate.

In spite of the reduction in the individual income tax rates, the accrual based average marginal tax rate on capital gains increased from 3.03 percent under the 1986 Tax Law to 5.62 percent under the Tax Reform Act of 1986. The Tax Reform Act did not include a provision for excluding dividend payments from corporate income. In addition, the deductibility of dividends received by corporations was reduced from 85 to 80 percent. This change mainly affects the tax burden on corporate equity owned through life insurance and other insurance companies and has little impact on the overall tax burden on corporate equity.

The Tax Reform Act of 1986 also repealed the 10 percent investment tax credit for property placed in service after December 31, 1985. Since this tax credit was applicable mainly to

investments in short-lived business assets, it had been a major source of non-neutralities in the taxation of income from different types of assets. Table 4 shows the differential impact of the investment tax credit on the cost of capital for short-lived and long-lived assets in the corporate and noncorporate sectors. Under the 1986 Tax Law the average rate of the investment tax credit in the corporate sector was 9.44 percent for short-lived assets and 4.26 percent for long-lived assets.[22] The repeal of the investment tax credit has substantially reduced differences in the tax treatment of assets of different types.

Compared with the 1986 Tax Law, the Tax Reform Act of 1986 spreads capital cost recovery over longer periods of time. The 1986 Act retains the three-year class, but automobiles, light duty trucks, and property used in connection with research and experimentation were moved to the five-year class. In addition, the 1986 Act provides for seven-, 10-, 15-, and 20-year capital cost recovery classes for equipment. Structures are classified into residential rental property and nonresidential property with tax lives of 27.5 years and 31.5 years, respectively.

Table 4 shows that the Tax Reform Act of 1986 increased the present value of capital consumption allowances for short-lived corporate assets at low or moderate rates of inflation and reduced the present value for high rates of inflation. This reflects the repeal of investment tax credit, since the basis of capital cost recovery was reduced by 50 percent of the investment tax credit under the 1986 Tax Law.[23] Capital cost recovery was made less rapid for producers' durable equipment, primarily through longer tax lifetimes. For structures the adoption of longer tax lives works in the same direction, reducing the present value of capital

[22] If capital cost recovery coincides with economic depreciation, equality of effective tax rates requires that the investment tax credit must be larger for long-lived assets than short-lived assets, since short-lived assets can take the credit more frequently than long-lived assets.

[23] If we adjust the present value of capital consumption allowances by increasing the basis for capital cost recovery to 100 percent, we find that the tax reform reduced the present value of capital cost recovery for short-lived assets. In order to adjust capital consumption allowances under the 1986 Tax Law for the effect of the provision reducing the basis of capital cost recovery by 50 percent of the investment tax credit, we can multiply the present value of capital cost recovery in Table 4 under the 1986 law by 1/(1-0.5 ITC), where ITC is the rate of investment tax credit in the same table. For example, when the annual rate of inflation is zero, the adjusted present value of capital cost recovery for a short-lived corporate asset is 0.9223/(1 - 0.5*0.0944) = 0.9680, which is larger than the corresponding value, 0.9472, under the Tax Reform Act of 1986.

cost recovery.

3. Effective Tax Rates

The tax burden on capital income can be summarized by means of the effective marginal tax rates on income from each type of assets. Effective tax rates represent the complex provisions of tax law in terms of a single ad valorem tax rate. This tax rate is based on the social rate of return, defined as income per dollar of capital, adjusted for inflation and depreciation but not for taxes. This social rate of return can be compared with the corresponding private rate of return, which excludes all tax liabilities at both corporate and individual levels. The effective tax rate is defined as the difference between the social and private rates of return, divided by the social rate of return.[24]

To describe the Tax Reform Act of 1986, the pre-existing 1986 Tax Law, and the alternative reform proposals presented by the Treasury and the President we present effective tax rates for assets held by three different legal forms of organization -- corporate, noncorporate, and household -- and for short-lived and long-lived assets. We also present tax wedges among different types of assets, defined as differences between social rates of return on these assets. We give tax wedges for transfers between asset categories within a sector, between sectors, and between the present and the future. We refer to these as interasset, intersectoral, and intertemporal tax wedges.

In generating effective marginal tax rates and tax wedges we have employed parameters describing the alternative tax laws and tax reform proposals from Tables 1 through 3. In addition, we have set the values of parameters describing the financial structure of each sector, the after corporate tax rate of return to corporate capital, and the rate of interest at corresponding averages for the 1967-1986 period. Property tax rates are set at 1986 values.

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[24] The definition of effective tax rates is discussed in more detail in our earlier paper, Jorgenson and Yun (1986b), 357-364. The effective tax rates presented below are based on the "traditional view" of corporate finance discussed by Poterba and Summers (1983). Effective tax rates at the corporate level have compared for Germany, Sweden, the U.K. and the U.S. for the year 1980 by King and Fullerton (1984). These effective tax rates are based on the so-called "new view" of corporate finance. The literature on the new view is surveyed by Auerbach (1983). Auerbach (1987) presents effective tax rates based on the new view for different types of assets within the corporate sector under the Tax Reform Act of 1986. Fullerton, Gillette, and Mackie (1987) give effective tax rates under the 1986 Tax Act for both views of corporate finance.

Finally, we assume that an increase in the rate of inflation raises the nominal rate of interest point for point.

3.1. The 1986 Tax Law

We present effective tax rates under the 1986 Tax Law in Table 5.

(Table 5 goes about here)

With a six percent rate of inflation these rates are 2.4 percent for short-lived assets and 44.4 percent for long-lived assets in the corporate sector. The difference in the social rates of return between the two asset classes is 4.0 percent. This tax wedge represents the difference between the marginal productivities of long-lived assets and short-lived assets. Transferring one dollar's worth of capital from short-lived to long-lived assets would increase the national income in perpetuity by four cents per year with no additional investment. This is a very substantial tax wedge, comparable in magnitude to the social rate of return, suggesting that the potential gains from tax reform are very large.

The provisions of tax law interact with the rate of inflation in determining the tax burden on capital income. First, a higher rate of inflation reduces the present value of capital cost recovery, since cost recovery is not indexed against the impact of inflation. Second, taxation of nominal interest income, coupled with tax deductibility of nominal interest expenses, tends to reduce the tax burden as the rate of inflation increases. For corporate and noncorporate assets the firm's marginal tax rate for the deduction of interest expenses is higher than the individual's marginal tax rate on interest income. On balance the tax burden on corporate and noncorporate assets increases with the rate of inflation.[25] As the rate of inflation rises, the tax burden on short-lived assets increases faster than that on long-lived assets. As a consequence the interasset tax wedge declines with the rate of inflation.

Under the 1986 Tax Law assets in the noncorporate sector have lower tax burdens than

[25] Another mechanism, which we do not model, is that firms using the first-in-first-out (FIFO) inventory accounting method overstate their profits and hence their taxable income when inflation is positive.

corresponding assets in the corporate sector. Table 5 shows that the effective marginal tax rates for short-lived and long-lived assets are -15.2 and 31.2 percent, respectively. These rates are substantially lower than the corresponding rates in the corporate sector. The interasset tax wedge between short-lived and the long-lived assets is 3.0 percentage points. Although this tax wedge is smaller than that in the corporate sector, the interasset tax wedge in the noncorporate sector suggests substantial opportunities for gains from tax reform.

A striking feature of effective tax rates in the noncorporate sector is that the effective tax rate on short-lived assets is negative. The provisions for capital cost recovery and the investment tax credit are so favorable that the tax system, in effect, provides subsidies to noncorporate investment in short-lived assets. These subsidies take the form of "tax shelter" that can be used to reduce tax liabilities for other types of income. The effects of inflation on the tax burdens and the interasset tax wedge in the noncorporate sector is similar to that in the corporate sector. Inflation increases the tax burden on capital income and reduces the interrasset tax wedge.

The value of capital services of household assets, such as the rental equivalent of owner-occupied housing or the services of consumers' durables, is not included in taxable income. However, effective tax rates on household assets are affected by provisions of the individual income tax, since payments for personal and mortgage interest are deductible and interest income from the debt claims on household assets is taxable. Like the assets in the corporate and noncorporate sectors, household assets are also subject to property taxes. Table 5 shows that the effective tax rate on household assets is 12.7 percent with six percent inflation. The rate increases slightly with inflation. Since the income from household assets is not taxable, there is no interasset tax wedge in the household sector.

Table 5 shows the intersectoral tax wedges under the 1986 Tax Law for short-lived and long-lived assets. When the rate of inflation is six percent per year, the intersectoral tax wedge between the corporate and noncorporate sectors is 0.9 percent for short-lived assets and 1.9 percent for long-lived assets. The wedges between the noncorporate and

household sectors are -0.7 percent for short-lived assets and 2.3 percent for long-lived assets. The wedges between the corporate and household sectors are 0.2 percent for short-lived assets and 4.2 percent points for long-lived assets. Unlike the interasset tax wedges, the intersectoral tax wedges tend to increase with the rate of inflation, since the tax burden of corporate assets increases faster than that of noncorporate assets, which in turn increases faster than that of household assets.

3.2. The Treasury Proposal

Effective marginal tax rates on business assets given in Table 6

(Table 6 goes about here)

are similar to those under the 1986 Tax Law. A comparison of Tables 5 and 6 reveals that at six percent inflation the Treasury proposal would have slightly reduced the effective marginal tax rate from 35.9 to 35.1 percent for corporate assets and from 29.3 to 27.1 percent for noncorporate assets. Since the 1986 Tax Law does not index taxable income and tax deductions, the Treasury proposal would have increased the tax burden at a lower rate of inflation, but would have decreased it at a higher inflation rate.

The effective marginal tax rates under the Treasury proposal reflect the combined effects of the repeal of investment tax credit, the introduction of economic depreciation, lowering of statutory tax rates, and indexing of interest income, interest expenses, and capital gains. Of the many tax policy changes in the Treasury proposal, the repeal of investment tax credit would have had the greatest impact on effective tax rates on income from capital. Since short-lived business assets received the most important benefits from the investment tax credit under the 1986 Tax Law, the increase in the tax burden on short-lived assets under the Treasury proposal would have been most marked.

The objectives of the Treasury proposal were to reduce tax wedges among different forms of investment and to insulate the tax structure from the impact of inflation. We find that the Treasury proposal would have reduced interasset tax wedges substantially. Under

the 1986 Tax Law with six percent inflation, the tax wedges between short-lived and long-lived assets are 4.0 percent in the corporate sector and 3.0 percent in the noncorporate sector. They would have been reduced to only 1.2 percent and 0.6 percent, respectively, under the Treasury proposal. To the extent that the welfare cost of a tax distortion increases with the tax wedge, reductions in the interasset tax wedges of this magnitude could have improved the efficiency of capital allocation within each sector significantly.

Second, the Treasury proposal would have substantially reduced the intersectoral tax wedges for long-lived assets, but would have had mixed effects for short-lived assets. The impact of the proposal on intersectoral tax wedges for short-lived assets would have depended on the rate of inflation. The Treasury proposal would have been relatively ineffective in eliminating the substantial intersectoral tax wedges for long-lived assets under the 1986 law, since long-lived assets would have born a heavier tax burden than the short-lived assets under the proposal. In addition, corporate assets would have been more heavily taxed than noncorporate assets which, in turn, would have been more heavily taxed than household assets.

Third, the repeal of investment tax credit would have increased the tax burden roughly as much as as the reduction of the statutory tax rates would have decreased it at a six percent rate of inflation. The average effective tax rate for the entire corporate sector would have changed only from 35.9 percent to 35.1 percent and the intertemporal tax wedge would have increased slightly from 2.9 percent to 3.0 percent. The effect of the repeal of investment tax credit is seen most clearly in the case of the short-lived business assets. At a six percent rate of inflation, the effective tax rate on short-lived corporate assets would have increased from 2.4 percent under the 1986 law to 28.0 percent under the Treasury proposal and the intertemporal tax wedge would have increased from 0.1 percent to 2.1 percent. The pattern is reversed for long-lived assets, since the intertemporal tax wedges would have been smaller under the Treasury proposal.

Finally, the Treasury proposal would have reduced the impact of inflation on the tax

burden on capital income by defining taxable income to approximate economic income more closely. The tendency of the tax burden to decline with inflation under the Treasury proposal is due to incomplete indexing of interest payments.[26] To the extent that interest is not completely indexed, inflation tends to increase the after tax real interest rate and reduce the present value of capital consumption allowances, even if tax depreciation is completely indexed against inflation. On the other hand incomplete indexing reduces the cost of debt financing. Table 6 indicates that the result of these two opposing effects would have been to reduce the marginal tax burden of capital with higher rates of inflation under the Treasury proposal.

3.3. The President's Proposal

We summarize effective tax rates under the President's proposal in Table 7.

(Table 7 goes about here)

Overall, the effects of the President's proposal would have been similar to those of the Treasury proposal. The tax burden on income from capital would have increased at a low rate of inflation and decreased at a high rate. The interasset tax wedges in the corporate and noncorporate sectors would have been reduced; the intersectoral tax wedges of long-lived assets would also have been reduced, but effects on the tax wedges for the short-lived assets would have been mixed. However, a careful comparison of Tables 6 and 7 reveals a number of subtle differences between the Treasury and President's proposals, many of which are attributable to differences in the impact of inflation on the tax system.

With no inflation the President's proposal would have been more favorable to investment, since it would have imposed lower tax burdens on capital through the retention of accelerated schedules for capital cost recovery. At six or 10 percent inflation rates, the President's proposal would have been even more favorable to investment, since the indexing

[26] We assume that the real interest is 3.57 percent as opposed to the six percent used in the proposal. Under our assumptions interest income and expenses would have been incompletely indexed and inflation would have had an impact on effective tax rates.

of capital consumption allowances would have been coupled with the deduction of nominal interest expenses. This would have increased the present value of capital consumption allowances at higher rates of inflation. In addition, inflation would have lowered the tax burden on capital as a consequence of the tax deductibility of nominal interest expenses. The value of the resulting deductions would have been greater than the additional tax liabilities resulting from the taxation of nominal interest income at the the individual level. Similar reasoning can be applied to explain the decline of the intersectoral tax wedges with inflation.

Under the 1986 Tax Law and the Tax Reform Act of 1986 capital cost recovery is not indexed for inflation, so that an increase in the inflation rate adds to the tax burden on income from capital. Under the Treasury proposal, the recovery of capital cost would have been indexed and interest would have been indexed incompletely. There would have been a slight tendency for the tax burden on capital income to decline with inflation. This tendency would have been strengthened under the President's proposal, since capital cost recovery would have been indexed, while interest deductions would not. Tables 6 and 7 show that the President's proposal would have narrowed the intersectoral tax wedges relative to the Treasury proposal. By contrast the Treasury proposal would have had uniformly smaller interasset tax wedges.

3.4. The Tax Reform Act of 1986

Since the Tax Reform Act of 1986 embraced many of the ideas contained in the Treasury and President's proposals, the impact of the tax reform on effective tax rates and tax wedges is similar to that of the two proposals. Table 8 shows that the repeal of the investment tax

(Table 8 goes about here)

credit more than offset the reduction in the statutory tax rates, so that the overall tax burden on income from capital is increased. Despite the acceleration of capital cost recovery and lower marginal tax rates, the impact of repeal of the investment tax credit is most evident in the increase of the tax burden on short-lived business assets. At six percent inflation, the Tax

Reform Act of 1986 imposes an effective tax rate on short-lived assets of 38.2 percent in the corporate sector and 28.2 percent in the noncorporate sector, while the corresponding tax rates are 2.4 percent and -15.2 percent under the 1986 Tax Law.

For long-lived assets, effective tax rates are not much affected by tax reform. The effects of lower tax rates are approximately offset by the combined effects of the longer cost recovery period and the repeal of the investment tax credit. At six percent inflation, the interasset tax wedges in the corporate and noncorporate sectors are only 1.0 percent and 0.6 percent, while the corresponding figures are 4.0 percent and 3.0 percent, respectively, under the 1986 Tax Law. Table 8 shows that the effective tax rates on household assets are essentially unaffected by the reform, since the difference between the average marginal tax rates on equity and debt claims is nearly unchanged and property taxes remain the same.

Overall, the tax burden on the income from capital is increased by the 1986 tax reform. As a consequence, the intertemporal tax wedges are larger and the efficiency of intertemporal resource allocation is adversely affected. On the other hand, the interasset tax wedges are considerably reduced and the efficiency of interasset capital allocation is enhanced. At six percent inflation intersectoral wedges are increased for short-lived assets and decreased for long-lived assets.

Since the tax reform did not incorporate the indexing of capital income taxation, as provided in the Treasury proposal, the impacts of inflation on effective tax rates and tax wedges under the Tax Reform Act of 1986 are similar to those under the 1986 Tax Law. The tax burden on income from capital increases with inflation. Since the tax burden on short-lived assets rises faster than that on long-lived assets, interasset tax wedges decline with the rate of inflation. The tax burden on corporate assets increases faster than that on noncorporate assets, which in turn increases faster than that on household assets, so that intersectoral tax wedges increase with the rate of inflation.

4. Tax Reform and Economic Growth

In this section we estimate the impact of alternative tax policies -- the Treasury proposal, the President's proposal, and the Tax Reform Act of 1986 -- on U.S. economic growth. We evaluate the effect of each of the alternative tax reform proposals by comparing the resulting level of welfare with that attainable under the "base case" given by the 1986 Tax Law. Since effective tax rates and tax wedges depend on the rate of inflation, we consider three alternative rates of inflation -- zero, six, and 10 percent. In these comparisons we impose the requirement that the revenue and expenditure of the government sector are the same as in the base case.

We consider four alternative methods for adjusting tax revenues so as to keep the budgetary position of the government sector the same as in the base case. The first method is to increase or decrease government revenues by means of a "lump sum" tax or subsidy. We model a lump sum tax by altering the budget constraint facing the representative consumer. A tax results in a contraction of the budget available to the consumer and a corresponding increase in government revenue. Similarly, a subsidy expands the budget available to the consumer and decreases government revenue. A lump sum tax or subsidy does not distort decisions in the household or business sectors of the economy by altering the tax wedges facing the representative consumer or the representative producer.

We also consider three methods for adjusting government revenues that involve changes in tax induced distortions. These include proportional adjustments to labor income taxes, sales taxes on investment and consumption goods, and taxes on income from both capital and labor. The labor income tax adjustment affects the tax rate for labor services, the sales tax adjustment affects the tax rates for consumption and investment goods, and the income tax adjustment affects the tax rates for both capital and labor services. By considering all three methods we are able to assess the sensitivity of the welfare rankings of alternative tax policies to changes in the constraints imposed by the requirement of revenue neutrality.

4.1. The Tax Reform Act of 1986

We summarize the results of our simulations of U.S. economic growth under alternative tax policies in Table 9. An important conclusion we can draw

(Table 9 goes about here)

from Table 9 is that the Treasury proposal, the President's proposal and the Tax Reform Act of 1986 all improve potential economic welfare substantially. In our central case with six percent inflation and a lump sum tax adjustment, the President's proposal would have generated a welfare gain of $2452.2 billion, while the Treasury proposal would have generated a gain of $1907.6 billion. However, the welfare gain associated with the Tax Reform Act of 1986 is only $448.4 billion.[27]

With no change in government expenditures the Tax Reform Act of 1986 results in more revenue than is necessary to keep the government in the same budgetary position as under the 1986 Tax Law. In order to leave government revenue the same under the two tax policies, tax revenues must be rebated to the household sector. Replacing the lump sum tax adjustment with a distortionary tax adjustment lowers the rates of the distortionary taxes involved and improves the performance of the economy under the Tax Reform Act of 1986. By contrast, the Treasury and the President's proposals would have resulted in less revenue than the 1986 Tax Law. The welfare gains would have been smaller under the distortionary tax adjustments than under the lump sum tax adjustment.

Another perspective on the economic impact of the alternative tax reform proposals is provided by a comparison of the welfare gains from tax reform with the private national wealth. The nominal value of the U.S. private national wealth at the beginning of 1987 was $15,920.2 billion. Making use of this figure, we estimate that the welfare gains from the Treasury and the President's proposals would have been equivalent to increases of 12.0 and 15.4 percent, respectively, of U.S. private national wealth in 1987.[28] The welfare gain from the

[27] These welfare gains are measured in 1987 dollars.

[28] In interpreting these comparisons in terms of the U.S. private national wealth, it is useful to bear in mind that the private national wealth includes only nonhuman wealth, while the welfare gains from tax reform accrue to the owners of nonhuman capital and also to recipients of labor income, which can be

Tax Reform Act of 1986 is equivalent to an increase of only 2.8 percent of the national wealth.

Under distortionary tax adjustments the welfare gains would have been somewhat smaller for the President's proposal and slighly smaller for the Treasury proposal. The gains are substantially larger for the 1986 Tax Reform Act. However, these gains are not sensitive to the differences among the distortionary tax adjustments.[29] If we consider a sales tax adjustment with a six percent inflation rate, the welfare gains would have been $1600.1 billion for the Treasury proposal and $2014.9 billion for the President's proposal. These gains would have totaled 10.1 and 12.3 of the U.S. private national wealth in 1987. The corresponding welfare gain is $901.2 billion for the Tax Reform Act of 1986. This is equivalent to 5.7 percent of the national wealth.

It is worth recalling that inflation reduces the interasset tax wedges and increases the intertemporal and the intersectoral tax wedges under the 1986 Tax Law and the Tax Reform Act of 1986.[30] Under the Treasury and President's proposals, inflation has little effect on the interasset wedges but tends to reduce the intersectoral and intertemporal tax wedges. The results presented in Table 9 show that inflation improves the performance of the economy under the Treasury and President's proposals and affects economic performance adversely under the 1986 Tax Law and the Tax Reform Act of 1986. We conclude that the positive impact of inflation on intertemporal and intersectoral resource allocation more than offsets its negative impact on interasset allocation.

Table 9 also shows how the welfare effects of alternative tax reforms would be affected by the rate of inflation. It is useful to focus on lump sum tax adjustments since distortionary tax adjustments result in reallocations of resources due to substitutions as well as to changes in the rate of inflation. Economic welfare improves with higher inflation under the Treasury and President's proposals. On the other hand, welfare declines with inflation under the 1986

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regarded as a return to human capital.

[29] This does not imply that the distortionary effects of the taxes used for revenue adjustments are similar. Rather it reflects the fact that the size of the required revenue adjustments is not large enough to produce sizable differences.

[30] To be more precise, inflation increases the intersectoral tax wedges under the 1986 Tax Law, but has mixed effects on the absolute size of the intersectoral tax wedges where the wedges have a negative sign.

Tax Law and the Tax Reform Act of 1986. This is due to the fact the tax burden on capital income is reduced with higher inflation under the two proposals, while inflation increases the tax burden on capital income under the 1986 Tax Law and the Tax Reform Act of 1986. An increase in the rate of inflation from zero to six percent is sufficient to alter the welfare ranking between the Treasury proposal and the Tax Reform Act of 1986.

4.2. Alternative Approaches to Tax Reform.

We have measured the impact of the Tax Reform Act of 1986 on economic welfare, employing the 1986 Tax Law as a basis for comparison. We have also assessed the potential impact of the Treasury and President's tax reform proposals. We next consider alternative approaches to tax reform based on the elimination of tax wedges among different types of assets. As before, the growth path of the U.S. economy under the 1986 Tax Law is taken as a basis for comparison. We measure the potential gains in economic welfare from changes in tax policy by comparing the resulting levels of welfare with those corresponding to the 1986 Tax Law.

For the purposes of this analysis we find it useful to distinguish between atemporal tax wedges and intertemporal tax wedges. The elimination of an atemporal tax wedge requires that the social rates of return on the corresponding assets are equalized within a given time period. We eliminate atemporal tax wedges among assets by equalizing the corresponding social rates of return at a weighted average of the social rates of return, where stocks of assets are used as weights. More precisely, we equalize social rates of return associated with balanced growth equilibrium under the 1986 Tax Law, using the balanced growth proportions of assets as weights.

To model the integration of the corporate and individual income taxes we set the social rates of return on corporate assets equal to those on the corresponding noncorporate assets. This procedure does not affect the private rates of return in the two sectors, so that effective tax rates are not equalized between the sectors. The private rates of return of assets in dif-

ferent sectors differ for two reasons. The first is that debt/asset ratios differ across sectors. The second is that average marginal tax rates on individual income vary from sector to sector due to the differences in the distribution of asset ownership among taxpayers in different income tax brackets.

We consider the elimination of five sets of tax wedges: (1) the interasset tax wedges within the corporate and noncorporate sectors, (2) intersectoral tax wedges between assets of the same type held in the corporate and noncorporate sectors, (3) intersectoral tax wedges among assets of the same type held in the business and household sectors, where the business sector includes both the corporate and noncorporate business. (4) all the atemporal tax wedges in the business sector, and (5) all the atemporal tax wedges in the business and the household sectors. We also consider the integration of corporate and noncorporate taxes.

Elimination of an intertemporal tax wedge requires equalizing the social and private rates of return, so that the effective tax rate on the corresponding assets is reduced to zero. We consider two possible approaches to tax reform for eliminating intertemporal tax distortions. First, we consider the elimination of intertemporal tax wedges resulting from the income and property taxes. This leaves the sales tax on investment goods at its level in the base case, while reducing the effective tax rate on capital income to zero. Second, we eliminate the tax burden on capital altogether by removing the the sales tax on investment goods as well as the taxes on income from capital and property taxes. These two approaches correspond to alternative implementations of consumption tax rules for the taxation of capital income.

We summarize the social rates of return, effective tax rates, and the sum of the investment tax credit and the present value of tax deductions for capital cost recovery with the elimination of tax wedges among different classes of assets in Table 10.

(Table 10 goes about here)

Panel A represents the base case corresponding to 1986 Tax Law. Panel B represents the elimination of interasset tax wedges within the corporate and noncorporate sectors. This can

be achieved by setting the sums of the investment credit and the present value of tax deductions for capital cost recovery at the values specified in the table. The social rates of return and the effective tax rates must be the same for short-lived and long-lived assets within each sector, since the private rate of return is the same for all assets within the sector. After interasset wedges are eliminated, the intersectoral and intertemporal tax wedges remain.

In Panel C we eliminate the intersectoral tax wedges between assets in the corporate and noncorporate sectors by equalizing social rates of return on short-lived assets in the two sectors. Similarly, we equalize social rates of return on long-lived assets. After the intersectoral tax wedges within the business sector are removed, the interasset tax wedges and intersectoral wedges between the business and household sectors still remain. In Panel D we also eliminate the intersectoral tax wedges between business and household sectors. This approach to tax reform eliminates all the intersectoral tax wedges, but creates an interasset tax wedge in the household sector where none existed before the change in tax policy. There are interasset tax wedges in the corporate and noncorporate sectors as well.

In Panel E we eliminate both the interasset and intersectoral tax wedges in the business sector. Conceptually, the tax reforms represented in Panel E are a combination of the reforms represented in Panels B and C. In Panel F all the atemporal tax wedges are eliminated, so that the only remaining sources of tax distortions are the intertemporal tax wedges. In Panel G, we eliminate the intersectoral tax wedges between corporate and noncorporate sectors by setting the social rates of return on corporate assets equal to the corresponding rates on noncorporate assets. The substantial reduction in tax revenue can be offset by a lump sum tax or by proportional adjustments in the labor income tax, sales tax, or individual income tax. Finally, in Panel H all the intertemporal tax wedges are eliminated and the social and private rates of return are equalized for all assets.

4.3. Welfare Impacts of Tax Reform

We summarize the welfare impacts of the eight hypothetical tax reform proposals in

Table 11. Beginning with lump sum tax adjustments, we find that the welfare

(Table 11 goes about here)

gain from elimination of interasset tax wedges that exist under the 1986 Tax Law is $443.9 billion. The elimination of intersectoral tax wedges between assets in the corporate and noncorporate sectors yields welfare losses instead of gains. Given Harberger's (1966) analysis of the impact of the corporate income tax, this is a rather surprising result. The elimination of a tax wedge would usually be expected to increase the efficiency of resource allocation and improve the level of economic welfare. However, the demand for capital services is much more elastic in the noncorporate sector than in the corporate sector. Equalizing the social rates of return between the corporate and noncorporate assets reduces the total demand for the business capital services.

The third change in tax policy analyzed in Table 11 is the elimination of intersectoral tax wedges between the household and business sectors. The results suggest that there is a very large potential welfare gain to be realized from this change in tax policy under the 1986 Tax Law. The estimated gain is $2262.6 billion at a six percent rate of inflation, which is much larger than *that* we have estimated for the Tax Reform Act of 1986. Given the substantial tax wedges between business and household assets under the 1986 Tax Law, this result is not surprising. For example, the intersectoral tax wedges for short-lived assets are 0.2 percent between the corporate and household sectors and -0.7 percent between the noncorporate and household sectors. The corresponding figures for long-lived assets are 4.2 percent and 2.3 percent, respectively.

The welfare gain from eliminating the interasset and intersectoral wedges among business assets is estimated to be only $326.4 billion under the 1986 Tax Law. The welfare gain from eliminating all the atemporal tax wedges in the private sector of the U.S. economy is estimated to be $2663.7 billion. This gain is much larger than the welfare gain resulting from elimination of interasset distortions within each sector and somewhat larger than that resulting from elimination of intersectoral tax distortions for all sectors. In view of the relative

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magnitude of these effects, we can attribute most of the welfare gain to elimination of intersectoral tax wedges between business and household assets.

In the sixth change in tax policy we consider is the elimination of intersectoral tax wedges between assets in the corporate and noncorporate sectors. For this purpose we set social rates of return on corporate assets equal to the corresponding rates of return on noncorporate assets under the 1986 Tax Law. The effective tax burden on corporate assets is unambiguously reduced by this hypothetical change in tax policy. The estimated welfare gain from this change in tax policy is $1313.1 billion. The gain is about half of that attainable by eliminating all intersectoral tax wedges.

In the six changes in tax policy we have considered up to this point, we have focused attention on the distortionary impact of atemporal tax wedges. We next consider the elimination of intertemporal tax wedges by setting effective tax rates on all types of income from capital equal to zero. We find that the elimination of intertemporal tax wedges generates huge welfare gains under lump sum tax adjustment. When sales taxes on investment goods are also abolished, the welfare gain becomes even larger. Taking the 1986 Tax Law as the base case, the welfare gain from removing intertemporal tax wedges on all assets is $3853.9 billion. The elimination of the sales taxes on investment goods produces a gain of $4128.1 billion.

The magnitudes of welfare gains from elimination of the intertemporal tax wedges under distortionary tax adjustments presented in Table 11 are substantially lower than those under lump sum tax adjustment. The changes in marginal tax rates required to offset revenue losses can generate significant subsitution effects. The welfare effects resulting from the elimination of intertemporal tax wedges, as given in Table 11, are also sensitive to the choice among distortionary tax adjustments, since the required increase in tax revenue is large.

If a proposed tax reform is roughly revenue neutral, so that the magnitude of the required adjustment in tax revenue is small, the welfare ranking of alternative policy changes does not depend on the method for adjusting tax revenue. For a change in tax policy that involves substantial rate cuts with no compensating enhancement of tax revenues through

base broadening, the welfare measures under the lump sum tax adjustment can be interpreted as upper bounds of the welfare gains that can may be achieved. Any realistic tax reform involving revenue adjustment through changes in distortionary taxes would result in welfare gains well below those attainable under the hypothetical lump sum tax adjustment.

The fact that the estimated welfare gains from the elimination of the intertemporal tax wedges is in the range of four trillion dollars suggests that the potential welfare gain from replacing the current system of income taxes with consumption based taxes is very large indeed. However, the welfare gains are reduced by approximately half under the more realistic assumption that revenue losses are offset by distortionary tax adjustments. These welfare gains are still impressive. We conclude that improvements in the efficiency of intertemporal resource allocation must be carefully weighed against possible worsening of atemporal resource allocation as a consequence of distortions associated with taxes on consumption.

5. Conclusion

The Tax Reform Act of 1986 increases the effective marginal tax burden on income from capital at any positive inflation rate. Nonetheless, the change in economic welfare relative to the 1986 Tax Law is positive. The 1986 Tax Act improves the efficiency of atemporal resource allocation sufficiently to offset the negative impact of greater effective tax rates on capital income. Higher rates of inflation result in a marked reduction in the sizable welfare gains from the 1986 tax reform at rates of inflation near zero. For example, we estimate that the welfare gain is $448.4 billion at a six percent rate of inflation, which amounts to 2.8 percent of U.S. private national wealth in 1987. The 1986 Tax Act substantially reduces interasset tax wedges within the business sector, so that potential welfare gains from further reductions is small.

An important feature of the Treasury and President's proposals is that the tax base would have been largely indexed against inflation. By contrast the tax burden on income from capital under the Tax Reform Act of 1986 increases significantly with the rate of inflation. While the gains from the 1986 Tax Act are comparable to those of under the Treasury and President's proposals at inflation rates near zero, the gains under the two proposals are much greater at moderate or high rates of inflation. For example, the President's proposal would have resulted in a welfare gain of $2452.2 billion dollars at a six percent inflation rate, which dwarfs the corresponding gain from the Tax Reform Act of 1986. We conclude that insulating the tax system from the effects of inflation should remain a top priority for future tax reform.

However, the largest welfare gains from tax reform would have been obtained by transferring part of the tax burden on business capital to household capital. There are obviously important political obstacles to such a transfer. Limitations on the deductibility of mortgage interest and elimination of the tax deductibility of state and local property taxes were included in the Treasury proposal. However, only a very modest limitation of the deductibility of mortgage interest survived into the final 1986 tax reform legislation. The welfare gain

from a tax policy that treats all forms of capital income symmetrically would have been $2663.7 billion dollars at a six percent inflation rate. This exceeds the gain from the 1986 Tax Act by $2215.3 billion dollars and outranks the gains from both the Treasury and President's proposals.

An alternative approach to equalizing the tax burdens between business and household assets would have been to replace the 1986 Tax Law with a tax system based on consumption. At a six percent inflation rate the welfare gain from shifting to a consumption based tax system from a system primarily based on income would have been much larger than the gain from the Tax Reform Act of 1986. This conclusion holds for any of the alternative methods we have considered for maintaining government revenue at same level as under the 1986 Tax Law. The prospective revenue losses associated with elimination of capital income taxation would have required large increases in distortionary taxes. However, the resulting welfare losses would have been outweighed by gains in efficiency from eliminating capital income taxes.

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Table 1. Tax Rates

1. Average Marginal Tax Rates of Individual Capital Income

A. 0% Inflation

	1986 LAW	TREAS	PRESID	1986 ACT
TEQ	0.2555	0.2261	0.2240	0.2029
TEM	0.2934	0.2427	0.2572	0.2494
TGQ	0.0303	0.0596	0.0325	0.0562
TGM	0.0293	0.0607	0.0322	0.0624
TDQ	0.1533	0.1452	0.1532	0.1285
TDM	0.1971	0.1805	0.1912	0.1670
TDH	0.2717	0.2252	0.2387	0.2310
TDG	0.2205	0.1868	0.1970	0.1852

B. 6% Annual Inflation

	1986 LAW	TREAS	PRESID	1986 ACT
TEQ	0.2559	0.2261	0.2240	0.2033
TEM	0.2934	0.2427	0.2572	0.2494
TGQ	0.0303	0.0596	0.0600	0.0562
TGM	0.0293	0.0607	0.0643	0.0624
TDQ	0.1730	0.1452	0.1532	0.1434
TDM	0.2151	0.1805	0.1912	0.1807
TDH	0.2722	0.2252	0.2387	0.2314
TDG	0.2260	0.1868	0.1970	0.1894

C. 10% Annual Inflation

	1986 LAW	TREAS	PRESID	1986 ACT
TEQ	0.2560	0.2261	0.2240	0.2034
TEM	0.2934	0.2427	0.2572	0.2494
TGQ	0.0303	0.0596	0.0600	0.0562
TGM	0.0293	0.0607	0.0643	0.0624
TDQ	0.1806	0.1452	0.1532	0.1492
TDM	0.2222	0.1805	0.1912	0.1861
TDH	0.2724	0.2252	0.2387	0.2315
TDG	0.2282	0.1868	0.1970	0.1910

Note: We set TEH=TEM and TGH=0.

TEQ, TEM, TEH: average marginal tax rates (AMTR) of individual income accruing to corporate, noncorporate and household equities, respectively.

TGQ, TGM, TGH: AMTR of capital gains accruing to corporate, noncorporate and household equities, respectively.

TDQ, TDM, TDH, TDG: AMTR of interest income accruing to corporate, noncorporate, household, and government debts, respectively.

Table 1. Tax Rates (Concluded)

2. Marginal Tax Rates of Labor Income, Corporate Income and Average Personal Tax Rates.

	1986 LAW	TREAS	PRESID	1986 ACT
TLM	0.2967	0.2512	0.2536	0.2517
TQ	0.5084	0.4006	0.4006	0.3847
TAP	0.1315	0.1203	0.1223	0.1233

TLM: average marginal tax rate of labor income
TQ: corporate income tax rate (Federal + State & Local)
TAP: average tax rate of individual income. The Treasury proposal, the President's proposal, and the 1986 Tax Reform Act are assumed to reduce TAP by 8.5%, 7.0%, and 6.2%, respectively.

3. Tax Rates Held Constant Across the Alternative Tax Policies

TPQ = 0.0100	TPM = 0.0096	TPH = 0.0100
TC = 0.0579	TI = 0.0579	
TT = 0.0229		
TW = 0.0006		

TPQ, TPM, TPH: property tax rates of corporate, noncorporate and household assets, respectively.
TC, TI: sales tax rates of consumption and investment goods
TT: rate of personal nontaxes
TW: effective rate of wealth taxation

Table 2. Indexing and Deduction of Capital Incomes.

	1986 LAW	TREAS	PRESID	1986 ACT
1. Indexing				
DC	0.0	1.0	0.0(1.0)*	0.0
DI	0.0	INF/(0.06+INF)	0.0	0.0
HDI	0.0	0.0	0.0	0.0
2. Deduction of Capital Income				
DD	0.0	0.5	0.1	0.0
ICDD	0.85	0.50	0.90	0.80
IRCR	0.0	1.0	1.0	0.0
DHI	1.0	1.0	1.0	1.0
Inclus	0.4	1.0	0.5(1.0)*	1.0
3. Deduction of State and Local Taxes				
DSLI	1.0	0.0	0.0	1.0
DSLQ	1.0	1.0	1.0	1.0
DSLM	1.0	1.0	1.0	1.0
DSLH	1.0	0.0	0.0	1.0

DC: indexing of long term capital gains, DC=1.0 for complete indexing.
DI: indexing of interest income and interest expenses of the corporate and noncorporate sectors, DI=1.0 for complete indexing.
HDI: indexing of household interest payment.
DD: deduction of dividend paid for corporate tax purposes.
ICDD: deduction of intercorporate dividends received.
IRCR: fraction of accrual based taxation of life-insurance company's inside build-up.
DHI: deduction of household interest expenses.
Inclus: fraction of long term capital gains taxed as ordinary income.
DSLI: deduction of State & Local income taxes.
DSLQ: deduction of State & Local other taxes, corporate.
DSLM: deduction of State & Local other taxes, noncorporate.
DSLH: deduction of State & Local other taxes, households.
INF: annual rate of inflation.

*: Beginning in 1991, instead of exculding 50% of long term capital gains taxpayers will have the option of 100% inclusion and complete indexing. We assume that if inflation is higher than 6% taxpayers choose indexing.

Table 3. Tax Lives, ITC, and Economic Rate of Repreciation.

Asset	DEL	ITC85	BEA	LAW86	TREAS	PRESID	ACT86
1	0.138	0.10	12.0	5.0	17.0	7.0	5.0
2	0.118	0.10	14.0	5.0	17.0	7.0	7.0
3	0.092	0.10	18.0	5.0	17.0	7.0	7.0
4	0.052	0.10	32.0	10.0	25.0	10.0	15.0
5	0.206	0.10	8.0	10.0	25.0	10.0	10.0
6	0.145	0.10	9.0	5.0	12.0	6.0	7.0
7	0.163	0.10	8.0	5.0	12.0	6.0	5.0
8	0.118	0.10	14.0	5.0	17.0	7.0	7.0
9	0.172	0.10	10.0	5.0	12.0	6.0	5.0
10	0.150	0.10	11.0	5.0	12.0	6.0	7.0
11	0.123	0.09	16.0	5.0	17.0	7.0	5.0
12	0.103	0.10	16.0	5.0	17.0	7.0	7.0
13	0.123	0.10	16.0	5.0	17.0	7.0	7.0
14	0.273	0.10	8.0	5.0	8.0	5.0	5.0
15	0.165	0.10	10.0	5.0	12.0	6.0	5.0
16	0.110	0.10	15.0	7.0	17.0	7.0	10.0
17	0.050	0.10	33.0	7.0	17.0	7.0	10.0
18	0.165	0.10	10.0	5.0	17.0	7.0	5.0
19	0.183	0.10	9.0	5.0	17.0	7.0	5.0
20	0.254	0.07	9.0	5.0	8.0	5.0	5.0
21	0.333	0.06	10.0	3.0	5.0	4.0	5.0
22	0.183	0.10	16.0	5.0	12.0	6.0	7.0
23	0.061	0.10	27.0	5.0	25.0	10.0	10.0
24	0.055	0.10	30.0	5.0	25.0	7.0	7.0
25	0.135	0.10	12.0	7.0	12.0	6.0	7.0
26	0.180	0.10	9.0	5.0	12.0	6.0	5.0
27	0.147	0.10	11.0	5.0	12.0	6.0	5.0
28	0.036	0.03	31.0	19.0	63.0	28.0	31.5
29	0.056	0.00	16.0	19.0	63.0	28.0	31.5
30	0.025	0.00	36.0	19.0	63.0	28.0	31.5
31	0.022	0.00	40.0	19.0	63.0	28.0	31.5
32	0.026	0.07	34.0	10.0	17.0	7.0	15.0
33	0.019	0.00	48.0	19.0	63.0	28.0	31.5
34	0.019	0.08	48.0	19.0	63.0	28.0	31.5
35	0.023	0.00	48.0	19.0	63.0	28.0	31.5
36	0.025	0.00	32.0	19.0	63.0	28.0	31.5
37	0.047	0.10	30.0	10.0	17.0	7.0	15.0
38	0.037	0.00	38.0	19.0	63.0	28.0	31.5
39	0.017	0.10	54.0	5.0	38.0	10.0	7.0
40	0.023	0.08	40.0	10.0	38.0	10.0	15.0
41	0.023	0.10	40.0	15.0	38.0	10.0	20.0
42	0.023	0.06	40.0	10.0	38.0	10.0	20.0
43	0.045	0.10	38.0	5.0	38.0	10.0	5.0
44	0.045	0.10	40.0	5.0	38.0	10.0	15.0
45	0.024	0.00	38.0	19.0	63.0	28.0	20.0
46	0.056	0.10	16.0	5.0	38.0	7.0	7.0
47	0.056	0.10	16.0	5.0	38.0	7.0	7.0
48	0.023	0.00	40.0	19.0	63.0	28.0	31.5
49	0.024	0.10	38.0	5.0	38.0	10.0	7.0
50	0.250	0.10	6.0	5.0	12.0	6.0	7.0
51	0.013	0.00		19.0	63.0	28.0	27.5

Table 4. Investment Tax Credit and Tax Deduction of Depreciation Allowances

1. 1986 LAWS

A. Investment Tax Credit

INF	CORPORATE		NONCORPORATE	
	SHORT	LONG	SHORT	LONG
0.00	0.0945	0.0423	0.0954	0.0056
0.06	0.0944	0.0426	0.0953	0.0057
0.10	0.0944	0.0427	0.0953	0.0057

B. Present Value of Capital Consumption Allowances

INF	CORPORATE		NONCORPORATE	
	SHORT	LONG	SHORT	LONG
0.00	0.9223	0.6347	0.9204	0.5529
0.06	0.8755	0.5569	0.8714	0.4609
0.10	0.8469	0.5156	0.8416	0.4143

2. Treasury Proposal

A. Investment Tax Credit

INF	CORPORATE		NONCORPORATE	
	SHORT	LONG	SHORT	LONG
0.00	0.0000	0.0000	0.0000	0.0000
0.06	0.0000	0.0000	0.0000	0.0000
0.10	0.0000	0.0000	0.0000	0.0000

B. Present Value of Capital Consumption Allowances

INF	CORPORATE		NONCORPORATE	
	SHORT	LONG	SHORT	LONG
0.00	0.8926	0.4997	0.8981	0.3960
0.06	0.9194	0.5479	0.9237	0.4441
0.10	0.9275	0.5647	0.9313	0.4610

INF: annual rate of inflation

Table 4. Investment Tax Credit and Tax Deduction of Depreciation Allowances (Concluded).

3. President's Pro[illegible]

A. Investment Tax Credit

INF	CORPORATE		NONCORPORATE	
	SHORT	LONG	SHORT	LONG
0.00	0.0000	0.0000	0.0000	0.0000
0.06	0.0000	0.0000	0.0000	0.0000
0.10	0.0000	0.0000	0.0000	0.0000

B. Present Value of Capital Consumption Allowances

INF	CORPORATE		NONCORPORATE	
	SHORT	LONG	SHORT	LONG
0.00	0.9471	0.6142	0.9490	0.4843
0.06	1.0059	0.7320	1.0058	0.6487
0.10	1.0452	0.8283	1.0437	0.7925

4. Tax Act of 1986

A. Investment Tax Credit

INF	CORPORATE		NONCORPORATE	
	SHORT	LONG	SHORT	LONG
0.00	0.0000	0.0000	0.0000	0.0000
0.06	0.0000	0.0000	0.0000	0.0000
0.10	0.0000	0.0000	0.0000	0.0000

B. Present Value of Capital Consumption Allowances

INF	CORPORATE		NONCORPORATE	
	SHORT	LONG	SHORT	LONG
0.00	0.9472	0.5929	0.9515	0.4861
0.06	0.8714	0.4626	0.8807	0.3407
0.10	0.8281	0.4058	0.8397	0.2807

INF: annual rate of inflation

Table 5. Effective Tax Rates and the Distortionary Impacts of Capital Income Taxation --- 1986 Tax Law.

1. 0% Inflation

Sector	Short-Lived Assets SROR	GAP	ETR	long-Lived Assets SROR	GAP	ETR	All Assets SROR	GAP	ETR
Corp.	0.049	-0.007	-0.133	0.094	0.039	0.410	0.080	0.025	0.308
Ncorp.	0.044	-0.011	-0.257	0.076	0.021	0.272	0.074	0.018	0.251
Housh.	0.058	0.007	0.119	-- same as short-lived assets --					

Interasset Tax Wedge (S-L)

Corporate	Noncorporate
-0.045	-0.032

Intersector Tax Wedge (S and L)

C-NC short	C-NC long	C-HH short	C-HH long	NC-HH short	NC-HH long
0.005	0.018	-0.008	0.036	-0.014	0.018

2. 6% Inflation

Sector	Short-Lived Assets SROR	GAP	ETR	long-Lived Assets SROR	GAP	ETR	All Assets SROR	GAP	ETR
Corp.	0.053	0.001	0.024	0.094	0.042	0.444	0.081	0.029	0.359
Ncorp.	0.045	-0.007	-0.152	0.075	0.023	0.312	0.073	0.021	0.293
Housh.	0.052	0.007	0.127	-- same as short-lived assets --					

Interasset Tax Wedge (S-L)

Corporate	Noncorporate
-0.040	-0.030

Intersector Tax Wedge (S and L)

C-NC short	C-NC long	C-HH short	C-HH long	NC-HH short	NC-HH long
0.009	0.019	0.002	0.042	-0.007	0.023

3. 10% Inflation

Sector	Short-Lived Assets SROR	GAP	ETR	long-Lived Assets SROR	GAP	ETR	All Assets SROR	GAP	ETR
Corp.	0.056	0.006	0.110	0.093	0.043	0.461	0.082	0.032	0.387
Ncorp.	0.045	-0.004	-0.085	0.074	0.025	0.337	0.072	0.023	0.319
Housh.	0.048	0.006	0.133	-- same as short-lived assets --					

Interasset Tax Wedge (S-L)

Corporate	Noncorporate
-0.037	-0.029

Intersector Tax Wedge (S and L)

C-NC short	C-NC long	C-HH short	C-HH long	NC-HH short	NC-HH long
0.011	0.019	0.009	0.045	-0.002	0.026

Table 6. Effective Tax Rates and the Distortionary Impacts of Capital Income Taxation --- Treasury Proposal.

1. 0% Inflation

Sector	Short-Lived Assets SROR	GAP	ETR	long-Lived Assets SROR	GAP	ETR	All Assets SROR	GAP	ETR
Corp.	0.080	0.025	0.310	0.091	0.036	0.397	0.088	0.033	0.373
Ncorp.	0.071	0.016	0.224	0.077	0.022	0.284	0.076	0.021	0.280
Housh.	0.060	0.009	0.156	-- same as short-lived assets --					

Interasset Tax Wedge (S-L)		Intersector Tax Wedge (S and L)					
		C-NC		C-HH		NC-HH	
Corporate	Noncorporate	short	long	short	long	short	long
-0.011	-0.006	0.009	0.015	0.020	0.031	0.010	0.016

2. 6% Inflation

Sector	Short-Lived Assets SROR	GAP	ETR	long-Lived Assets SROR	GAP	ETR	All Assets SROR	GAP	ETR
Corp.	0.076	0.021	0.280	0.088	0.033	0.379	0.085	0.030	0.351
Ncorp.	0.069	0.014	0.207	0.075	0.021	0.275	0.075	0.020	0.271
Housh.	0.060	0.009	0.157	-- same as short-lived assets --					

Interasset Tax Wedge (S-L)		Intersector Tax Wedge (S and L)					
		C-NC		C-HH		NC-HH	
Corporate	Noncorporate	short	long	short	long	short	long
-0.012	-0.006	0.007	0.013	0.017	0.029	0.009	0.016

3. 10% Inflation

Sector	Short-Lived Assets SROR	GAP	ETR	long-Lived Assets SROR	GAP	ETR	All Assets SROR	GAP	ETR
Corp.	0.075	0.020	0.271	0.087	0.033	0.373	0.084	0.029	0.345
Ncorp.	0.068	0.014	0.203	0.075	0.020	0.272	0.074	0.020	0.268
Housh.	0.059	0.009	0.158	-- same as short-lived assets --					

Interasset Tax Wedge (S-L)		Intersector Tax Wedge (S and L)					
		C-NC		C-HH		NC-HH	
Corporate	Noncorporate	short	long	short	long	short	long
-0.012	-0.007	0.007	0.013	0.016	0.028	0.009	0.016

Table 7. Tax Rates and the Distortionary Impacts of Capital Income Taxation --- President'S Proposal.

1. 0% Inflation

Sector	Short-Lived Assets SROR	GAP	ETR	long-Lived Assets SROR	GAP	ETR	All Assets SROR	GAP	ETR
Corp.	0.077	0.021	0.271	0.091	0.034	0.381	0.086	0.030	0.351
Ncorp.	0.069	0.013	0.187	0.077	0.021	0.273	0.076	0.020	0.268
Housh.	0.061	0.009	0.154	-- same as short-lived assets --					

Interasset Tax Wedge (S-L)

Corporate	Noncorporate
-0.014	-0.008

Intersector Tax Wedge (S and L)

C-NC short	C-NC long	C-HH short	C-HH long	NC-HH short	NC-HH long
0.008	0.014	0.016	0.029	0.008	0.016

2. 6% Inflation

Sector	Short-Lived Assets SROR	GAP	ETR	long-Lived Assets SROR	GAP	ETR	All Assets SROR	GAP	ETR
Corp.	0.066	0.012	0.182	0.080	0.026	0.330	0.076	0.022	0.290
Ncorp.	0.061	0.008	0.134	0.070	0.016	0.235	0.069	0.016	0.229
Housh.	0.056	0.009	0.162	-- same as short-lived assets --					

Interasset Tax Wedge (S-L)

Corporate	Noncorporate
-0.014	-0.008

Intersector Tax Wedge (S and L)

C-NC short	C-NC long	C-HH short	C-HH long	NC-HH short	NC-HH long
0.004	0.011	0.010	0.024	0.005	0.013

3. 10% Inflation

Sector	Short-Lived Assets SROR	GAP	ETR	long-Lived Assets SROR	GAP	ETR	All Assets SROR	GAP	ETR
Corp.	0.058	0.005	0.091	0.073	0.020	0.271	0.068	0.015	0.224
Ncorp.	0.057	0.005	0.089	0.065	0.013	0.196	0.064	0.012	0.190
Housh.	0.053	0.009	0.167	-- same as short-lived assets --					

Interasset Tax Wedge (S-L)

Corporate	Noncorporate
-0.014	-0.008

Intersector Tax Wedge (S and L)

C-NC short	C-NC long	C-HH short	C-HH long	NC-HH short	NC-HH long
0.001	0.008	0.005	0.019	0.004	0.011

Table 8. Effective Tax Rates and the Distortionary Impacts of Capital Income Taxation --- 1986 Tax Reform Act.

1. 0% Inflation

Sector	Short-Lived Assets SROR	GAP	ETR	long-Lived Assets SROR	GAP	ETR	All Assets SROR	GAP	ETR
Corp.	0.078	0.022	0.279	0.092	0.036	0.390	0.087	0.031	0.360
Ncorp.	0.068	0.012	0.182	0.076	0.020	0.268	0.075	0.020	0.262
Housh.	0.059	0.007	0.125	-- same as short-lived assets --					

Interasset Tax Wedge (S-L)		Intersector Tax Wedge (S and L)					
		C-NC		C-HH		NC-HH	
Corporate	Noncorporate	short	long	short	long	short	long
-0.014	-0.008	0.009	0.016	0.019	0.033	0.009	0.017

2. 6% Inflation

Sector	Short-Lived Assets SROR	GAP	ETR	long-Lived Assets SROR	GAP	ETR	All Assets SROR	GAP	ETR
Corp.	0.084	0.032	0.382	0.094	0.042	0.449	0.091	0.039	0.430
Ncorp.	0.071	0.020	0.282	0.077	0.026	0.335	0.076	0.025	0.332
Housh.	0.052	0.007	0.135	-- same as short-lived assets --					

Interasset Tax Wedge (S-L)		Intersector Tax Wedge (S and L)					
		C-NC		C-HH		NC-HH	
Corporate	Noncorporate	short	long	short	long	short	long
-0.010	-0.006	0.012	0.017	0.031	0.041	0.019	0.025

3. 10% Inflation

Sector	Short-Lived Assets SROR	GAP	ETR	long-Lived Assets SROR	GAP	ETR	All Assets SROR	GAP	ETR
Corp.	0.0[illegible]	0.[illegible]	0.439	0.093	0.045	0.478	0.091	0.043	0.467
Ncorp.	0.0[illegible]3	0.025	0.342	0.077	0.029	0.373	0.076	0.028	0.371
Housh.	[illegible].048	0.007	0.143	-- same as short-lived assets --					

Interasset Tax Wedge (S-L)		Intersector Tax Wedge (S and L)					
		C-NC		C-HH		NC-HH	
Corporate	Noncorporate	short	long	short	long	short	long
-0.006	-0.00[illegible]	0.014	0.017	0.039	0.045	0.025	0.029

Table 9. Welfare Effects of Tax Reform

(Billions of 1987 dollars)

Rate of Inflation	Revenue Adjustment	1986 Tax Law	Treasury Proposal	President's Proposal	1986 Tax Act
0%	Lump Sum Tax	724.0	1489.6	1691.4	1561.8
	Labor Income Tax	478.2	1468.8	1642.4	1565.0
	Sales Tax	400.3	1452.9	1614.6	1558.7
	Individual Income Tax	374.5	1456.1	1619.1	1563.1
6%	Lump Sum Tax	0.0	1907.6	2452.2	448.4
	Labor Income Tax	0.0	1711.4	2170.4	746.9
	Sales Tax	0.0	1600.1	2104.9	901.2
	Individual Income Tax	0.0	1595.8	2007.9	999.4
10%	Lump Sum Tax	-477.1	2060.4	3015.6	-200.8
	Labor Income Tax	-333.7	1791.6	2584.7	267.3
	Sales Tax	-285.2	1623.5	2356.4	517.0
	Individual Income Tax	-221.9	1604.8	2353.1	748.6

Note: In 1987, the national wealth (beginning of the year) and GNP are projected to be $15,920.2 and $4,488.5 billion dollars.

Table 10. Elimination of Tax Wedges: 1986 Tax Law

Capital Stock in the Steadt State of the Reference case (%)

Corporate		Noncorporate		Household	
short	long	short	long	short	long
0.0893	0.2563	0.0185	0.2580	0.0909	0.2870

Removal of Capital Income Tax Distortions

A. 1986 Tax Law

Class of Assets	Social Rate of Return	Effective Tax Rate	ITC + T.Z
Corporate			
short	0.0518	0.0229	0.5395
long	0.0914	0.4460	0.3257
Noncorporate			
short	0.0433	-0.1544	0.3510
long	0.0731	0.3152	0.1409
Household			
short	0.0503	0.1301	0.0000
long	0.0503	0.1301	0.0000

B. No Within Sector Interasset Wedges

Class of Assets	Social Rate of Return	Effective Tax Rate	ITC + T.Z
Corporate			
short	0.0812	0.3762	0.4652
long	0.0812	0.3762	0.3942
Noncorporate			
short	0.0711	0.2960	0.2552
long	0.0711	0.2960	0.1641
Household			
short	0.0503	0.1301	0.0000
long	0.0503	0.1301	0.0000

Table 10. Elimination of Tax Wedges: 1986 Tax Law (Continued).

C. No Intersector Wedges: Business Assets

Class of Assets	Social Rate of Return	Effective Tax Rate	ITC + T.Z
Corporate			
short	0.0504	-0.0052	0.5432
long	0.0822	0.3840	0.3873
Noncorporate			
short	0.0504	0.0068	0.3267
long	0.0822	0.3913	0.0341
Household			
short	0.0503	0.1301	0.0000
long	0.0503	0.1301	0.0000

D. No Intersector Wedges: All Sectors

Class of Assets	Social Rate of Return	Effective Tax Rate	ITC + T.Z
Corporate			
short	0.0503	-0.0062	0.5433
long	0.0708	0.2844	0.4639
Noncorporate			
short	0.0503	0.0058	0.3268
long	0.0708	0.2930	0.1677
Household			
short	0.0503	0.1311	-0.0002
long	0.0708	0.3821	-0.3766

E. No Tax Wedges: All Assets, Business Sector

Class of Assets	Social Rate of Return	Effective Tax Rate	ITC + T.Z
Corporate			
short	0.0767	0.3397	0.4766
long	0.0767	0.3397	0.4243
Noncorporate			
short	0.0767	0.3476	0.2358
long	0.0767	0.3476	0.0985
Household			
short	0.0503	0.1301	0.0000
long	0.0503	0.1301	0.0000

ITC: investment tax credit T: tax rate at the firm level
Z: present value of capital consumption allowances

Note:
1. Steady State Allocation of Capital in the base case is used as the weights.
2. The annual rate of inflation is assumed to 6%.

Table 10. Elimination of Tax Wedges: 1986 Tax Law (Concluded).

F. No Tax Wedges: All Assets, All Sectors.

Class of Assets	Social Rate of Return	Effective Tax Rate	ITC + T.Z
Corporate			
short	0.0667	0.2408	0.5019
long	0.0667	0.2408	0.4911
Noncorporate			
short	0.0667	0.2499	0.2703
long	0.0667	0.2499	0.2152
Household			
short	0.0667	0.3444	-0.0666
long	0.0667	0.3444	-0.3020

G. Corporate Tax Integration: Apply Noncorporate Social Rates of Return to Corporate Assets

Class of Assets	Social Rate of Return	Effective Tax Rate	ITC + T.Z
Corporate			
short	0.0433	-0.1684	0.5610
long	0.0731	0.3069	0.4486
Noncorporate			
short	0.0433	-0.1544	0.3510
long	0.0731	0.3152	0.1409
Household			
short	0.0503	0.1301	0.0000
long	0.0503	0.1301	0.0000

H. Zero Effective Tax Rates (ETR=0)

Class of Assets	Social Rate of Return	Effective Tax Rate	ITC + T.Z
Corporate			
short	0.0506	0.0000	0.5425
long	0.0506	0.0000	0.5986
Noncorporate			
short	0.0500	0.0000	0.3279
long	0.0500	0.0000	0.4100
Household			
short	0.0437	0.0000	0.0265
long	0.0437	0.0000	0.1202

ITC: investment tax credit T: tax rate at the firm level
Z: present value of capital consumption allowances
Note: 1. Steady State Allocation of Capital in the base case is used as the weights.
2. The annual rate of inflation is assumed to 6%.

Table 11. Welfare Effects of Tax Distortions
(Billions of 1987 dollars)

	1986 Law
1. Within Sector Interasset Distortion	
Lump Sum Tax Adjustment	443.9
Labor Income Tax Adjustment	248.1
Sales Tax Adjustment	168.7
Individual Income Tax Adjustment	70.2
2. Intersector Distortion: C and NC Sectors	
Lump Sum Tax Adjustment	-93.3
Labor Income Tax Adjustment	-416.7
Sales Tax Adjustment	-523.8
Individual Income Tax Adjustment	-715.5
3. Intersector Distortion: All Sectors	
Lump Sum Tax Adjustment	2262.6
Labor Income Tax Adjustment	2156.9
Sales Tax Adjustment	2118.6
Individual Income Tax Adjustment	2067.7
4. No Tax Distortion: C and NC Sectors, All Assets	
Lump Sum Tax Adjustment	326.4
Labor Income Tax Adjustment	69.2
Sales Tax Adjustment	-29.1
Individual Income Tax Adjustment	-169.7
5. No Tax Distortion: All Sectors, All Assets	
Lump Sum Tax Adjustment	2663.7
Labor Income Tax Adjustment	2603.9
Sales Tax Adjustment	2572.4
Individual Income Tax Adjustment	2547.2
6. Corporate Tax Integration	
Lump Sum Tax Adjustment	1313.1
Labor Income Tax Adjustment	493.4
Sales Tax Adjustment	238.1
Individual Income Tax Adjustment	-274.5
7. Consumption Tax Rules (Zero Effective Tax Rates)	
Lump Sum Tax Adjustment	3853.9
Labor Income Tax Adjustment	2045.4
Sales Tax Adjustment	1749.3
Individual Income Tax Adjustment	2045.4
8. Consumption Tax Rules (Zero Effective Tax Rates) No Sales Tax on Investment Goods	
Lump Sum Tax Adjustment	4128.1
Labor Income Tax Adjustment	1988.0
Sales Tax Adjustment	1722.1
Individual Income Tax Adjustment	1988.0

Note: Inflation is fixed at 6% per year.

Coments by Ken Judd on

Tax Policy and U.S. Economic Growth

by Jorgenson and Yun

I must first say that Professors Jorgenson and Yun are to be congratulated for the impressive study which they have prepared for us. It is an ambitious analysis of important public policy issues. They have endeavored to examine a broad set of issues concerning the impact of tax policy on the U.S. economy, and to do so in a theoretically sound fashion.

In summary, Jorgenson and Yun have extended the perfect foresight, representative agent model of dynamic general equilibrium by replacing the single good specification with one allowing for many goods and many assets. This extension allows them to analyze various interasset and intersectoral tax issues. This is an important addition since much of the debate over the recent changes in tax law concern the value of a "level playing field," that is, a structure wherein assets and goods are taxed in a uniform fashion, and the importance of reducing the cost of capital. The numbers presented in this study indicate that the level playing field effects of the recent tax changes are substantial, as important as cost-of-capital effects.

My comments will focus on real-world considerations which are not modelled in their simulation analysis and the biases thereby generated, indicating points where this model is probably not reliable. I will have nothing to say about the empirical

analysis which underlies the simulation since the principle of comparative advantage strongly implies that I be silent. Finally, I should point out that these comments apply equally well to much of the literature on dynamic tax incidence, not just to the Jorgenson-Yun paper before us. The Jorgenson-Yun analysis is state-of-the-art work, but there are many directions along which the art can be advanced.

On the methodological side, I have one complaint. Just as an econometric analysis of data would report standard errors along with point estimates, I argue that any analysis of tax burden based on that econometric analysis should also report standard errors for the estimates of the benefits of tax reform as well as point estimates. In both cases standard errors are needed because we can never be completely certain about our point estimates and different estimates about the structural parameters may imply substantially different values for the welfare effects of the policy alternatives examined here.

Furthermore, not only is there uncertainty about what this particular study with its data and econometric analysis can conclude, there is also considerable disagreement among various techniques which have been used to estimate these parameters. Since the simulation anlaysis is operationally disjoint from the econometric analysis, using it only for calibration purposes, the simulation analysis should consider cases which are suggested by these other studies. For example, a critical parameter in these studies is the intertemporal elasticity of substitution in

consumption. Jorgenson and Yun use a value in excess of unity (with a small standard error) whereas Hall argues for a value of about .1, a value which would argue for much lower excess burden numbers for capital taxation. There are also wildly different estimates of the critical labor supply elasticities.

Ideally, a simulation study should be interesting and useful to all readers who believe in the hypothesized structure, not just those who also subscribe to a particular empirical estimate of that structure's parameters. It may be felt that this would result in hopeless disagreement about the basic issues. In this case, however, that would probably not be the case. In my examination of factor income taxation (Journal of Political Economy, 1987) I found that while the magnitude of the excess burden of taxation was affected by alternative parameter specifications, the ranking of various policy changes and the direction of efficiency-improving policies were not affected. Given this robustness of the qualitative conclusions, there is no need to settle the econometric issues in order to decide the critical issue of the desirable direction of policy changes.

The paper's results were generally well-explained and yielded useful estimates of the benefits of tax reform. However, some of the paper's results surprised me and I found no explanation for them. In particular, the estimates of the cost of labor taxation, about a dollar per dollar of revenue, are unusually high. Since the underlying compensated elasticity of labor supply is about .6 and the tax rate is about .25, the standard

rule-of-thumb approximation for total burden (one-half of the product of the compensated elasticity of labor supply and the square of the tax rate) is .0375, and the approximation for the marginal excess burden is .15. Since these static approximations are roughly correct in highly aggregated dynamic analyses, such as Judd (1987), the large numbers computed here must arise from some intersectoral and/or interasset effects. While it is always difficult to trace through the workings of a general equilibrium model, it would be interesting to find exactly what aspect of this model yields such a high welfare cost for labor taxation.

Next, I will consider several substantive issues concerning this analysis. They include the importance of human capital, the correct treatment of capital gains taxation, adjustment costs in investment, and the temporary nature of real-world tax reform. Some of these problems can be handled within the framework presented here, but some are well beyond the current technology.

First, in light of this conference's focus on human capital formation, it should be noted that these results would likely be substantially altered if human capital formation were modelled as well as physical capital. Driffill and Rosen (International Economic Review, 1985) used a partial equilibrium analysis to show that the excess burden of income taxation was substantially altered (increased by a factor of two to five) when human capital formation was included. I suspect that this would substantially affect the marginal excess burden of the relative value of labor income taxation if included here. Incorporating labor taxation

into the human capital formation models described elsewhere at this conference is a straightforward exercise and I anticipate we will soon have some more precise information about this issue. On the other hand, this conference has also focussed on the impacts of taxes on growth rates in models with linear technology. The papers of Eaton (Review of Economic Studies, 1981) and Hamilton (Public Finance, 1987) indicate that the magnitude of the excess burden of capital income taxation is not substantially affected as we move from the decreasing returns to a constant returns world.

Second, one of the more important changes in the 1986 act was the elimination of the exclusion for long-term capital gains. Jorgenson and Yun used standard arguments to represent the entire income tax system with an accrual equivalent; such a reduction ignores the fact that capital gains taxes are paid only when the owner chooses to realize the asset. I have serious reservations about the reliability of this treatment of capital gains taxation. Whenever the realization aspect of the capital gains tax regulations has been modelled, the conclusion is that capital gains taxation does not behave like accrual taxes, strongly indicating that reliable accrual approximations are not possible. For example, Constantinides and Scholes (Journal of Finance, 1980) argue that investors prefer large tax rates to small since the resulting tax arbitrage opportunities are larger. Also, Dr. Yves Balcer and I have shown (Journal of Finance, 1987) that an increase in capital gains tax rates may increase savings even

when an increase in the corporate income tax rate would reduce capital formation. Since the effects of accrual and realization taxes may differ even in sign, it is doubtful that this accrual approximation is at all reliable. Furthermore, the capital gains tax is also a tax on transactions as well as on income since it imposes a cost on investors whenever they want to alter their portfolio; Kovenock and Rothschild argue that this is a substantial cost which is ignored in conventional cost of capital calculations. These observations are important for the Jorgenson-Yun analysis since they model this part of the 1986 act as a two percentage point change in the effective tax rate of taxation, a nontrivial part of the change in the cost of capital induced by the 1986 act.

Third, this analysis assumes that capital is perfectly malleable, abstracting from costs in shifting capital stock across sectors. In particular, this assumes that if the deduction of mortgage interest were ended today then in a matter of months a substantial fraction of the housing stock would be converted into new equipment in new factories. Similarly, if interasset distortions are eliminated today, then it is assumed that in a short time much of the existing equipment (the currently favored asset class) would be converted into structures. This is surely an unrealistic description of how rapidly the economy can shift assets across sectors and assets. A more reasonable analysis would treat each asset in each sector as a separate state variable and model the costs of shifting.

While this would be a nontrivial extension of the simulation model used here, basic intuition indicates strongly that this would substantially reduce the efficiency gains from eliminating interasset distortions and mortgage interest deductions.

Fourth, implicit in the analysis of past and proposed future tax changes is the assumption that all agents believe that they are permanent. On the contrary, tax rates and regulations change frequently and, as far as I can tell, randomly. Casual reading of press reports indicate that many people believe that the current low rates are temporary. I also know many economists agree with this, particularly those who are not known advisors of active Presidential candidates. Analyzing alternative specifications of agent beliefs about the durability of tax changes is within the two-point boundary value problem simulation technique which Jorgenson and Yun use. In earlier work (Journal of Political Economy, 1987) I showed that the relative efficacy of various policies was altered under different expectations; for example, a suspension of investment incentives which is believed to be, and turns out to be, temporary is particularly bad since both tax revenues and efficiency declines. Furthermore, given the limited nature of the commitment of the U.S. government to any tax law, it could be that the current tax structure is a political equilibrium and that the only way to effect tax reform is to change the nature of the political decisionmaking process and/or the set of permissible tax instruments.

In summary, I found this general equilibrium tax reform to

be a subsantial advance in the techniques of tax analysis. It is important to bring these sophisticated econometric and simulation techniques into tax analysis exercises since they can discipline the debate on tax policy. There is much yet to be done to improve the art, but I think that this exercise shows that much can be done with standard economic analysis.

Comments on the paper by Dale W. Jorgenson and Kun-Young Yun, "Tax Reform and U.S. Economic Growth":

by:
Christophe Chamley

The approach of Jorgenson and Yun defines the current frontier in the analysis of tax reform in a dynamic context. By allowing for a high degree of disaggregation between the different tax instruments on the incomes of capital, while retaining full intertemporal optimization, this approach is particularily well suited to the issues that are considered here, i.e. the reform of the tax treatment of different assets.

We cannot untangle here the complex machine that is used. Nevertheless, the purpose of this study is to evaluate policy proposals, and policy advising needs to rely on some intuitive exposition if it is to be effective. I will therefore attempt to discuss the results from an intuitive point of view. I will comment mainly on the analysis of the directions for tax reforms and the numerical results in Tables 9 and 10 because they reveal the main features of the model. More specifically, I will consider (1) the analytical method for the analysis of the removal of atemporal tax wedges between assets, (2) the removal of the atemporal wedge between the business and the household sector ; this is the most efficient direction for tax reform and it has important consequences for the evaluation fo the four tax laws that are presented in the first part of the paper. (3) Finally, I will add a few miscallenous remarks.

1. Jorgenson and Yun introduce a distinction between the atemporal and the intertemporal tax wedges. This distinction is useful because it

provides a tool to compare some tax impacts in static and dynamic models. For example, Harberger, in his celebrated analysis of the corporate tax, has measured the efficiency gain that would be obtained by equalizing the tax rates in the corporate and the non corporate sector, for a given level of total capital. If there were no incidence of this reform on the level of savings and capital accumulation, one could presumably use the "static" result as an approximation by assuming that the economy is on a balanced growth path and discounting the flow of static gains at instant back to the time of tax reform. However, this method is not appropriate if the tax reform induces a change of balanced growth path.

Jorgenson and Yun take into account the dynamic impact of the tax changes. They define the elimination of the atemporal tax wedge between two (or more) assets by the equalization of their social rates of return, at a level that is the average of the rates of returns under the old (1986) tax law, where the weights are determined by the levels of assets before the tax change. This method does not raise much difficulty when the elasticities of demand for capital with respect to the cost of capital in the two sectors have similar values. However, if the elasticity of demand for capital, say in the non corporate sector, is much higher than in the corporate sector, the average elasticity of demand for capital increases. Therefore, at a given average effective tax rate, the intertemporal efficiency cost increases. In summary, the method removes the atemporal wedge, but it affects the intertemporal efficiency cost if different sectors have different elasticities of demand for capital.

An example of this effect is given by the elimination of intersector wedges in business assets (panel C of Table 10, and panel 2 of Table 11).

It is illustrated here by the Figures 1 and 2, which are approximations of the model. The removal of the tax wedge reduces the effective rate in the corporate sector and increases it in the non corporate sector. In the type of model that is used by Jorgenson and Yun the long-run supply of capital is infinitely elastic and the private rate of return (net of taxes) is exogenous. Its level is defined by ρ in the figures. Before the tax reform, the gap between the social and the private rates of return in the corporate sector, $r_0-\rho$, is determined by the effective tax rate. There is no such gap in the non corporate sector that is assumed to be untaxed for the sake of exposition.

After the equaltization of the social rates of return in the two sectors, two effects occur:

(1) At the time of the tax reform assets are reallocated instantly from the non corporate to the corporate sector. The level of corporate capital increases from k_0 to k_1, and the level of non-corporate capital decreases from n_0 to n_1. Note that the social rate of return of capital decreases from r_0 to r_1, which is lower than the long-run value r^*. This occurs because the elasticity of demand for capital in the non corporate sector is higher than in the corporate sector. If the effective tax rate on capital income is constant over time, the net private rate of return after the tax reform is lower than the long-run rate ρ. The efficiency gain is represented by the area ABCD and is the Harberger efficiency gain.

(2) The second impact is a gradual fall of the level of capital in both sectors after the tax reform. This fall occurs because the private rate of return is lower than the long-run rate that is determined by the

long-run supply of capital. The efficiency cost of this reduction of capital is measured by the gap between the social rate of return and the net rate of return at each instant of time. It is a equal to a fraction of the two areas represented in Figure 2. With the parameters of the model, I would venture that this fraction may be equal to about one half. The total efficiency effect is equal to the sum of the flow of the "Harberger effect" (discounted), wich has a positive impact on efficiency and of the efficiency loss represented in Figure 2. In Table 11, the total effect is negative because of the relatively high elasticity of the demand for capital in the non corporate sector.

Note that the same diagram shows also that the tax reform has a negative impact on the revenues from the taxation of capital income in the business sectors. When the revenue loss is matched by an increase of the labor income tax, the efficiency loss is greater because of the additional tax wedge between consumption and leisure (panel 2 of Table 11).

2. A. The main result of the analysis of the directions for tax reforms is that the largest efficiency gains are obtained by an equalization of the atemporal tax wedge between assets in the business sectors and in the household, respectively. The numbers in Table 11 show that this efficiency gain is almost the same with the lump-sum tax and the labor income tax adjustments. We can therefore infer that the revenue impact of this reform is relatively small and that the elasticities of the demand for capital in the business sector (taken as a whole) and the household sector are roughly equal. The argument of the previous paragraph which was illustrated in

Figures 1 and 2 shows also that the impact of the equalization of the tax wedges in all sectors has a relatively small impact on the net rate of return at the time of the reform and therefore on the level of total capital.

This implies that the equalization of the tax wedges is similar to the Harberger analysis, and that the dynamic effects may not be significant. If the impact on total capital accumulation is relatively small, the transition to a new steady state is negligeable and we can apply the tools of a static analysis. In this case, the welfare gain of the equalization of the social rates of returns between a taxed sector (corporate or business), and an untaxed sector (non corporate or household) is approximated by the formula $\Delta W = .5 * \Delta K * (r_1 - r_0)/(\rho - g)$, where ΔK, r_1, r_0, ρ and g represent the maginitude of the reallocation of capital, the social rates of return in the taxed and the untaxed sector, the net private rate of return and the growth rate, respectively. This formula is obviously a very rough approximation and cannot do justice to the effects that a taken into account in the model of the paper. It provides nevertheless some guidance.

From the numbers in Tables 10 and 11, one can infer that the ratio $(r_1 - r_0)/(\rho - g)$ is about equal to one and that the decrease of capital in the household sector is about equal to 4 trillion. Since the total level non human capital is equal to 16 trillion and household capital is about 40 percent of this value, the level of the reallocation of assets is a very large fraction of household capital, greater than one half. Such computation is rather crude but it is unlikely that a full general equilibrium model would produce different stylized facts. The magnitude of

this reallocation, which occurs instantly at the time of the reform, seems to be too large to ignore the cost of transition. Such costs are not taken into account in the model but they would lower the welfare gain of tax reform as other studies have shown, (Bovenberg).

B. The other results in Table 11 show that a complete removal of all taxes on capital on capital income with an increase of the labor tax to keep revenues constant, is not as efficient as the equalization of the atemporal tax wedges. This may be due to the following effect: The zero effective tax rates remove, by and large (see below), all atemporal and intertemporal wedges on the incomes of capital. However such a reform implies a loss of tax revenues on the assets that are already in place at the time of the tax reform. The taxation of these fixed assets is equivalent to a lump-sum tax. The zero rating of all capital taxes implies therefore the loss of this lump-sum tax that has to be matched by an increase of the labor income tax and of its efficiency cost. In some cases, this effect may exceed the efficiency gain that is induced by the removal of the intertemporal tax wedge.

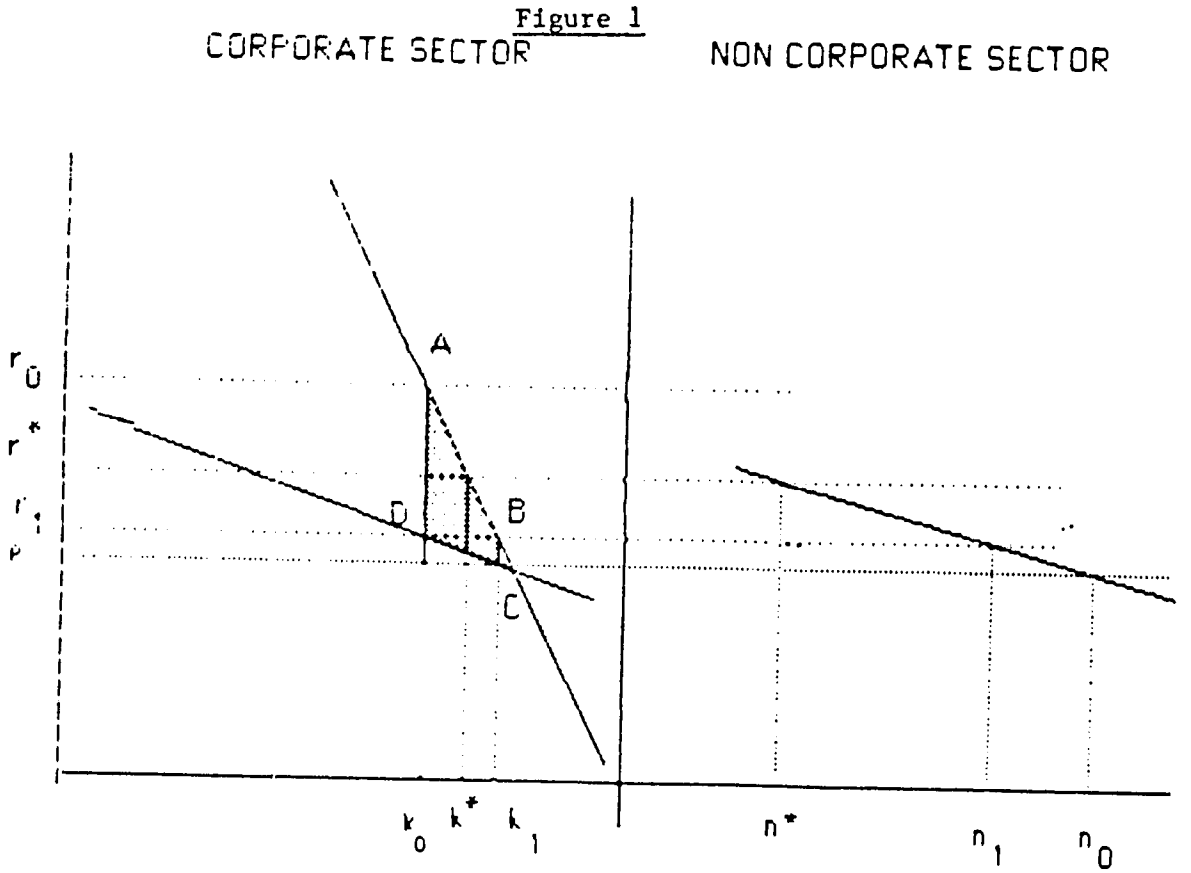
C. These results may help to explain why the 1986 Tax Reform Act produces smaller gains than the Treasury or the President's proposal. The Tables 5-8 show that the Reform Act increases the gap between the social rates of return in the business and the household sector (in the case of a 6% inflation rate), while the two other proposals reduce this gap.. For a more detailed analysis of all the tax proposals one would like to have a measure of the welfare impacts of the various tax changes. This work could be undertaken in the future.

3. I have finally two minor comments:

A. The same argument as in 2.B suggests that a shift to a sales tax on consumption goods (excluding investment goods), is more efficient than a shift to a labor income tax. This is apparently contradicted by the results in Table 11 (panel 8), which is puzzling.

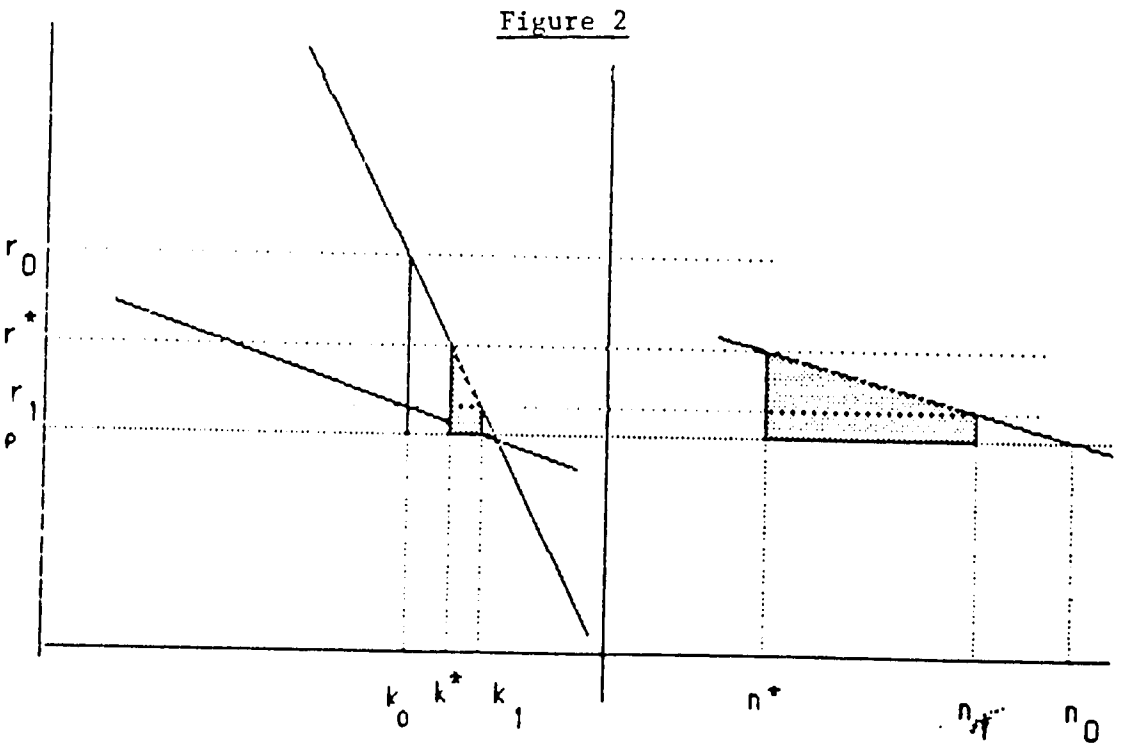
B. The removal of the atemporal tax wedges and reduction to zero of all effective tax rates on the incomes of capital is not equivalent as one can see in Table 10. This is due to different leverage ratios which are exogenous in the model. Therefore, the no-tax equilibrium is not a social optimum. Furthermore, some tax policy (in fact a tax on household capital) is socially efficient. In this model, the government has some technological advantage over the private capital markets in the allocation of capital.

Figure 1



ADJUSTMENT AND EFFICIENCY GAIN AT TIME ZERO

Figure 2



DYNAMIC ADJUSTMENT AND EFFIENCY COST AFTER TIME ZERO

Success or Failure in Economic Takeoff

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Success or Failure in Economic Takeoff

S. C. Tsiang*

The 1987 Nobel laureate, Prof. Robert Solow, was awarded this high honor for his important contributions to the theory of economic growth among many others. His original model of economic growth published in 1956 served as the basis for many subsequent works on the theory of growth.

More significantly, Solow's model is the first important one which broke off with the then prevalent Keynesian demand-oriented growth theory which maintained that it was the expanding effective demand that constituted the motive force of economic growth. What Solow's model made clear is that it is the expansion of the productive capacity of its factors of production that constitutes the real growth of a country. It has thus contributed greatly towards weakening the baneful influence of the Keynesian type of growth policy which seeks to stimulate growth merely by expanding effective demand.

For the study of economic development starting from a very underdeveloped state, however, Solow's model still has some shortcomings. His model has difficulty explaining why some underdeveloped countries tend to be trapped at a low level of stagnation and unable to break loose therefrom, whereas others

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have been able to free themselves from similar traps and to continue on to a self-sustained growth in terms of real income per capita.

This latter phenomenon was designated very picturesquely as the "takeoff" by W. W. Rostow (Rostow, 1961). It is very desirable for us to have a theoretical model capable of explaining this phenomenon, so that the development policies of developing countries can be discussed and judged for their appropriateness within its framework.

The Solow model fails to perform this rôle because it contains several unrealistic assumptions, as a result of which the model would show that every country would be able to grow economically by its own internal forces, and that the rate of growth, which would be relatively high at first, would eventually settle down to the exogenously given rate of its own population growth. It is thus unable to explain why a poor undeveloped country would tend to experience some difficulties in breaking loose from an initial low income trap.

The unrealistic assumptions of Solow's model ,in my opinion, are:-

(a) In his model, land (or natural resources in general) was assumed to be either non-essential for production, or unlimited in supply (as in Ethiopia, as claimed by Solow). To us economists coming from the East Asian countries with great population pressure on land and a scarcity of natural resources, this

assumption is outrageously unrealistic.

(b) Population growth was assumed to remain at a constant exogenous rate, independent of economic factors. This assumption seems obviously untrue in developing countries where a modified Malthusian mechanism seems to operate.

(c) The propensity to save was assumed to be a given constant, independent of the income level as well as the rate of interest or the rate of return on investment.

This assumption is again unacceptable to those of us who have observed with our own eyes that the propensity to save in a country, such as Taiwan, could change from a mere 5% to 40%.

I have therefore replaced these assumptions with others that seem to be more realistic in developing countries. First, land (representing all natural resources) is added as an essential factor of production in the aggregate production function in addition to labor and capital, the only factors in Solow's production function.

The aggregate production function used in our model remains a simple one-commodity function of the Cobb-Douglas type, such as

$$(1) \qquad Y = AK^{\alpha(t)}L^{\beta(t)}N^{\gamma(t)}\exp\left(\int_0^t g(\tau)d\tau\right),$$

where K, L, and N stand for the total amounts of capital, labor and natural resources (land), respectively, and A is a constant. The parameters α, β, and γ are not supposed to be given constants but to be variable over time in accordance with the biased nature of technical progress, but are always subject to

the constraint that

(2) $\alpha(t) + \beta(t) + \gamma(t) = 1,$

at all times. Since we lack the knowledge of the law governing the variations in these technological parameters, we shall for the present assume them to be exogenously determined in our model.

Assuming that N, the amount of natural resources in a given country, is inaugmentable, the rate of growth of output in general is then

(3) $\dot{Y}/Y = y = \alpha k + \beta \ell + g^{*},$

where $y = \dot{Y}/Y$, $k = \dot{K}/K$, $\ell = \dot{L}/L$,

and

(4) $g^{*} = g + \dot{\alpha}\log K + \dot{\beta}\log L + \dot{\gamma}\log N,$

Obviously, g^{*}, the net effect of technical progress on the rate of growth of output, might be biased towards different factors of production in different manners at different times, subject to the constraint that

(5) $\dot{\alpha} + \dot{\beta} + \dot{\gamma} = 0$

at all times. When technical progress is strictly neutral, $\dot{\alpha}$, $\dot{\beta}$ and $\dot{\gamma}$ will all be zero, and g^{*} will be identical with g.

Secondly, the rate of growth of population, and hence the rate of growth of labor which we assume for the sake of simplicity to be a constant proportion of the total population, is assumed to be a function of the current real wage rate, or the real income of labor, in the neo-Malthusian manner, such that

(6) $L_t = L_0 \exp(\int_0^t \ell[Y_L]d\tau),$

where ℓ, the rate of growth of population (and labor supply), is written as a function of the marginal productivity of labor, Y_L, which we assume to be equal to the real wage rate.

The form of this function, however, is understood not to be a monotonic rising function of real income. During the first stage, it would be increasing rather fast with the increase in real income on account of the decline in the death rate. As real income per worker rose higher and higher, the awareness of the advantages of family planning would be more prevalent. Then the rate of growth of the population would stop increasing and might even start to decline following further increases in the real wage rate.

If we use R to represent the capital/labor ratio K/L, r its rate of growth, and $\bar{Y}$ the output per worker Y/L, with $\bar{y}$ its rate of growth, then

$$(7) \qquad \bar{y} = \frac{1}{\bar{Y}} \frac{d\bar{Y}}{dt} = \alpha r + g^{*} - \gamma \ell$$

Moreover, we shall follow Solow in making the classical assumption that the savings of the community always result in equal increases in capital, so that in a closed economy-

$$(8) \qquad \bar{S} = K/L,$$

where $\bar{S}$ is the average saving per capita as in Solow's model. Thus

$$(9) \qquad \dot{R} = \frac{\dot{K}}{L} - \frac{K}{L} \cdot \frac{\dot{L}}{L} = \bar{S} - R\ell$$

When we later on extend this model to open economics, however, (8) would have to be amended to

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(8') $\bar{S} + (M - X)/L = K/L,$

and (9) to be amended to

(9') $\dot{R} = [\bar{S} + (M - X)/L] - R\ell,$

where M and X are total imports and exports of the country concerned in terms of the real income units.

With our new assumptions about the function of the rate of population growth, we may redraw the $R\ell$ curve for a given level of technology and size of population (the $r\ell$ curve in Solow's diagram) as in Figure 1. It takes on its particular shape because ℓ would be negative for very low (below subsistence) levels of $\bar{Y}$, and hence for very low values of R, and then rise to a positive maximum, beyond which it would tend to fall.

Similarly, with a given level of technology and population, the average saving per capita, $\bar{S}$, may also be treated as a function of average income per head, $\bar{Y}$, the marginal productivity of capital, $\alpha\bar{Y}/R$, and the share of capitalists' and landowners' earnings in the national income which, with a Cobb-Douglas production function, can be represented by the parameters $(\alpha+\gamma)=(1-\beta)$. Thus with given technology and size of population, $\bar{S} = \bar{S}\{\bar{Y}, \alpha\bar{Y}/R, \beta\}$ therefore reduces to a function of R.

This $\bar{S}$ curve, however, will not be simply a curve proportionately below the $\bar{Y}$ curve, as drawn by Solow in his diagram. It will start from a negative value on the vertical axis and rise with the increase in R (hence $\bar{Y}$). It will rise into the positive quadrant as $\bar{Y}$ increases beyond the mere subsistence

level, but the positive slope of the $\bar{S}$ curve is likely to taper off as R grows larger and larger because of the diminishing marginal productivity of capital, which not only may have an adverse effect on the inducement to save, but also implies that $\ddot{Y}$ itself will rise increasingly more slowly with a given increase in R.

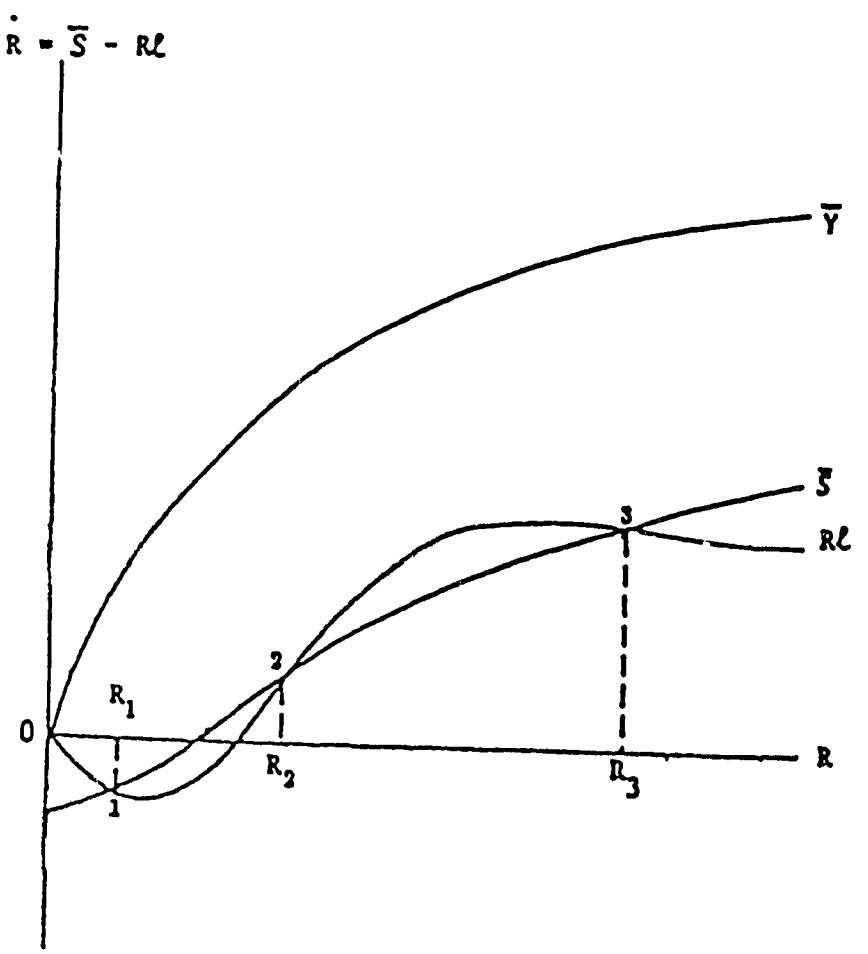

Figure 1

It is very likely that these two curves will intersect more than once, as shown in Figure 1, creating stable as well as unstable equilibrium points. Three such points are depicted in this diagram, of which 1 and 3 are unstable equilibria, and of which 2 is a stable one. This is because a deviation in either direction of R from R_1 or R_3, corresponding to intersections 1 or 3, respectively, would bring about changes in R, i.e., $\dot{R}$, as measured by the vertical distance between the $\bar{S}$ and $R\ell$ curves, pushing it further away from R_1 or R_3, as the case may be, whereas small deviations in either direction from 2 would bring about changes in R returning it to the initial equilibrium position.

An undeveloped country before achieving its economic takeoff may be characterized as an economy that is trapped in a low income stable equilibrium, such as 2, where the corresponding capital/labor ratio R_2 yields a real wage rate that is close to the bare subsistence level (i.e., the real wage rate that corresponds to the point of intersection of the $R\ell$ curve with the horizontal axis). The basic problem of economic development is how to raise the capital/labor ratio in the underdeveloped country to a level beyond R_3, from which it will take off into self-sustained growth until perhaps some possible high-level equilibrium point is reached (not shown in this diagram).

There are four possible ways in which the hump on the way to the takeoff point may be cleared:

(1) The $R\ell$ curve may be lowered by decreasing the net reproduction

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rate of the population at each level of per capita income, which would narrow the gap between 2 and 3, and eventually make them merge into one point and then disappear. Once 2 and 3 merge into a single point, which will be stable on the left hand side, but unstable on the right, then it will be very easy to cross over and to take off therefrom into continuous self-sustained growth.

(2) The $\bar{S}$ curve may be raised upward by increasing the propensity to save by means of propaganda and tax incentives. This will have the same effect as lowering the $R\ell$ curve. Of course, both measures can be carried out at the same time to speed things up.

(3) R might be increased forcibly and quickly beyond the hump by an injection of additional capital from outside or from forced exertion on the part of the domestic population (as in the case of the so-called "Great Leap Forward" once attempted by the People's Republic of China).

(4) The production function can be raised by introducing more advanced technology or by engaging in increased international division of labor through the liberalization of foreign trade.

As the production function is involved in both the R and the $\bar{S}$ curves, an increase in productivity would shift both curves upwards. It is likely, however, that the $\bar{S}$ curve would shift upwards to a much greater extent than the $R\ell$ curve for a given improvement in technology, except when the technological change is significantly biased in favor of labor and against capital.[1]

Footnote

1. This may be demonstrated in the following.

Both the $R\ell$ and $\bar{S}$ curves are drawn in our diagram as two-dimensional curves, but in fact both R and $\bar{S}$ are functions of other variables also, e.g., the state of technology and the size of population, which are treated in the short run as parameters. When these parameters change, the two curves will both shift in this two-dimensional space.

Let us first take the $R\ell$ curve. The equation that underlies this curve is

$$(10) \qquad R\ell = R\ell(Y_L) = R\ell(A\beta R^{\alpha}(\frac{N}{L})^{\gamma}\exp\int_0^t g(\tau)dt).$$

Differentiating this equation logarithmically with respect to time, and making use of equation (6) above, we obtain

$$(11) \qquad r + \hat{\ell} = r + \eta(\alpha r + g^{*} - \gamma\ell + \hat{\beta}),$$

where r is the rate of change in the capital/labor ratio; $\hat{\ell}$ is the rate of change in the rate of increase in labor supply; β is the rate of change in the parameter β for the factor labor in the aggregate production function; η is the elasticity of the response of the population growth rate to the real wage rate, i.e.,

$\eta = \frac{\beta\bar{y}}{\ell}\cdot\frac{d\ell}{d(\beta\bar{Y})}$, and g^{*}, as defined above, is the net effect of technological improvements on the growth rate of output allowing for all their biases towards different factors of production. Equation (10) sums up how all the variables involved in the R curve would change in relation to each other.

Now let us suppose that we hypothetically hold r, the rate of change of R, at zero, and examine how $R\ell$ would change in response to changes in other variables other than R. Then from (11) we get

$$(11') \qquad \hat{\ell}\,\Big|_{r=0} = \eta\,(g^{*} - \gamma\ell + \hat{\beta}),$$

which, so long as the elasticity of population response is positive, will take the sign of the terms inside the brackets. This equation will thus indicate the extent of the shift in the R curve at each given abscissa on the R axis.

Similarly, from the equation underlying the $\bar{S}$ curve, i.e.,

$$\bar{S} = \bar{S}(\bar{Y},\ \alpha\bar{Y}/R,\ \beta),$$

we can obtain through total logarithmic differentiation

$$(12) \qquad S = \varepsilon_{\bar{y}}\bar{y} + \varepsilon_{y_k}(\hat{\alpha} + \bar{y} - r) + \varepsilon_{\beta}\hat{\beta}$$

$$= \varepsilon_{\bar{y}}(\alpha r + g^{\bullet} - \gamma\ell) + \varepsilon_{y_k}(\hat{\alpha} + \alpha r + g^{\bullet} - \gamma\ell - r) + \varepsilon_{\beta}\hat{\beta}.$$

Setting r to zero hypothetically, we get

$$(12') \qquad \bar{S}\Big|_{r=0} = (\varepsilon_{\bar{y}} + \varepsilon_{y_k})(g^{\bullet} - \gamma\ell) + \varepsilon_{y_k}\hat{\alpha} + \varepsilon_{\beta}\hat{\beta}.$$

This equation would indicate how the $\bar{S}$ curve would shift vertically at each abscissa on the R axis in response to changes in other variables apart from R.

Comparing equation (11') with equation (12'), we can see that technological progress big enough to overcome the adverse effects of the growing population pressure on land, i.e., a positive $(g^{\bullet} - \gamma\ell)$, will shift both the $R\ell$ and $\bar{S}$ curve upwards, since for a poor developing country the relevant elasticities, η, $\varepsilon\bar{y}$ and ε_{y_k}, are all positive.

Some economists may have doubts about the sign of ε_{y_k}, the elasticity of savings with respect to the marginal productivity of capital or the interest rate. I have argued strongly in my 1964 article on growth that for poor developing countries as distinguished from rich developed countries, the positive substitution effect is likely to overwhelm the negative income effect, because the income effect depends for its magnitude on the current amount of saving which is necessarily very low to start with. In a short paper on the interest rate and consumption in 1973, I further reinforced this argument by pointing out that apart from the usually recognized substitution effect and income effect, a rise in the interest rate would exert a wealth effect on current saving which is always positive, since a rise in the interest rate would depress the current vlue of all durable assets and hence would depress consumption expenditures through the wealth effect. (Tsiang, 1973).

Moreover, while both curves will be shifted upwards, the $\bar{S}$ curve will most likely shift upward to a greater extent than the $R\ell$ curve in the short run on account of the different effects of time lags. Though all three elasticities necessarily operate with some time lags, the time lag for the response of the population would probably be longer than for the other two, and, furthermore, the lag would make for a diminution in the short run response of population growth. Conversely, the time lag for the response of saving to income would make for an enlargement of the short run saving as it would be the consumption habit of the population that would lag behind the increase in income. Thus, as the short run effect of an improvement in productivity, the $\bar{S}$ curve would very likely shift upward relative to the $R\ell$ curve, and if the increase in productivity is going on continuously and rapidly, the relative shift could be long-lasting or even show signs of increasing.

Thus a developing country which aspires to achieve a takeoff into self-sustained growth quickly should adopt effective policies to pursue all of the four above-mentioned ways to cross over the hump or to eliminate it.

Alternatively, we can say that our model indicates that the necessary condition for takeoff is to bring about the condition

(13) $\bar{S} > R\ell$

so as to ensure a steady positive $\dot{R}$, i.e., a steady increase in capital per unit of labor when the country is trapped at point 2. (See equation 9 above). Since $\bar{S} = S/L$ and $R = K/L$, this

inequality can also be written as

(13') $S/Y > (K/Y)\ell$,

which means that the percentage of income saved in the country should be raised above the capital/output ratio of the country times the rate of population growth to ensure that the capital per unit of labor for the entire economy will continue to grow.

Since the total stock of capital is very difficult to measure and the statistics for it are generally not available particularly for developing countries, however, we shall use $\Delta K/\Delta Y$ or $I/\Delta Y$ in the place of K/Y. This substitution actually has an advantage in that when the condition (13') is rewritten as

(13") $S/Y > (I/\Delta Y)\ell$,

the latter would directly imply that domestically generated savings would be enough to finance investment projects yielding an increase in national product more than proportionate to the increase in population, provided Δy is positive. When Δy is negative, inequality (13") would be meaningless and unnecessary, for the fact that Δy is negative is <u>ipso facto</u> a sign that the takeoff condition is not fulfilled.

On the other hand, $S/Y > (K/Y)\ell$, i.e., (13'), can also be said to imply the same only if we assume with Solow the condition of constant returns to capital and labor. Since we have from the very beginning rejected the constant returns to scale assumption of Solow's model, we would have to supplement (13') with a further condition to ensure that the available savings invested

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will indeed yield a net increase in output per capita, viz.,

(14) $\dot{g} - \gamma\ell > 0,$

i.e., that the net positive effect on productivity of technological changes must be able to more than offset the adverse effect of the increased relative scarcity of land. Now with (13") as the criterion for takeoff, however, the ability to generate a steady increase in real income per capita is directly implied with the changes in technology and population implicitly taken into consideration. Since (14) would involve more unmeasurable concepts, we shall in the following part of the paper use (13") as the criterion for the economic takeoff of a developing country to circumvent the difficulties encountered in measuring them.

The policy implications of this criterion are of course the same as before, viz., that the propensity to save of the country should be raised; the marginal productivity of investment should be increased either through technological improvement or through participation in international trade and a more efficient allocation of resources; and, last but not least, the rate of increase of population should be lowered.

Unfortunately, under the mistaken guidance of various wrong economic theories, many countries in the past actually adopted policies that operated in the opposite direction, and thus their economic takeoff was made much more difficult.

Sometimes countries, which had already passed beyond the poverty trap and were on their way to steady takeoff to begin

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with, were liable to come under the delusion of the wrong development theories and thus switch to misguided policies as enumerated below, which would shunt them back to a state similar to that experienced in pre-takeoff struggles. The policy mistakes are:

(1) For instance, many socialist countries, that are steeped in the Marxist dogma that all economic values are created by labor alone and thus cannot accept the idea that there could be difficulties arising from over-population, would, therefore, refuse to adopt any measures for population control, in spite of all persuasions. An eminent example of this is the experience of the P.R.C. before the 1985 reform, where the modest achievements of the bungling efforts in development, including the questionable "Great Leap Forward," were offset by the rapid increase in population.

(2) In the early postwar years, under the influence of prevailing Keynesian monetary theory, the banking policy in most developing countries tended to hold the interest rates in their own countries at artificially low levels with controls that would often, in the face of domestic inflation, reduce the real rates of interest close to zero, or, in some cases, even to negative levels. Thus the local population would either be discouraged from saving altogether, or would keep their savings away from financial institutions and instead would put them into hoardings of foreign exchanges and precious metals, or invest them in real estate,

which are in most cases non-productive kinds of investment. The formation of real productive capital for the development of the country was thus severely hampered.

Furthermore, the artificially enforced cheapness of capital in spite of the reality of a great scarcity in its supply would tend to lead to the irrational allocation and wasteful usage of the available supply and thus result in the unnecessarily low productivities of the capital investments actually undertaken. As we may readily see from the necessary condition for takeoff, i.e., inequality (13"), this would directly make takeoff more difficult to achieve.

(3) In the postwar period most underdeveloped countries were under the influence of the then prevalent economic thinking that the surest way to speed up the industrialization at home is to provide a safe sheltered market for domestic import substituting industries protected by high tariffs and quantitative import control; and moreover that it is an astute policy to keep domestic currency overvalued in the face of inflation at home, because it was believed that devaluation would worsen the terms of trade and aggravate domestic inflation by imparting a strong costpush. The resulting overvaluation of the domestic currency would make the export of domestic products extremely difficult and would thus in turn necessitate stringent import and exchange controls to keep the balance of payments balanced.

This kind of trade and exchange policy would effectively deny

the country concerned the advantages to be obtained from the international division of labor and specialization in lines of production in which the country has the greatest comparative advantages. It is equivalent to denying oneself of a rapid way to raise the effective productivity of the country.

With these popular yet clearly misconceived policies in operation, it is little wonder that economic takeoff would seem so hard to achieve for some countries even though they are apparently very favorably endowed for rapid economic development.

On the other hand, there are some developing countries, that are apparently very poorly endowed with natural resources, that have managed to take off successfully with apparently not too much difficulty. Eminent recent examples of such countries are the Asian NIC's. Previously I have written about the experiences of the four Asian NIC's elsewhere (Tsiang and Wu, 1985), and especially about Taiwan (Tsiang, 1984, 1985). Generally speaking, the common features of their development policies may be summarized as follows:

(1) All of them had deliberately rejected the erstwhile fashionable strategy of ensuring a sheltered market for domestic industries and of maintaining an unrealistically high exchange rate for domestic currency supported by strict import restrictions and exchange control.

(2) All of them had allowed their domestic interest rate to rise to a reasonable level while endeavoring to curb domestic

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inflation. Thus their savings through domestic financial institutions would not be discouraged. At the same time, this sort of realistically high interest rate policy would prevent the wasteful use and misallocation of scarce investible capital and thus ensure fair returns to their investment projects.

(3) All four NIC's had adopted a more or less open attitude towards the inflow of foreign capital into their countries to supplement their own saving in capital formation at home. In this way, foreign capital was enlisted to help push their capital per unit of labor over the hump.

(4) all four countries had adopted sensible population control policies, so that their population would not spurt up in response to the increase in their per capita real income to offset the results of their own efforts in capital formation.

Under the framework of our theoretical model of growth, it is not difficult to see how these policies would make a difference in helping to achieve the takeoff as compared with the prevailing policies in other countries. Since, as we have shown above, the necessary condition for economic takeoff is to ensure that $S/Y > (I/\Delta Y)\ell$, i.e., inequality (13") above, we may evaluate the effects of different development strategies from the following three points of view: (i) how the percentage of national income saved S/Y has been raised from its initial unsatisfactory level; (ii) how the incremental capital/output ratio $(I/\Delta Y)$, (the reciprocal of the marginal productivity of investment) has been lowered, or

been prevented from rising rapidly, by such measures as a better allocation of resources, the introduction of technological improvements and the international division of labor; and (iii) how the rate of increase of the population has been kept from increasing, and has even been reduced. The answer to these questions would determine the success or failure of the country concerned in achieving economic takeoff.

Let us first of all look at the four NIC's of Asia. These four countries all started with a very low real income per head, were very meagerly endowed with natural resources and were also very heavily overpopulated in terms of their limited territories. The odds seemed to be very heavily against their attempt to achieve economic development. Yet they all managed to bring about a successful takeoff and have continued ever since to increase rapidly their incomes per head which have now overtaken from behind the incomes of many more favorably endowed countries.

The following tables (Tables 1 and 2) give the population density per square kilometer, and the GNP per head (in US$) for a number of developing countries including the Asian NIC'S[1]. It can be readily seem that there was a much higher population density and consequently a relatively lower income per head in the NIC's

[1] GNP figures were used in this table instead of statistics of national incomes for the reason of its availability in internationally comparable terms.

60's, the real income per head, gross national product and exports of the four all started to spurt up rapidly. Why the NIC's have managed to do better than other countries can be realized by observing how the criterion for takeoff (13") has been fulfilled and then surpassed over the years.

In the early 1950's, Taiwan and Korea, together with several other Asian countries, had per capita real incomes of below or not far above one hundred U.S. dollars (current values), i.e., lower than most of the Latin American countries. Only Hong Kong and Singapore, because of their former entrepôt and mainly urban status, and the Philippines had already reached a per capita income level of well above one hundred U.S. dollars comparable to some of the Latin American countries (except for the very rich ones). Furthermore, the Asian countries all had far greater population densities than developing countries in other continents, and were much less favorably endowed with natural resources.

This is manifested in the fact that few Asian countries were able to save enough out of their own national income to finance the investment needed to increase their capital stock in proportion to the growth of their population (i.e., to satisfy the condition that $(S/Y) > R\ell$, let alone to finance enough investment to raise the real income per capita in spite of the increase in population pressure on land, i.e., to satisfy the condition $S/Y > (I/\Delta y)\ell$.

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$S/Y > (I/\Delta y)\ell$.

Nevertheless, some of them, especially Taiwan and Korea, adopted special measures to encourage savings through financial institutions by relaxing the control over bank interest rates and allowing the money rate of interest to rise above the expected inflation rate, and thus succeeded in raising their propensity to save significantly. At the same time, they switched from the then popular industrial development policy of protected import substitution to a policy of exchange devaluation to encourage export expansion accompanied by considerable import liberalization. This implied that the country was now able to exploit more fully its comparative advantage in certain industries, and, as a result, the average productivity of the country was thus greatly raised. This resulted in a fall in $(I/\Delta Y)$ on the right hand side of the condition for takeoff (13"), and thus facilitated their takeoff.

From Table 3, we may observe that Taiwan had a propensity to save of 5% or less in the early part of the 50's, which was certainly not high enough for takeoff, since at that time her rate of population growth was pretty high (over 3.5%). She was able to avoid sliding back into deeper and deeper poverty only because of the foreign aid which she began to receive from the United States soon after the start of the Korean War. From the late 1950's and the beginning of the 1960's, however, Taiwan broke away from the popular development strategy whereby emphasis was placed on

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protecting import-substituting industries, and instead endeavored to foster export industries suitable for her specific factor endowment. At the same time, she adopted a monetary policy that would allow the money rate of interest to rise above the expected rate of inflation even when inflation was still rampant. This policy not only did not exacerbate the inflation as Keynesian cost-push inflation theorists claimed that it surely would, but it also helped to curb inflation by checking wasteful investments, in the hoarding of goods, the storing of gold and foreign currencies, and excessive investment in real estate, etc. The government also exercised considerable self-restraint in fiscal and monetary policies to prevent a rapid increase in money supply and in prices.

The relative stability of prices and attractive interest rates on savings deposits revived the traditional thrifty habits of the Chinese people. Furthermore, as incomes rose because of the rapid development of the export industries, the inducement to save was reinforced by the natural tendency for consumption habits to lag behind rising income. In this way, Taiwan rapidly turned from a country with a very low propensity to save to one with a remarkably high savings propensity.

In 1952 only 5.2 per cent of Taiwan's national income was saved. By 1963, the percentage had already risen to 13.4 per cent, surpassing the corresponding figures for both the United Kingdom (9.8 per cent) and the United States (9.1 per cent) for

the same year. In 1986, it rose to an incredible 36.1 per cent.

On the other hand, because of the trade liberalization which led to the development of the export industries, the incremental capital output ratio ($I/\Delta Y$) actually declined after 1960, when Taiwan devalued her currency and thus switched to an export-oriented industrial policy, for a couple of years (to a level even below 2) and then rose only very gently, even though the steadily rising real wage rate in Taiwan compared with the other developing countries around it had made it imperative for Taiwan to shift to more and more capital-intensive industries and technologically more advanced methods of production.

Moreover, Taiwan adopted a sensible population policy in encouraging family planning and effectively spreading the knowledge and methods of birth control, so that the rate of population increase in Taiwan dropped from 4.0% in 1952 to 3.5% in 1963, to 1.9% in 1973, and finally to 1.5% in 1985.

These three factors combined to make the takeoff for Taiwan's economy fairly easy to accomplish. As one can observe from the table showing the gradual fulfilment of the takeoff condition $(S/Y)>(I/\Delta Y)\ell$, we can safely say that around 1963 Taiwan had successfully entered the stage of self-sustained economic growth. By 1965 the excess of S/Y over $(I/\Delta Y)\ell$ had already reached double figures in percentage terms, indicating that the country's domestically-generated savings had already well exceeded the minimum needed to finance the investment needed to ensure the same

standard of living for the increasing population.

Another Asian country that has successfully taken off into self-sustained growth is Korea. Like Taiwan it started from a low per capita income (U.S.$126 in 1953). Besides, it suffered severe inflation as well as physical devastation during the prolonged war with the communist north during 1958 and 1959. Although inflation was gradually brought under control after the cease-fire, in the 60's it started to flare up again. The economy also had the full paraphenalia of quantitative inport restrictions and exchange controls and a complex structure of multiple exchange rates that was biased against the more viable exports and favored the less competitive ones. Nominal interest rates, even on long-term deposits, ranged from only 10 to 15 per cent, whereas in 1963-64, the annual rate of inflation, as measured by the GNP deflator, was about 30 per cent.

The success of Taiwan's reforms obviously made an impression on Korea. In Sept. 1965, the Korean monetary authorities finally decided to abandon the low interest policy and sharply raised the nominal interest rate on 18 month time deposits to 34.5% per annum (or 2.5% per month compounded monthly). The new nominal interest rate was expected to ensure a positive real rate of interest for depositors, and thus to rekindle their willingness to save. The result, as in the case of Taiwan, turned out to be exactly as expected. The propensity to save, which used to be mostly negative or merely a fraction of one per cent before the sharp

rise in the nominal interest rate, jumped to 3.9 per cent in 1966 and then, after a setback in 1967 and 68, continued to rise rapidly. In 1970, it reached 6.8 per cent, in 1980 17.7 per cent and in 1984 21.9 per cent. Furthermore, as in Taiwan, the increase in the nominal rate of interest not only did not exacerbate the rampant inflation in Korea but also dampened it down considerably, although the continuation of the financing of investment by monetary and credit expansion kept the inflation going on until 1980 when the Park administration was replaced by that led by General Chun.

On the other hand, Korea also adopted the devaluation and trade liberalization policy that had begun to show signs of success in Taiwan. In 1961 the Korean government unified the won exchange rate and devalued the won from 65 won per US$1.00 to 130 won per US$1.00 in order to correct the overvaluation of the inflated domestic currency. Since no effective measures were taken to stop inflation at that time, however, the won had to be devalued repeatedly, to 255 won per US$1.00 in May 1964 and again to 272 won per US$1.00 in June 1965. At the same time, the Korean government adopted many trade promotion measures, such as the exemption of imported raw materials used in export industries from tariffs and domestic commodity taxes, and preferential treatment in corporate income tax (50 per cent exemption) for profits arising from export activities, etc.

As a result, Korea's exports, which had stagnated in the

fifties, began to rise sharply after 1961 and attained an amazing average annual rate of growth of 38 per cent for the ten year 1961-70 period, and an average annual rate of 36 per cent for 1971-80. This rapid expansion of the export industries generated a lot of profitable investment opportunities, which resulted in an extraordinarily low investment/net increment of real income ratio. As shown in Table 4, the five year moving averages of ($I/\Delta Y$) ratios for the 1960's after 1961 were all under 2. (We take the five year moving averages of the annual ($I/\Delta Y$) ratios to smooth out their irregular movements.)

Thus soon after the monetary reform of 1965 which succeeded in making the country's propensity to save positive, Korea might be considered to have attained self-sustained growth, say, around 1970.

Hong Kong and Singapore are another two countries (or rather city states) which have been ranked together with Taiwan and South Korea to form the four Asian NIC's. Before World War II, they were, both entrepôts for Southeast Asia under British domination, and as such enjoyed much higher real incomes per head than either Taiwan or South Korea. Moreover, because they had been international trade centers since before the war, they both had excellent financial connections with foreign countries and especially with overseas Chinese in every part of the world. Thus, compared with Taiwan and Korea, they had a big headstart, as they had easy access to international financial markets.

Hong Kong in the past always relied on Mainland China as its hinterland and served as the funnel for China's foreign trade. With the outbreak of the Korean War, the United Nations' embargo on trade with Mainland China, after the latter joined with the North Koreans, dealt a lethal blow to its traditional entrepôt trade. With its traditional means of making a living severely restricted, and with the population sharply increased by the vast inflow of refugees, Hong Kong had to find a new way to survive. It was quickly realized that in view of Hong Kong's total lack of natural resources, the best solution was to utilize the abundant and cheap labor supply to manufacture labor-intensive products using imported raw materials from wherever they could be obtained most cheaply, and to export the products to labor-scarce countries. Since Hong Kong had always been an open entrepôt, its entrepreneurs were well informed about the tastes and preferences of foreign markets and the practices of foreign trade. By the end of the 1950's more than two-thirds of Hong Kong's exports consisted of domestically-manufactured products instead of re-exports. In the next decade, Hong Kong's exports expanded by 14.5 per cent, and in the seventies by 17.1 per cent. These growth rates reflected fully the expansion of domestically produced exports.

Thus the rapid expansion of Hong Kong's exports of manufactured products provided ample opportunities for profitable investment, the high productivity of which was reflected in the

extraordinarily low ($I/\Delta Y$) ratio, which was often below 2 in the early years (i.e., up to 1971).

At first, Hong Kong's investment was to a considerable extent financed by capital inflows, but with the steady rise in real income generated by astute investments, Hong Kong's own propensity to save soon became sufficient to finance the investment necessary to keep real income per head growing, and Hong Kong may thus be said to have taken off successfully around 1964.

Singapore, like Hong Kong, was an entrepôt for neighboring regions before World War II. After the war, its entrepôt trade was severely circumscribed by the rising economic nationalism of the newly independent nations of the region, each having its own aspiration for direct trade with foreign markets and for processing its own raw materials prior to export, and each being eager to promote domestic industrialization by imposing restrictions on manufactured imports. In the meantime, the rapid growth of population in the 1950's resulted in a much expanded labor force which could not be fully absorbed by the stagnant trade. The People's Action Party, which came to power in 1959, therefore advocated industrialization as a solution to Singapore's growing unemployment.

At first, federal ties with Malaysia obliged Singapore to go along with a common import-substitution policy for the Malaysian Common Market. This strategy made little headway in Malaysia, as in other parts of the world. It was only after Singapore seceded

from the Malaysian Federation in August 1965 that it began to embark on an export-oriented industrialization policy like that of the other three Asian NIC's.

Thus, although Singapore experienced little export growth during the decade before its independence in 1965, in the five years that immediately followed independence, exports increased at an average annual rate of 8.2 per cent. In the seventies the average annual growth rate of exports accelerated to 28.8 per cent, and in 1984 Singapore's exports reached US$24.1 billion, which was even bigger than the corresponding figure for Australia in the same year, though Singapore still ranked only fourth among the Asian NIC's.

At first, even in the early part of the 1960's, Singapore had a very low saving propensity, which was in fact mostly negative. Because of its open financial market, however, Singapore could not arbitrarily raise the interest rate to stimulate saving and encourage capital inflow. Nevertheless, the newly independent Singaporean government adopted a measure that, in conjunction with the political stability it had established, appeared very successful in significantly raising the propensity to save. This measure was to establish the Central Provident Fund, a sort of combined pension and social insurance fund to which both employees and employers were legally required to contribute. As of 1982 the employee was required to contribute 22 per cent of his or her wages or salary and the employer to contribute a further 20.5 per

cent.

The effectiveness of this measure in raising the propensity to save in Singapore can be observed from Table 6. Singapore's net savings had been negative up to 1964. In 1965, they became barely positive, being less than 1 per cent of her national income. After 1965, however, the propensity to save rose rapidly so that by 1970 it had already reached 12.3 per cent, and by 1980, 29.1 per cent. In 1984 it had actually risen to 41.4 per cent.

On the other hand, the very high rate of population growth in the early fifties (around 5 per cent) was quickly reduced to less than 2 per cent by the end of the sixties, and was brought down to nearly 1 per cent in the eighties. At the same time, the liberalization of trade and the rapid expansion of exports created vast opportuinties for very profitable investment which kept Singapore's investment/net real income increment ratio at a very low level for a long time even though Singapore was moving steadily towards more capital-intensive and technology-intensive industries. Thus the takeoff condition was satisfied by 1966 even though during the following year, 1967, the country experienced a minor recession.

Two other East Asian countries, namely, India and Thailand, represent another type of country which has apparently taken off but has not yet soared into very rapid growth as did the four NIC's, though Thailand is perhaps close to them. The available statistical data does not go back far enough to enable us to

observe clearly the process by which they freed themselves from the poverty trap and got off the ground. Almost from the very beginning of the period for which data is available, i.e., (1961-85), these two countries seem to have satisfied the takeoff condition or have been very close to it, even though their average incomes per capita were still very low in 1960 (i.e., US$97 in Thailand, US$73.5 in India, both being less than US$100 per annum at the then current value of the dollar).

Nevertheless, their takeoffs were rather marginal. The domestically-generated savings never exceeded the minimum amount of investment necessary to ensure the same real income per head by a big margin (say, by a two digit percentage figure, i.e., 10 percentage points), so that the growth rates of their income per head, though quite respectable by world standards, have not been as spectacular as those of the NIC's. India's average growth rate was 3.8 per cent during the sixties, 3.3 per cent during the seventies, and 5.1 per cent during the first five years of the eighties. Thailand's average growth rate was 7.4 per cent for the sixties, 6.8 per cent for the seventies, and 4.2 per cent for the first half of the eighties. (See Tables 7 and 8).

These two countries both had quite respectable propensities to save (10 per cent or more of the national income) even when their real incomes per head were quite low. However, particularly in the case of Thailand, the propensity to save failed to expand with the substantial increase in the real income per head, as in

the NIC's. In fact, in Thailand, the propensity to save in the 80's was lower than in the 60's and the 70's.

In India, the main reason for the less rapid growth seems be the exceptionally high investment/income increment ratio. The five year moving average ($I/\Delta Y$) ratios were frequently as high as 5 or 6, and mostly around 4, which compared very unfavorably with the investment/income increment ratio in the Asian NIC's which usually started below 2 and only gradually rose higher as the increase in real wages in those countries called for more and more capital- and technology-intensive production. In the case of India, the tendency to resort to excessively capital-intensive methods of production and industries seems to have originated from her belief that heavy industries form the necessary basis for the industrialization process and that capital-intensive and high technology industries would enhance the prestige and power of the country. This strategy, however, seems to have retarded the growth in the real income per head of the population even if the country in fact managed to takeoff into self-sustained growth.

Unfortunately, this strategy supported by trade restrictions and exchange control seems to be a very widely pursued policy. In the cases of Latin American countries, this seems to be one of the most important obstacles to their smooth economic takeoff.

Most Latin American countries, compared with their Asian counterparts, are much more favorably endowed with natural resources and much less densely populated. Their per capita

incomes in the fifties and sixties were mostly much higher than those of all those Asian countries we have discussed apart from Hong Kong and Singapore. For instance, in 1950 the per capita incomes of Columbia, Mexico, Peru, and Venezuela were US$354, 181, 134, and 635, respectively, at the then current value of the US dollar, and in 1960 the corresponding figures were US$261, 346, 203, and 1,043, respectively. It seems, judging by the Asian experiences, that at such levels of income per head, economic takeoff should have presented no great difficulty.

In this category of relatively more fortunate nations, we might also include the Philippines, because it also started with a per capita income of well over US$100 (in fact US$171 in 1950, and US$250 in 1960), on account of her relatively low population density vis-à-vis other Asian countries and the infrastructure she had inherited from the Americans or built with postwar American aid. As a result, the Philippines like the Latin American countries, might be recognized as having already taken off and in fact grew at a very satisfactory rate at a very early date. For instance, her real income per head grew on average at the rate of 8.5% per year in the first five years of the 1950's, well ahead of all of the four Asian NIC's. However, for some reasons, of which political instability and some erroneous economic policies are the most important, the growth faltered and eventually came to a halt in the early 80's. In this respect, the Philippines is rather like most Latin American countries.

In Tables 8 to 14, we shall display how the takeoff conditions were being fulfilled or being aborted in these countries. It might be observed that in fact all the Latin American countries as well as the Philippines seemed to have already emerged out of the poverty trap and were growing steadily, and in some cases quite rapidly as witness Brazil during the latter part of the 60's and the first part of the 70's, Mexico in the early part of the 60's, and the Philippines in the early 50's.

Unlike the cases of the four Asian NIC's, however, the would-be takeoffs of the Latin American countries all came to an end during the international debt crisis of the 1980's, despite their initial successes in economic growth. Their reasons for failure are certainly various and some are noneconomic, including, for instance, political disturbances and revolution.

If we concentrate on the economic policies followed by these countries, we will find that there are some common features that seem to be present in most of them. The first is that most of these countries failed to further encourage their people to save more when the initial growth raised the per capita income so as to generate more and more domestic finance for faster and faster growth. The second is that most countries in this group believed in developing domestic industries in a sheltered domestic market, instead of encouraging their exports and discovering new exportable goods. The third is that they had a preference for large scale industrial projects involving substantial initial

capital outlays with no or only small immediate returns, i.e., projects involving high investment/net output increment ratios.

These three causes combined seemed sufficient to bring to a halt a takeoff with a very successful beginning even after it had gathered considerable momentum in the early stages. The preference given to protecting import-substituting industries without any real competitive advantages, particularly those involving big capital outlays and long protracted returns, magnified the investment/output-increment ratio and increased the finance required for the investment necessary merely to maintain the real per capita income at the same level. If the country is at the same time enforcing a controlled low interest rate policy in the face of considerable domestic inflation, as most countries are in fact practicing, then the resulting negative real interest rate will actually encourage a wasteful allocation and usage of the scarce investible funds. Thus the sharp rise in the $I/\Delta Y$ ratio in some countries, while the propensity to save is not encouraged but discouraged by inflation and the resulting negative real rate of interest, might be observed to be the principal reason why an economy that has already started to take off may come to a premature standstill.

Since most of these countries had good access to foreign capital markets, they could easily supplement the deficiency of their own savings with capital imports (embodied in the net import surplus) from abroad. This is indeed a wise and proper way of

boosting one's own economic takeoff. Unfortunately, these countries followed the fashionable import substitution strategy and believed in the superiority of large-scale industries with high capital intensity, which absorbed a lot of investible funds but yielded relatively little output that could be exported to earn foreign exchange to pay for debt servicing. Thus with the sharp rise in interest rates on the world capital markets, these countries quickly got into difficulties in servicing their heavy debts, and had to ask repeatedly for moratoria on their interest payments.

This contrasted strongly with the experiences of the Asian NIC's, some of which, viz., South Korea, is still heavily in debt with foreign countries, but are able to take the increase in world interest rates in their stride.

Finally, we shall deal with two African countries, Morocco and Tanzania, countries which are still struggling in their attempts to take off into self-sustained growth.

Tanzania is a typical country that started with a very low income. In 1960, its average income per head at current prices, was US$47.1, which was even lower than that of India for the same year i.e., US$55.7. In 1975, however, Tanzania's income per head rose to US$168.6 and in 1980 to US$283.6, whereas India's income per head in 1975 was US$147.2 and in 1980, US$240.1, obviously having been surpassed by Tanzania. Nevertheless, although we said above that India had narrowly achieved her takeoff, we shall have

to say that Tanzania has not succeeded yet in taking off into self-sustained growth.

The following table (Table 15) shows that for the whole period of the 1970's the necessary condition for takeoff ($S/Y > (I/\Delta Y)\ell$) was not satisfied, and since 1981 the real income of the country even started to decline. It seems that the substantial positive growth rates of Tanzania's real national income in the 70's was chiefly due to the large inflows of capital imports, and/or foreign aid, which amounted in some years to as much as 16% of its national income. This kind of growth supported by foreign loans or aid cannot be sustained for long unless domestic savings can gradually take over the role played by foreign capital as in the Asian NIC's.

Unfortunately, instead of encouraging domestic savings, Tanzania did exactly the opposite. It followed the Keynesian policy of keeping the nominal interest low at 4% to 6% per annum while allowing the domestic price level to rise at double-digit rates. The resulting negative real interest rates naturally caused the domestic saving propensity to decline sharply. In 1965-70, Tanzania's average propensity to save was as high as 12%, but in 1984 it was down to 4.3%.

At the same time, the $I/\Delta Y$ ratio in Tanzania tended to be much higher than in the Asian NIC's. In the early 1970's, the $I/\Delta Y$ ratio was as high as 4 and at the close of the decade it soared into double-digit figures. This contrasted strongly with

the experiences of the Asian NIC's, which not only made it a point to foster their propensity to save, but also endeavored to keep their I/ΔY ratios as low as possible, particularly at the beginning of their takeoff processes.

The case of Morocco is more or less similar, even though Morocco is a much better off country than Tanzania. Indeed, with an income per head of US$185 in 1955, it was much better off than the two Asian NIC's, Korea and Taiwan, in the same year. In the period 1970-76, the growth rate of the real national income per head in Morocco appeared to be quite satisfactory. In 1977, the growth rate declined sharply and the buoyancy of the economy was never recovered. Judging from our conditions for takeoff, Morocco cannot be said to have successfully achieved it, since this condition was mostly unsatisfied except in the few golden years of 1971-75. (See Table 16).

The reason for the non-fulfilment of the takeoff condition was again the insufficiency of domestic savings, which the government did nothing to encourage even though the country was quite well off as a developing country. The authorities kept the nominal interest rates of the financial institutions at fairly low levels that ranged from 4.5% to 6.5% while letting domestic price inflation continue at a brisk rate that sometimes ran into two-digits. The resulting negative real interest rate inevitably caused the fairly satisfactory savings ratio in the golden year of the 70's to drop sharply in the 80's. At the same time, the

ambitious development plans frequently pushed the $I/\Delta Y$ ratio up to levels that would make the takeoff condition impossible to fulfill. Thus, like Tanzania, the actual positive growth of the economy of Morocco that had taken place in recent years should be mainly attributed to the inflows of foreign lendings and aid. The economy itself could not be said to have entered into self-sustained growth.

Summing up the paper, we may say that the success or failure of a developing country in attempting to take off into self-sustained growth can be better understood with the help of a theoretical model that describes the process of takeoff in terms of real factors. When the necessary condition for takeoff is identified, development policies should be evaluated according to whether they are in fact promoting or thwarting the fulfilment of this condition.

The hitherto prevalent Keynesian development policy of expanding effective demand to generate growth coupled with a low interest policy to stimulate investment appears to be of very doubtful value. However, if the leader of the Free World continues to indulge in spending way beyond her national income, and save a lesser percentage of her own national income than a poor developing country, such as India and Tanzania, while claiming to be the "locomotive" of world growth, who can blame the developing countries for constantly getting into debt crises and for failing to achieve self-sustained growth?

Table 1
GNP per capita (Nominal) of Some Developing Countries
unit:U.S. dollars

	1950	1960	1970	1980	1985	1986	1987
ASIA							
Hong Kong	246.4	---	911.9	5,472.6	6,238.9	6,765	
Korea	126.4(1)	155.9	272.1	1,637.4	2,113.8	2,271	2,826
Singapore	---	430.9	916.1	4,862.3	6,839.2	6,949	
Taiwan	144(2)	153	387	2,314	3,144	3,784	4,989
India	56.1	73.5	99.6	240.1	262.2		
Thailand	51.5	96.6	179.9	719.4	747.4	813	872
Philippines	171.4	250.4	191.9	728.8	584.4	544	
LATIN AMERICA							
Brazil	---	---	423.7	1,966.1	1,672.9		
Colombia	354.0	261.5	350.7	1,290.1	1,194.5		
Mexico	180.8	346.0	701.2	2,685.4	2,260.3		
Peru	133.9	203.3	462.4	994.8	730.7		
Venezuela	635.3	1,042.7	1,143.5	3,942.7	2,864.0		
AFRICA							
Morocco	---	154.3	250.8	888.9	540.4		
Tanzania	---	53.1	96.8	283.6	284.7		

Sources:(for this Table and Tables 3-16)
Taiwan: Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Statistical Abstract of National Income in Taiwan Area, Republic of China, 1951-1987.
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2. E.K.Y. Chen, Hyper-Growth in Asian Economics (London:MacMillan, 1979), (1954-65).
Singapore:
1. Department of Statistics, Singapore, Economic & Social Statistics Singapore, 1960-82.
2. Department of Statistics, Singapore, Yearbook of Statistics, Singapore, 1986, (1983-86).
3. IMF, International Financial Statistics, April 1988(1986).
Korea:
1. Bank of Korea(1986-87).
2. Korea Economic News, March 26th, 1988(1986-87).
3. IMF, International Financial Statistics.
Other Countries:
International Monetary Fund, International Financial Statistics.
Notes:
(1). 1953's data
(2). 1951's data

Table 2
Population Density of Some Developing Countries
(persons per km2)

	1950	1960	1970	1980	1985
ASIA					
Hong Kong	2,231	2,892	3,955	4,850	5,309
Korea	134	149	207	255	280
Singapore	---	2,813	3,528	4,115	4,403
Taiwan	210	300	408	495	535
India	113	136	168	202	228
Thailand	36	[illegible]	70	90	100
Philippines	65	[illegible]	128	161	181
LATIN AMERICA					
Brazil	6	8	11	14	16
Columbia	10	12	19	24	25
Mexico	13	18	26	36	40
Peru	7	8	11	14	15
Venezuela	5	8	11	15	19
AFRICA					
Morocco	21	26	35	45	49
Tanzania	8	10	14	---	23

Sources:
1. Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Statistical Abstract.
2. United Nations, New York, Demographic Yearbook.

Table 3 Statistics Related to Economic Takeoff-Taiwan

(in percentage)

	1	2	3	4	5	6	7	8
	ΔY/Y	ΔL/L	S/Y	Interest Rate	ΔP/P	I/ΔY	(S/Y)-(I/ΔY) (ΔL/L)	(X-M)/Y
1951	- -	- -	- -	41.40	- -	- -	- -	- -
1952	11.38	- -	- -	36.00	25.00	- -	- -	-7.23
1953	9.37	- -	- -	27.00	21.84	- -	- -	-6.11
1954	6.06	3.66	4.61	23.40	0.15	172.31	-1.70	-10.22
1955	7.68	3.51	4.81	21.60	10.04	195.04	-2.03	-5.30
1956	4.49	3.57	4.83	21.60	8.70	223.97	-3.17	-8.50
1957	6.11	3.47	5.12	19.80	8.68	220.01	-2.51	-6.43
1958	6.34	3.56	5.74	19.80	4.83	239.19	-2.78	-8.03
1959	7.90	3.86	6.42	18.00	7.13	232.21	-2.55	-10.38
1960	7.72	3.90	6.77	18.00	13.49	246.35	-2.83	-9.33
1961	7.48	3.81	8.60	16.20	4.86	215.85	0.38	-8.74
1962	5.63	3.68	11.02	15.80	2.13	190.15	4.02	-6.72
1963	10.71	3.52	12.87	14.00	3.42	193.22	6.07	-1.42
1964	13.03	3.10	15.08	14.00	4.17	204.64	8.75	0.94
1965	10.26	2.92	17.36	14.00	-0.62	209.16	11.25	-3.73
1966	8.43	2.81	18.51	14.00	2.73	248.16	11.54	0.35
1967	10.30	3.19	19.68	13.30	4.56	298.29	10.15	-2.57
1968	7.60	2.94	21.16	13.30	6.79	285.42	12.75	-3.60
1969	6.55	2.80	23.06	13.30	6.38	256.12	15.88	-0.94
1970	12.72	2.73	25.65	12.60	3.47	235.21	19.24	-0.06
1971	14.24	2.56	28.84	12.00	3.03	217.80	23.27	3.12
1972	12.59	1.96	30.40	11.30	5.83	287.60	24.77	7.97
1973	12.64	1.93	30.24	13.30	14.88	355.70	23.36	6.79
1974	1.83	1.83	31.09	14.80	32.25	344.07	24.79	-9.86
1975	3.08	1.81	31.29	13.30	2.34	366.57	24.65	-4.24
1976	13.12	1.82	31.56	12.00	5.54	354.45	25.12	2.81
1977	10.17	1.86	32.32	8.25	6.40	318.16	26.41	6.34
1978	12.88	1.88	33.41	8.25	5.29	311.61	27.54	8.44
1979	7.87	1.95	32.91	11.00	11.34	356.95	25.93	1.49
1980	8.72	1.89	31.82	11.00	16.04	390.31	24.43	-1.55
1981	6.95	1.85	30.90	11.75	12.11	408.17	23.36	2.63
1982	4.28	1.77	30.48	7.75	3.44	317.12	24.87	6.59
1983	7.19	1.60	30.18	7.25	1.92	277.68	25.75	11.32
1984	11.53	1.51	31.47	6.75	0.83	184.10	28.70	14.29
1985	5.54	- -	- -	5.25	0.21	- -	- -	17.70
1986	13.49	- -	- -	4.77	3.65	- -	- -	24.81

Notes:

Col. 1 Annual rate of increase in net real national income.

Col. 2 Annual rate of increase of population calculated from five year moving averages of population numbers.

Col. 3 Percentage of national income saved calculated from five year moving averages of total net savings and the five year moving averages of national income.

Col. 4 Nominal rate of interest.

Col. 5 Rate of increase of GDP deflator.

Col. 6 Net annual investment/annual increment of real national income, both in five year moving averages.

Col. 7 Column 3 minus Column 2 multiplied by Column 6 divided by 100.

Col. 8 Exports surplus (capital outflow; if negative, then capital inflow) as percentage of national income.

Table 4 Statistics Related to Economic Takeoff-South Korea

(in percentage)

	1	2	3	4	5	6	7	8
	ΔY/Y	Δ L/L	S/Y	Interes Rate	ΔP/P	I/ΔY	(S/Y)-(I/ΔY) (ΔL/L)	(X-M)/Y
1951	- -	- -	- -	- -	- -	- -	- -	- -
1952	- -	- -	- -	- -	- -	- -	- -	- -
1953	- -	1.03	- -	- -	- -	- -	- -	-8.11
1954	4.66	1.51	- -	- -	31.38	- -	- -	-6.70
1955	5.38	1.96	-1.11	- -	64.97	- -	- -	-8.72
1956	-1.63	2.35	-1.78	- -	34.48	193.26	-6.32	-12.34
1957	7.56	2.66	-2.17	- -	21.14	199.93	-7.48	-11.02
1958	5.27	2.89	-2.73	- -	-1.57	235.19	-9.53	9.19
1959	3.37	2.90	-1.52	- -	2.30	179.63	-6.72	-8.01
1960	1.54	2.89	-2.42	- -	11.26	217.97	-8.72	-9.80
1961	6.18	2.89	-1.76	- -	13.25	205.39	-7.69	-10.01
1962	1.64	2.89	-1.02	- -	18.41	169.17	-5.91	-12.21
1963	9.00	2.77	-0.14	- -	29.90	163.85	-4.40	-11.69
1964	9.84	2.63	1.91	- -	29.79	161.48	-2.34	-7.99
1965	5.42	2.88	3.75	- -	6.14	174.17	-1.27	-7.79
1966	12.50	2.77	4.90	- -	14.34	187.80	-0.31	-10.33
1967	5.99	2.64	7.12	- -	16.16	175.19	2.46	-11.20
1968	10.56	2.61	8.68	- -	16.25	179.32	4.00	-13.41
1969	21.77	2.55	9.14	22.80	7.13	198.46	4.08	-12.59
1970	11.66	2.14	10.19	22.80	14.18	207.99	5.73	-10.16
1971	8.49	2.02	11.96	20.40	13.59	197.63	7.96	-11.03
1972	4.97	1.92	12.43	12.00	16.48	251.31	7.61	-5.05
1973	12.54	1.82	12.81	12.00	13.51	282.58	7.68	-3.27
1974	7.80	1.74	14.72	15.00	29.51	248.22	10.40	-12.22
1975	6.71	1.67	16.87	15.00	26.85	237.37	12.90	-9.32
1976	13.25	1.63	18.60	16.20	20.91	252.08	14.50	-1.37
1977	10.00	1.58	20.27	14.40	15.87	283.14	15.79	0.23
1978	12.09	1.56	20.82	18.60	21.55	411.98	14.39	-3.26
1979	6.02	1.55	20.58	18.60	19.94	499.87	12.82	-8.00
1980	-4.77	1.56	19.90	19.50	25.22	596.06	10.63	-8.78
1981	6.20	1.55	19.42	16.20	15.47	559.19	10.74	-6.09
1982	4.35	1.54	19.79	8.00	6.48	489.57	12.25	-2.94
1983	11.10	1.50	- -	8.00	3.92	- -	- -	-1.47
1984	7.53	1.43	- -	9.20	3.91	- -	- -	-0.35
1985	- -	- -	- -	10.00	4.03	- -	- -	- -
1986	- -	- -	- -	10.00	2.41	- -	- -	- -

Notes:

Col. 1 Annual rate of increase in net real national income.

Col. 2 Annual rate of increase of population calculated from five year moving averages of population numbers.

Col. 3 Percentage of national income saved calculated from five year moving averages of total net savings and the five year moving averages of national income.

Col. 4 Nominal rate of interest.

Col. 5 Rate of increase of GDP deflator.

Col. 6 Net annual investment/annual increment of real national income, both in five year moving averages.

Col. 7 Column 3 minus Column 2 multiplied by Column 6 divided by 100.

Col. 8 Exports surplus (capital outflow; if negative, then capital inflow) as percentage of national income.

Table 5 Statistics Releated to Economic Takeoff-Hong Kong

(in percentage)

	1	2	3	4	5	6	7	8
	ΔY/Y	ΔL/L	S/Y	Interest Rate	ΔP/P	I/ΔY	(S/Y)-(I/ΔY) (ΔL/L)	(X-M)/Y
1951	- -	- -	- -	- -	- -	- -	- -	- -
1952	- -	- -	- -	- -	- -	- -	- -	- -
1953	- -	- -	- -	- -	- -	- -	- -	- -
1954	- -	- -	- -	- -	- -	- -	- -	- -
1955	- -	- -	- -	- -	- -	- -	- -	- -
1956	6.69	- -	- -	- -	- -	- -	- -	- -
1957	6.22	- -	- -	- -	- -	- -	- -	- -
1958	8.26	5.43	-0.96	- -	- -	109.60	-6.96	- -
1959	5.02	5.23	-1.11	- -	- -	231.48	-13.20	- -
1960	21.48	7.22	-0.89	- -	- -	232.99	-17.72	- -
1961	10.78	3.57	0.56	- -	- -	251.26	-8.42	- -
1962	10.21	3.27	1.78	- -	- -	270.77	-7.06	- -
1963	11.67	3.15	3.78	- -	- -	283.39	-5.13	- -
1964	8.31	2.60	7.67	- -	- -	151.11	3.74	- -
1965	18.29	-0.46	10.57	- -	- -	170.28	11.34	- -
1966	30.66	2.14	11.56	- -	- -	176.30	7.79	-1.24
1967	1.90	1.64	13.23	- -	5.93	144.40	10.86	5.86
1968	3.20	1.95	14.99	- -	3.05	150.09	12.08	5.25
1969	11.80	2.19	16.02	- -	4.99	216.13	11.28	9.44
1970	9.40	2.03	17.68	- -	8.82	186.06	13.90	8.09
1971	7.30	2.08	19.18	- -	7.25	169.82	15.65	0.86
1972	11.00	2.55	19.93	- -	8.71	231.43	14.03	4.19
1973	12.70	2.12	19.91	- -	14.20	308.68	13.38	4.28
1974	2.20	1.89	21.93	- -	11.55	238.46	17.41	6.93
1975	0.20	1.83	22.43	- -	4.02	235.08	18.11	4.43
1976	17.10	1.75	22.24	- -	9.06	265.11	17.58	7.55
1977	12.50	2.52	23.34	- -	3.22	245.19	17.15	4.13
1978	9.49	2.81	24.48	- -	7.58	237.28	17.81	-1.73
1979	11.67	3.03	24.00	- -	18.11	283.12	15.43	-1.73
1980	10.97	2.99	23.54	- -	15.50	352.88	12.99	-4.99
1981	9.42	2.88	23.02	- -	10.13	363.54	12.57	-4.28
1982	2.93	1.89	22.61	- -	9.80	342.63	16.13	-3.85
1983	6.53	1.47	21.80	- -	4.69	418.10	15.63	-1.00
1984	9.43	- -	21.30	- -	9.07	333.66	86.23	3.79
1985	-0.11	- -	- -	- -	5.13	- -	- -	2.88
1986	11.16	- -	- -	- -	3.26	- -	- -	4.48

Notes:

Col. 1 Annual rate of increase in net real national income.

Col. 2 Annual rate of increase of population calculated from five year moving averages of population numbers.

Col. 3 Percentage of national income saved calculated from five year moving averages of total savings and the five year moving averages of national national income.

Col. 4 Nominal rate of interest.

Col. 5 Rate of increase of GDP deflator.

Col. 6 Net annual investment/annual increment of real national income, both in five year moving averages.

Col. 7 Column 3 minus Column 2 multiplied by Column 6 divided by 100.

Col. 8 Exports surplus (capital outflow; if negative, then capital inflow) as percentage of national income.

Table 6 Statistics Related to Economic Takeoff-Singapore

(in percentage)

	1	2	3	4	5	6	7	8
	ΔY/Y	ΔL/L	S/Y	Interest Rate	ΔP/P	I/ΔY	(S/Y)-(I/ΔY)(ΔL/L)	(X-M)/Y
1951	- -	4.46	- -	- -	- -	- -	- -	- -
1952	- -	5.01	- -	- -	- -	- -	- -	- -
1953	- -	5.12	- -	- -	- -	- -	- -	- -
1954	- -	5.04	- -	- -	- -	- -	- -	- -
1955	- -	5.12	- -	- -	- -	- -	- -	- -
1956	- -	4.87	- -	- -	- -	- -	- -	- -
1957	- -	4.79	- -	- -	- -	- -	- -	- -
1958	- -	4.43	- -	- -	- -	- -	- -	- -
1959	- -	4.24	- -	- -	- -	- -	- -	- -
1960	- -	3.82	- -	- -	- -	- -	- -	-14.95
1961	8.45	3.55	- -	- -	0.01	- -	- -	-16.07
1962	7.04	3.08	-5.36	- -	0.86	- -	- -	-11.75
1963	10.44	2.99	-2.46	- -	0.94	177.01	-7.74	-16.25
1964	-2.76	2.68	1.65	- -	0.82	138.41	-2.05	-12.38
1965	7.60	2.50	3.91	- -	1.27	193.03	-0.91	-12.68
1966	24.16	2.22	7.42	- -	-9.30	196.34	3.06	-8.67
1967	-0.52	2.07	9.48	- -	12.43	168.11	5.99	-8.94
1968	13.23	1.83	11.00	- -	1.14	196.05	7.41	-7.01
1969	13.33	1.79	11.47	- -	2.33	275.90	6.52	-11.33
1970	12.90	1.67	13.38	- -	1.69	264.45	8.98	-21.87
1971	11.27	1.73	15.34	- -	4.47	309.73	9.97	-23.68
1972	13.31	1.80	16.63	- -	5.38	389.39	9.63	-18.41
1973	9.36	1.77	18.67	- -	12.19	435.80	10.96	-11.34
1974	6.24	1.65	21.33	- -	15.58	475.09	13.52	-18.92
1975	6.31	1.62	23.04	- -	2.43	518.85	14.64	-12.28
1976	7.10	1.42	24.42	- -	1.94	501.43	17.32	-8.94
1977	7.23	1.31	26.66	4.06	1.46	464.75	20.57	-2.91
1978	9.66	1.29	27.84	4.75	2.32	498.59	21.40	-5.49
1979	9.23	1.28	29.52	6.20	5.22	496.07	23.19	-7.68
1980	6.79	1.18	31.56	9.37	10.80	529.26	25.34	-9.96
1981	9.57	1.24	34.08	10.71	6.36	533.79	27.44	-6.30
1982	7.65	1.15	36.46	7.21	4.71	521.06	30.48	-4.93
1983	10.46	1.22	37.74	6.31	4.16	621.75	30.18	-1.97
1984	10.84	1.20	38.07	6.97	0.72	733.62	29.26	-2.96
1985	-0.18	- -	- -	4.99	-2.01	- -	- -	-2.88
1986	1.96	- -	- -	3.91	-3.72	- -	- -	-0.07

Notes:

Col. 1 Annual rate of increase in net real national income.

Col. 2 Annual rate of increase of population calculated from five year moving averages of population numbers.

Col. 3 Percentage of national income saved calculated from five year moving averages of total net savings and the five year moving averages of national income.

Col. 4 Nominal rate of interest.

Col. 5 Rate of increase of GDP deflator.

Col. 6 Net annual investment/annual increment of real national income, both in five year moving averages.

Col. 7 Column 3 minus Column 2 multiplied by Column 6 divided by 100.

Col. 8 Exports surplus (capital outflow; if negative, then capital inflow) as percentage of national income.

Table 7 Statistics Related to Economic Takeoff-India (in percentage)

	1	2	3	4	5	6	7	8
	ΔY/Y	ΔL/L	S/Y	Interest Rate	ΔP/P	I/ΔY	(S/Y)-(I/ΔY) (ΔL/L)	(X-M)/Y
1951	- -	1.30	- -	- -	- -	- -	- -	-1.97
1952	- -	1.42	- -	2.09	- -	- -	- -	0.11
1953	- -	1.54	- -	2.19	- -	- -	- -	-0.10
1954	- -	1.82	- -	2.49	- -	- -	- -	-0.43
1955	- -	1.89	- -	2.72	- -	- -	- -	-0.71
1956	- -	1.96	- -	3.17	- -	- -	- -	-3.62
1957	- -	2.03	- -	3.20	- -	- -	- -	-4.37
1958	- -	2.11	- -	2.57	- -	- -	- -	-2.97
1959	- -	2.18	- -	2.73	- -	- -	- -	-1.73
1960	- -	2.32	- -	3.67	- -	- -	- -	-3.18
1961	3.20	2.39	- -	4.35	2.74	- -	- -	-1.98
1962	2.32	2.39	10.82	3.70	4.17	- -	- -	-2.33
1963	5.80	2.38	11.19	3.76	9.13	500.87	-0.75	-2.04
1964	7.82	2.36	11.49	4.00	8.96	617.67	-3.07	-2.35
1965	-4.64	2.26	11.57	6.28	9.36	406.49	2.39	-2.34
1966	0.99	2.22	11.52	4.37	13.45	476.98	0.94	-3.03
1967	8.48	2.23	11.86	5.36	7.94	505.61	0.58	-2.27
1968	2.60	2.23	12.23	3.90	0.22	295.44	5.63	-0.96
1969	6.27	2.24	12.62	3.92	4.09	288.82	6.14	-0.35
1970	5.47	2.24	13.02	5.68	3.29	447.23	2.98	-0.12
1971	2.33	2.24	13.59	6.30	5.24	423.34	4.13	-0.96
1972	-0.72	2.22	14.08	4.69	11.20	662.69	-0.61	0.39
1973	4.17	2.19	14.73	6.64	18.87	510.45	3.56	-0.62
1974	0.37	2.15	15.64	13.52	17.89	567.91	3.41	-1.44
1975	9.38	2.12	16.17	10.40	-3.01	366.41	8.41	-1.22
1976	1.42	2.33	17.00	11.28	6.61	350.52	8.82	0.70
1977	8.30	2.33	17.40	10.18	3.55	488.52	6.00	0.15
1978	6.40	2.36	17.20	8.05	2.02	556.22	4.07	-0.34
1979	-4.87	2.38	16.74	8.47	15.58	464.08	5.68	-1.74
1980	6.41	2.40	16.72	7.24	11.33	621.76	1.79	-3.82
1981	5.40	2.19	16.32	8.61	9.33	557.31	4.11	-3.31
1982	2.87	2.20	16.41	7.27	7.85	395.85	7.69	-2.71
1983	7.71	2.15	17.21	8.30	9.01	394.35	8.73	-2.44
1984	3.34	2.11	- -	9.95	6.41	- -	- -	-1.81
1985	6.22	- -	- -	10.00	6.88	- -	- -	- -
1986	- -	- -	- -	9.97	- -	- -	- -	- -

Notes:

Col. 1 Annual rate of increase in net real national income.

Col. 2 Annual rate of increase of population calculated from five year moving averages of population numbers.

Col. 3 Percentage of national income saved calculated from five year moving averages of total net savings and the five year moving averages of national income.

Col. 4 Nominal rate of interest.

Col. 5 Rate of increase of GDP deflator.

Col. 6 Net annual investment/annual increment of real national income, both in five year moving averages.

Col. 7 Column 3 minus Column 2 multiplied by Column 6 divided by 100.

Col. 8 Exports surplus (capital outflow; if negative, then capital inflow) as percentage of national income.

Table 8 Statistics Releated to Economic Takeoff-Thailand

(in percentage)

	1	2	3	4	5	6	7	8
	ΔY/Y	ΔL/L	S/Y	Interest Rate	ΔP/P	I/ΔY	(S/Y)-(I/ΔY) (ΔL/L)	(X-M)/Y
1951	- -	3.00	- -	- -	12.42	- -	- -	- -
1952	- -	3.00	- -	- -	11.39	- -	- -	- -
1953	- -	2.99	- -	- -	0.45	- -	- -	- -
1954	- -	3.01	- -	- -	3.16	- -	- -	- -
1955	- -	3.00	- -	- -	4.34	- -	- -	- -
1956	- -	2.99	- -	- -	0.26	- -	- -	- -
1957	- -	3.00	- -	- -	4.40	- -	- -	- -
1958	- -	3.00	- -	- -	-0.07	- -	- -	- -
1959	- -	2.93	- -	- -	-1.52	- -	- -	- -
1960	- -	2.87	- -	- -	2.83	- -	- -	-1.42
1961	5.03	2.75	- -	- -	3.74	- -	- -	0.26
1962	7.65	3.29	- -	- -	0.07	- -	- -	-2.20
1963	7.89	3.32	13.88	- -	-1.54	242.68	5.83	-3.67
1964	5.97	3.39	15.33	- -	2.88	220.70	7.84	-1.62
1965	7.69	3.46	15.99	- -	4.64	234.51	7.87	-1.37
1966	12.12	3.58	16.17	- -	7.18	241.78	7.51	-0.38
1967	7.17	3.14	16.44	- -	-0.90	249.87	8.59	-2.35
1968	7.84	3.23	16.36	- -	-0.60	273.23	7.53	-4.33
1969	7.33	3.22	15.12	- -	2.03	323.32	- -	-4.65
1970	5.87	3.18	14.98	- -	-0.63	340.10	4.18	-5.24
1971	3.88	3.11	16.27	- -	1.55	316.78	6.41	-3.43
1972	4.77	3.03	17.08	- -	8.63	334.23	6.96	-1.30
1973	10.60	2.85	17.52	- -	20.20	340.81	7.80	-1.76
1974	6.29	2.76	17.95	- -	18.86	307.62	9.47	-2.95
1975	6.18	2.67	17.68	- -	2.78	305.05	9.53	-4.97
1976	8.25	2.58	16.99	- -	3.94	305.34	9.10	-2.62
1977	6.86	2.50	16.48	8.00	8.59	323.61	8.40	-5.84
1978	9.27	2.10	16.21	8.00	8.61	328.70	9.29	-4.38
1979	5.11	2.02	15.69	8.25	11.60	359.25	8.45	-6.74
1980	5.84	1.94	15.57	12.00	16.43	377.77	8.24	-5.93
1981	5.01	1.87	14.32	12.50	7.99	392.16	7.01	-5.39
1982	3.44	1.79	14.14	13.00	3.39	378.49	7.36	-0.13
1983	6.14	1.98	14.29	13.00	3.21	426.16	5.85	-5.70
1984	4.59	1.86	15.24	13.00	1.30	435.69	7.13	-2.35
1985	1.97	- -	- -	13.00	2.02	- -	- -	-0.67
1986	3.35	- -	- -	9.75	1.95	- -	- -	3.74

Notes:

Col. 1 Annual rate of increase in net real national income.

Col. 2 Annual rate of increase of population calculated from five year moving averages of population numbers.

Col. 3 Percentage of national income saved calculated from five year moving averages of total net savings and the five year moving averages of national income.

Col. 4 Nominal rate of interest.

Col. 5 Rate of increase of GDP deflator.

Col. 6 Net annual investment/annual increment of real national income, both in five year moving averages.

Col. 7 Column 3 minus Column 2 multiplied by Column 6 divided by 100.

Col. 8 Exports surplus (capital outflow; if negative, then capital inflow) as percentage of national income.

Table 9 Statistics Releated to Economic Takeoff-Philippines

(in percentage)

	1 ΔY/Y	2 ΔL/L	3 S/Y	4 Interest Rate	5 ΔP/P	6 I/ΔY	7 (S/Y)-(I/ΔY)(ΔL/L)	8 (X-M)/Y
~~1951~~	9.99	3.00	11.02	2.00	0.78	146.27	6.62	0.54
1952	7.60	3.06	12.12	2.00	-2.14	140.25	7.83	0.77
1953	6.97	3.05	11.73	2.00	-1.93	151.95	7.09	2.46
1954	7.86	3.06	11.66	1.50	-3.64	161.92	6.70	1.18
1955	6.48	3.06	11.64	1.50	0.03	186.71	5.93	-0.33
1956	7.64	3.06	11.15	1.50	1.47	207.97	4.79	-0.51
1957	5.20	3.05	11.53	4.50	3.66	227.88	4.57	-2.99
1958	3.89	3.07	11.66	4.50	1.91	284.76	2.93	-0.88
1959	5.80	3.16	11.77	6.50	2.35	297.42	2.37	0.49
1960	0.86	3.14	11.64	5.00	5.44	294.37	2.40	0.23
1961	6.65	3.01	12.45	3.00	2.52	270.80	4.29	-1.61
1962	5.04	3.01	12.26	6.00	6.46	315.92	3.15	-2.57
1963	6.48	2.99	13.27	6.00	8.67	288.58	4.64	1.24
1964	2.93	2.90	13.94	6.00	4.46	315.92	4.76	-0.65
1965	4.60	2.91	14.32	6.00	4.12	327.51	4.78	0.05
1966	4.16	3.01	13.51	4.75	5.50	343.90	3.15	1.77
1967	4.76	3.01	12.55	6.00	6.49	309.58	3.24	-2.03
1968	5.33	3.01	12.40	7.50	5.02	328.29	2.52	-3.54
1969	5.09	2.97	11.88	10.00	4.56	311.70	2.60	-3.81
1970	3.14	2.95	11.68	10.00	14.32	303.61	2.72	-0.39
1971	5.20	2.93	11.86	10.00	12.32	233.71	5.03	-0.87
1972	4.60	2.92	12.82	10.00	6.70	245.01	5.67	-0.90
1973	10.91	2.67	13.04	10.00	18.11	272.24	5.75	-0.21
1974	6.06	2.75	14.08	6.00	31.00	289.65	6.11	-3.43
1975	4.27	2.72	15.22	6.00	8.32	304.45	6.95	-7.55
1976	7.75	2.68	15.90	6.00	9.18	374.65	5.86	-7.06
1977	6.42	2.64	16.53	6.00	7.39	382.39	6.42	-4.20
1978	5.83	2.80	17.07	4.00	9.22	383.92	6.30	-5.55
1979	6.94	2.68	17.05	11.00	15.23	455.00	4.88	-6.13
1980	5.13	2.64	16.12	4.54	15.59	548.44	1.67	-6.30
1981	2.51	2.60	15.08	6.69	10.96	676.98	-2.50	-6.06
1982	1.63	2.55	13.21	6.30	8.41	3287.63	-70.52	-7.70
1983	1.09	2.50	11.23	8.05	11.67	-1041.02	37.25*	-7.62
1984	-6.91	2.10	9.67	12.11	49.83	-610.80	22.48*	-0.14
1985	-5.42	- -	- -	11.50	17.72	- -	- -	3.42
1986	1.01	- -	- -	9.63	1.15	- -	- -	7.22

Notes:

Col. 1 Annual rate of increase in net real national income.

Col. 2 Annual rate of increase of population calculated from five year moving averages of population numbers.

Col. 3 Percentage of national income saved calculated from five year moving averages of total net savings and the five year moving averages of national income.

Col. 4 Nominal rate of interest.

Col. 5 Rate of increase of GDP deflator.

Col. 6 Net annual investment/annual increment of real national income, both in five year moving averages.

Col. 7 Column 3 minus Column 2 multiplied by Column 6 divided by 100.

Col. 8 Exports surplus (capital outflow; if negative, then capital inflow) as percentage of national income.

*These positive figures have no meaning as they are obtained from negative investment/output increment ratios. (See above, p.13, second paragraph).

Table 10 Statistics Releated to Economic Takeoff-Brazil

(in percentage)

	1	2	3	4	5	6	7	8
	ΔY/Y	ΔL/L	S/Y	Interest Rate	ΔP/P	I/ΔY	(S/Y)-(I/ΔY)(ΔL/L)	(X-M)/Y
1951	- -	2.74	- -	- -	- -	- -	- -	- -
1952	- -	2.86	- -	- -	- -	- -	- -	- -
1953	- -	2.99	- -	- -	- -	- -	- -	- -
1954	- -	2.99	- -	- -	- -	- -	- -	- -
1955	- -	2.99	- -	- -	- -	- -	- -	- -
1956	- -	2.99	- -	- -	- -	- -	- -	- -
1957	- -	2.99	- -	- -	- -	- -	- -	- -
1958	- -	2.99	- -	- -	- -	- -	- -	- -
1959	- -	3.03	- -	- -	- -	- -	- -	- -
1960	- -	3.05	- -	- -	- -	- -	- -	- -
1961	- -	3.09	- -	- -	- -	- -	- -	- -
1962	- -	3.06	- -	- -	- -	- -	- -	- -
1963	- -	3.04	17.04	- -	- -	- -	- -	- -
1964	6.43	2.87	17.93	- -	87.91	- -	- -	- -
1965	44.18	2.81	17.48	- -	32.42	- -	- -	2.38
1966	1.61	2.74	18.14	- -	40.60	158.46	13.79	- -
1967	5.87	2.73	18.78	- -	27.52	167.75	14.21	- -
1968	10.92	2.70	18.88	- -	27.99	336.36	9.81	-0.87
1969	9.99	2.79	19.16	- -	20.96	261.75	11.85	- -
1970	1.99	2.80	19.92	- -	17.92	248.61	12.97	-0.54
1971	12.23	2.66	21.26	18.00	18.64	246.50	14.72	-1.63
1972	10.98	2.59	21.15	15.90	19.17	263.13	14.33	-1.85
1973	13.62	2.55	20.61	13.80	23.32	269.11	13.76	-1.32
1974	9.66	2.47	19.70	15.80	33.57	272.60	12.96	-6.32
1975	4.17	2.41	19.09	18.30	36.27	301.07	11.84	-4.24
1976	9.11	2.48	18.02	30.20	47.37	312.47	10.27	-2.57
1977	4.66	2.48	17.12	32.20	46.21	301.94	9.64	-0.73
1978	8.41	2.97	16.55	34.50	38.90	261.36	8.80	-1.23
1979	7.38	2.90	16.77	32.60	55.61	427.91	4.35	-2.14
1980	8.20	4.84	15.32	35.40	91.72	665.02	-3.58	-2.30
1981	-4.91	2.78	- -	88.70	102.50	- -	- -	-0.40
1982	-4.23	2.73	- -	110.00	92.87	- -	- -	-0.78
1983	- -	2.25	- -	168.60	151.86	- -	- -	- -
1984	- -	2.23	- -	- -	210.54	- -	- -	- -
1985	- -	- -	- -	- -	234.77	- -	- -	- -
1986	- -	- -	- -	- -	142.40	- -	- -	- -

Notes:

Col. 1 Annual rate of increase in net real national income.

Col. 2 Annual rate of increase of population calculated from five year moving averages of population numbers.

Col. 3 Percentage of national income saved calculated from five year moving averages of total net savings and the five year moving averages of national income.

Col. 4 Nominal rate of interest.

Col. 5 Rate of increase of GDP deflator.

Col. 6 Net annual investment/annual increment of real national income, both in five year moving averages.

Col. 7 Column 3 minus Column 2 multiplied by Column 6 divided by 100.

Col. 8 Exports surplus (capital outflow; if negative, then capital inflow) as percentage of national income.

Table 11 Statistics Releated to Economic Takeoff-Columbia (in percentage)

	1	2	3	4	5	6	7	8
	ΔY/Y	ΔL/L	S/Y	Interest Rate	ΔP/P	I/ΔY	(S/Y)-(I/ΔY) (ΔL/L)	(X-M)/Y
1951	- -	2.15	- -	- -	10.30	- -	- -	- -
1952	- -	2.16	- -	- -	1.53	- -	- -	- -
1953	- -	2.77	- -	- -	4.82	- -	- -	- -
1954	- -	3.36	- -	- -	11.22	- -	- -	- -
1955	- -	3.54	- -	- -	-0.06	- -	- -	- -
1956	- -	3.71	- -	- -	7.78	- -	- -	- -
1957	- -	3.86	- -	- -	17.23	- -	- -	- -
1958	- -	3.50	- -	- -	13.33	- -	- -	- -
1959	- -	3.20	- -	- -	6.66	- -	- -	- -
1960	- -	3.20	- -	- -	8.48	- -	- -	- -
1961	-0.98	3.19	- -	- -	8.21	- -	- -	-2.00
1962	6.05	3.19	7.86	- -	6.66	- -	- -	-0.90
1963	8.80	3.19	7.99	- -	23.20	181.37	2.20	-1.29
1964	8.26	3.02	8.91	- -	16.35	175.77	3.60	-1.62
1965	3.35	2.91	10.24	- -	9.17	206.99	4.22	1.13
1966	4.74	2.80	11.10	- -	14.92	242.86	4.29	-3.30
1967	4.09	2.71	11.73	- -	8.51	268.37	4.47	0.58
1968	5.89	2.62	13.53	- -	9.38	193.01	8.46	-1.46
1969	6.31	2.69	12.36	- -	8.20	257.96	5.42	-1.29
1970	19.01	2.71	13.98	- -	9.49	185.00	8.97	-1.31
1971	-4.62	2.80	15.74	- -	10.81	196.07	10.24	-4.62
1972	19.94	2.84	17.26	- -	12.97	218.86	11.05	0.46
1973	6.85	2.86	17.32	- -	20.16	316.50	8.25	2.31
1974	6.45	2.90	19.84	- -	25.38	271.46	11.96	-1.11
1975	1.88	2.23	20.61	- -	22.81	399.46	11.72	1.84
1976	4.68	2.19	20.69	- -	25.46	364.50	12.72	3.22
1977	4.85	2.00	20.57	- -	29.15	358.86	13.40	3.72
1978	8.62	1.84	20.63	- -	17.10	343.16	14.33	2.86
1979	5.76	1.68	19.74	- -	24.04	399.32	13.02	1.79
1980	4.28	2.16	18.51	- -	27.61	510.58	7.48	0.63
1981	1.85	2.00	17.83	31.30	22.77	798.12	1.88	-3.61
1982	0.03	2.03	17.43	29.50	24.77	1123.03	-5.34	-4.37
1983	1.10	2.02	- -	28.00	20.40	- -	- -	-2.85
1984	1.77	2.01	- -	28.70	22.18	- -	- -	-0.60
1985	- -	- -	- -	29.10	23.16	- -	- -	- -
1986	- -	- -	- -	- -	25.30	- -	- -	- -

Notes:

Col. 1 Annual rate of increase in net real national income.
Col. 2 Annual rate of increase of population calculated from five year moving averages of population numbers.
Col. 3 Percentage of national income saved calculated from five year moving averages of total net savings and the five year moving averages of national income.
Col. 4 Nominal rate of interest.
Col. 5 Rate of increase of GDP deflator.
Col. 6 Net annual investment/annual increment of real national income, both in five year moving averages.
Col. 7 Column 3 minus Column 2 multiplied by Column 6 divided by 100.
Col. 8 Exports surplus (capital outflow; if negative, then capital inflow) as percentage of national income.

Table 12 Statistics Releated to Economic Takeoff-Mexico (in percentage)

	1	2	3	4	5	6	7	8
	ΔY/Y	ΔL/L	S/Y	Interest Rat	ΔP/P	I/ΔY	(S/Y)-(I/ΔY) (ΔL/L)	(X-M)/Y
1951	- -	3.24	- -	- -	19.75	- -	- -	- -
1952	- -	3.32	- -	- -	7.57	- -	- -	- -
1953	- -	3.07	- -	- -	-1.00	- -	- -	- -
1954	- -	3.14	- -	- -	11.50	- -	- -	- -
1955	- -	3.21	- -	- -	12.54	- -	- -	- -
1956	- -	3.27	- -	- -	6.78	- -	- -	- -
1957	- -	3.32	- -	- -	6.77	- -	- -	-2.33
1958	5.29	3.36	- -	- -	5.66	- -	- -	-1.66
1959	2.95	3.38	5.60	- -	3.99	- -	- -	-0.33
1960	8.54	3.40	5.94	- -	4.71	134.93	1.35	-1.50
1961	4.53	3.42	8.10	- -	1.31	134.12	3.51	-0.61
1962	4.77	3.42	10.54	- -	3.65	136.04	5.88	0.25
1963	13.02	3.44	11.42	- -	0.33	161.46	5.86	-0.71
1964	13.63	3.44	12.08	- -	1.74	175.29	6.05	-1.62
1965	4.25	3.45	12.90	- -	6.91	179.70	6.69	-0.26
1966	4.18	3.46	12.95	- -	4.95	195.58	6.18	0.04
1967	7.60	3.47	12.85	- -	1.89	228.23	4.92	-0.71
1968	8.97	3.50	13.90	- -	2.39	227.07	5.96	-1.66
1969	6.23	3.51	14.57	- -	3.98	245.90	5.93	-0.89
1970	8.07	3.51	15.09	- -	10.84	246.12	6.45	-2.05
1971	4.24	3.51	15.58	- -	5.88	252.25	6.74	-1.16
1972	8.43	3.50	16.05	- -	6.22	269.41	6.62	-0.82
1973	8.41	3.48	16.10	- -	12.86	295.83	5.80	-1.13
1974	5.80	3.39	16.41	- -	22.71	314.27	5.76	-2.33
1975	5.33	3.28	17.09	- -	15.78	385.47	4.44	-2.94
1976	3.60	3.16	17.60	- -	19.57	383.69	5.46	-1.49
1977	2.98	3.03	18.38	11.00	30.40	351.45	7.72	0.11
1978	8.27	2.90	19.88	12.00	16.75	336.68	10.13	-0.62
1979	8.84	2.82	21.35	16.75	20.23	332.76	10.95	-1.38
1980	8.40	2.76	22.48	26.15	28.70	414.86	11.04	-1.03
1981	7.09	2.69	24.19	29.57	27.25	827.57	1.96	-1.81
1982	-2.76	2.60	25.43	52.54	61.19	1140.94	-4.25	6.95
1983	-6.18	2.50	- -	54.70	92.15	- -	- -	11.41
1984	3.85	2.22	- -	48.36	61.78	- -	- -	9.17
1985	- -	- -	- -	59.48	54.42	- -	- -	- -
1986	- -	- -	- -	84.68	- -	- -	- - -	- -

Notes:

Col. 1 Annual rate of increase in net real national income.

Col. 2 Annual rate of increase of population calculated from five year moving averages of population numbers.

Col. 3 Percentage of national income saved calculated from five year moving averages of total net savings and the five year moving averages of national income.

Col. 4 Nominal rate of interest.

Col. 5 Rate of increase of GDP deflator.

Col. 6 Net annual investment/annual increment of real national income, both in five year moving averages.

Col. 7 Column 3 minus Column 2 multiplied by Column 6 divided by 100.

Col. 8 Exports surplus (capital outflow; if negative, then capital inflow) as percentage of national income.

Table 13 Statistics Releated to Economic Takeoff-Peru (in percentage)

	1	2	3	4	5	6	7	8
	ΔY/Y	ΔL/L	S/Y	Interest Rate	ΔP/P	I/ΔY	(S/Y)-(I/ΔY) (ΔL/L)	(X-M)/Y
1951	- -	34.61	- -	- -	- -	- -	- -	1.06
1952	- -	20.23	- -	- -	- -	- -	- -	-2.99
1953	- -	1.98	- -	- -	- -	- -	- -	-4.61
1954	- -	2.08	- -	- -	- -	- -	- -	- -
1955	- -	2.23	- -	- -	- -	- -	- -	-3.64
1956	- -	2.38	- -	- -	- -	- -	- -	-4.87
1957	- -	2.55	- -	- -	- -	- -	- -	-7.42
1958	- -	2.66	- -	- -	- -	- -	- -	-6.13
1959	- -	2.78	- -	- -	- -	- -	- -	-0.23
1960	- -	2.87	- -	9.50	- -	- -	- -	0.20
1961	9.15	2.95	- -	9.50	- -	- -	- -	1.19
1962	10.54	3.00	17.02	9.50	5.65	- -	- -	0.59
1963	3.77	3.06	15.89	9.50	4.18	- -	- -	-3.46
1964	8.25	3.08	14.91	9.50	2.92	241.15	8.50	2.23
1965	4.98	2.97	13.51	9.50	14.90	250.38	7.20	-1.50
1966	6.44	2.94	12.76	9.50	13.08	310.22	4.30	-1.66
1967	2.33	2.92	11.60	9.50	11.22	342.80	2.69	-3.00
1968	-0.80	2.92	11.42	9.50	10.81	354.61	1.24	1.73
1969	4.69	2.49	10.61	9.50	18.42	250.92	4.10	3.16
1970	8.87	2.52	10.06	9.50	8.02	226.99	4.96	4.41
1971	5.42	2.52	10.29	9.50	7.32	168.34	5.82	0.90
1972	6.03	2.49	9.99	9.50	4.51	143.00	6.69	0.84
1973	7.19	2.44	8.74	9.50	5.30	156.44	6.10	-0.54
1974	7.79	2.76	8.36	9.50	14.77	225.01	3.25	-5.75
1975	2.32	2.76	7.90	9.50	16.59	272.38	0.85	-10.48
1976	2.49	2.72	8.53	12.50	20.10	393.59	-2.99	-6.07
1977	-1.22	2.70	11.61	14.50	34.45	1019.97	-19.18	-3.83
1978	-4.13	2.68	14.21	28.50	38.77	1626.77	-32.25	3.62
1979	4.58	2.65	15.43	29.50	61.39	919.11	-10.38	13.74
1980	5.00	2.66	16.98	29.50	78.31	937.55	-9.45	4.14
1981	2.85	2.66	16.81	44.50	54.91	879.91	-6.40	-4.82
1982	0.32	2.65	15.26	44.50	66.30	-4551.91	137.79*	-3.99
1983	-13.32	2.63	- -	60.00	65.01	-41468.31	1112.16*	0.27
1984	6.29	2.63	- -	60.00	110.77	- -	- -	4.93
1985	- -	- -	- -	- -	117.19	- -	- -	- -
1986	- -	- -	- -	- -	159.72	- -	- -	- -

Notes:

Col. 1 Annual rate of increase in net real national income.

Col. 2 Annual rate of increase of population calculated from five year moving averages of population numbers.

Col. 3 Percentage of national income saved calculated from five year moving averages of total net savings and the five year moving averages of national income.

Col. 4 Nominal rate of interest.

Col. 5 Rate of increase of GDP deflator.

Col. 6 Net annual investment/annual increment of real national income, both in five year moving averages.

Col. 7 Column 3 minus Column 2 multiplied by Column 6 divided by 100.

Col. 8 Exports surplus (capital outflow; if negative, then capital inflow) as percentage of national income.

* These positive figures have no meaning as they are obtained from negative investment/output increment ratios. (See above, p.13, second paragraph).

Table 14 Statistics Releated to Economic Takeoff-Venezuela

(in percentage)

	1	2	3	4	5	6	7	8
	ΔY/Y	ΔL/L	S/Y	Interest Rate	ΔP/P	I/ΔY	(S/Y)-(I/ΔY) (ΔL/L)	(X-M)/Y
1951	11.25	3.71	34.95	2.00	-1.51	- -	- -	12.86
1952	6.79	3.93	35.71	2.00	0.15	- -	- -	10.27
1953	6.38	4.19	36.22	2.00	-0.22	322.55	22.72	9.43
1954	10.53	4.13	36.04	2.00	0.87	338.15	22.09	10.39
1955	7.43	4.03	34.64	2.00	0.33	385.33	19.11	13.08
1956	8.38	3.97	32.65	2.00	3.12	356.66	18.48	11.88
1957	1.35	3.92	30.21	2.00	12.89	331.43	17.23	8.93
1958	7.59	3.83	28.21	2.00	1.75	345.33	14.98	5.31
1959	9.37	3.75	27.02	4.50	-3.76	337.64	14.37	6.91
1960	2.28	3.64	26.78	4.50	-3.42	228.31	18.47	14.75
1961	4.37	3.51	27.83	4.50	0.25	188.09	21.22	18.17
1962	8.02	3.44	28.67	4.50	0.19	173.43	22.70	19.62
1963	8.17	3.46	28.87	4.50	1.94	176.82	22.76	20.94
1964	10.09	3.49	28.22	4.50	0.98	202.24	21.17	14.68
1965	5.98	3.44	27.28	4.50	0.33	236.52	19.14	11.69
1966	2.75	3.44	27.46	4.50	1.69	307.18	16.88	11.59
1967	4.26	3.42	27.41	4.50	1.44	392.68	13.99	11.48
1968	5.02	3.37	27.87	4.50	3.03	334.17	16.61	8.73
1969	4.85	3.28	29.14	5.50	-1.21	395.16	16.18	8.20
1970	12.41	3.28	29.90	5.00	3.61	418.73	16.19	5.28
1971	1.86	3.23	30.93	5.00	6.55	407.78	17.76	7.30
1972	5.82	3.19	34.83	5.00	4.26	337.04	24.09	3.78
1973	6.51	4.37	35.78	5.00	12.10	370.89	19.59	10.93
1974	10.71	4.39	35.46	5.00	44.46	335.30	20.73	26.91
1975	8.58	4.44	34.95	7.00	-0.80	379.74	18.08	8.50
1976	8.67	4.48	32.58	7.00	5.17	494.98	10.41	1.48
1977	5.78	4.49	29.39	7.00	8.00	678.50	-1.06	-8.30
1978	1.30	3.46	28.19	7.50	6.30	992.57	-6.11	-14.22
1979	1.58	3.35	26.59	11.00	21.26	1874.91	-36.30	2.08
1980	-0.62	3.23	24.24	13.00	24.85	-10724.50	370.85*	8.77
1981	-0.22	3.09	22.78	14.00	12.54	-877.30	49.90*	6.21
1982	-3.11	2.97	21.40	13.00	1.44	-601.78	39.29*	-3.38
1983	-7.66	2.89	19.47	- -	5.66	-457.84	32.69*	12.30
1984	0.11	2.82	17.18	15.87	21.61	-635.62	35.09*	12.55
1985	-1.59	- -	- -	12.94	6.47	- -	- -	11.16
1986	4.44	- -	- -	12.79	3.23	- -	- -	-1.09

Notes:

Col. 1 Annual rate of increase in net real national income.
Col. 2 Annual rate of increase of population calculated from five year moving averages of population numbers.
Col. 3 Percentage of national income saved calculated from five year moving averages of total net savings and the five year moving averages of national income.
Col. 4 Nominal rate of interest.
Col. 5 Rate of increase of GDP deflator.
Col. 6 Net annual investment/annual increment of real national income, both in five year moving averages.
Col. 7 Column 3 minus Column 2 multiplied by Column 6 divided by 100.
Col. 8 Exports surplus (capital outflow; if negative, then capital inflow) as percentage of national income.

* These positive figures have no meaning as they are obtained from negative investment/output increment ratios. (See above, p.13, second paragraph).

Table 15 Statistics Releated to Economic Takeoff-Tanzania (in percentage)

	1	2	3	4	5	6	7	8
	ΔY/Y	ΔL/L	S/Y	Interest Rate	ΔP/P	I/ΔY	(S/Y)-(I/ΔY) (ΔL/L)	(X-M)/Y
1951	- -	- -	- -	- -	- -	- -	- -	- -
1952	- -	- -	- -	- -	- -	- -	- -	- -
1953	- -	2.08	- -	- -	- -	- -	- -	- -
1954	- -	2.06	- -	- -	- -	- -	- -	- -
1955	- -	2.08	- -	- -	- -	- -	- -	- -
1956	- -	2.15	- -	- -	- -	- -	- -	- -
1957	- -	2.25	- -	- -	- -	- -	- -	- -
1958	- -	2.33	- -	- -	- -	- -	- -	- -
1959	- -	2.40	- -	- -	- -	- -	- -	- -
1960	- -	2.48	- -	- -	- -	- -	- -	- -
1961	- -	2.48	- -	- -	- -	- -	- -	- -
1962	- -	2.47	- -	- -	- -	- -	- -	- -
1963	- -	2.47	- -	- -	- -	- -	- -	- -
1964	- -	2.48	- -	- -	- -	- -	- -	- -
1965	- -	2.47	- -	- -	- -	- -	- -	- -
1966	13.21	2.53	- -	- -	- -	- -	- -	4.95
1967	3.20	2.57	10.89	- -	1.65	- -	- -	0.97
1968	5.99	2.61	12.25	- -	0.23	- -	- -	1.66
1969	1.87	2.65	12.09	- -	1.95	242.50	5.93	0.31
1970	6.12	2.69	11.79	- -	3.15	383.99	1.91	-2.65
1971	3.87	2.68	11.29	- -	4.83	342.70	2.57	0.32
1972	7.04	2.68	9.66	- -	2.69	425.09	-0.10	-4.71
1973	1.75	2.91	7.73	- -	6.66	416.15	-1.50	-9.42
1974	4.26	3.86	9.24	4.00	13.81	405.74	-4.09	-5.54
1975	6.13	3.90	11.36	4.00	19.09	206.81	1.27	-7.40
1976	25.25	3.95	10.80	4.00	12.46	253.42	1.48	-14.35
1977	3.04	3.98	11.79	4.00	7.88	275.81	-0.09	-13.42
1978	3.05	3.89	11.89	4.00	11.81	327.84	-1.26	-2.23
1979	1.20	3.16	10.76	4.00	8.27	399.29	-3.64	-3.36
1980	0.69	3.17	9.04	6.25	10.63	1533.21	-37.69	-15.54
1981	-0.64	3.20	9.51	6.25	17.60	1761.31	-46.87	-13.19
1982	1.71	3.21	7.98	6.25	19.03	3519.85	-102.96	-13.35
1983	-0.20	3.18	7.17	6.25	17.50	2040.83	-57.55	-8.48
1984	2.62	3.22	6.22	4.00	9.52	2256.38	-64.62	-7.35
1985	-0.04	- -	- -	4.50	11.90	- -	- -	-5.69
1986	- -	- -	- -	8.50	43.19	- -	- -	-9.80
					- -	- -	- -	-9.50
								- -

Notes:

Col. 1 Annual rate of increase in net real national income.

Col. 2 Annual rate of increase of population calculated from five year moving averages of population numbers.

Col. 3 Percentage of national income saved calculated from five year moving averages of total net savings and the five year moving averages of national income.

Col. 4 Nominal rate of interest.

Col. 5 Rate of increase of GDP deflator.

Col. 6 Net annual investment/annual increment of real national income, both in five year moving averages.

Col. 7 Column 3 minus Column 2 multiplied by Column 6 divided by 100.

Col. 8 Exports surplus (capital outflow; if negative, then capital inflow) as percentage of national income.

Table 16 Statistics Releated to Economic Takeoff-Morocco

(in percentage)

	1	2	3	4	5	6	7	8
	ΔY/Y	ΔL/L	S/Y	Interest Rate	ΔP/P	I/ΔY	(S/Y)-(I/ΔY) (ΔL/L)	(X-M)/Y
1951	- -	2.03	- -	- -	- -	- -	- -	- -
1952	- -	2.25	- -	- -	- -	- -	- -	- -
1953	- -	2.48	- -	- -	- -	- -	- -	- -
1954	- -	2.69	- -	- -	- -	- -	- -	- -
1955	- -	2.74	- -	- -	- -	- -	- -	- -
1956	- -	2.81	- -	- -	- -	- -	- -	- -
1957	- -	2.90	- -	- -	- -	- -	- -	- -
1958	- -	2.86	- -	- -	0.39	- -	- -	-1.73
1959	-3.74	3.85	- -	- -	4.14	- -	- -	1.35
1960	2.11	2.75	5.19	- -	5.88	- -	- -	1.02
1961	1.71	2.59	5.39	- -	-2.46	255.91	-1.25	-3.56
1962	16.51	2.31	6.48	- -	1.28	219.38	1.41	-3.60
1963	-2.17	2.26	7.24	- -	15.23	236.75	1.89	-1.72
1964	1.11	2.24	8.44	- -	4.19	320.02	1.27	2.05
1965	1.67	2.27	9.59	- -	3.43	787.81	-8.30	2.96
1966	-1.93	2.60	11.19	- -	-1.05	256.13	4.52	1.20
1967	7.13	3.09	11.03	- -	-0.52	344.22	0.39	-0.98
1968	12.28	3.31	10.91	- -	0.12	321.11	0.27	- -
1969	-2.71	2.82	11.22	- -	21.15	249.18	4.20	-0.45
1970	4.74	2.73	11.23	- -	2.85	286.35	3.43	-3.22
1971	6.25	2.80	10.39	- -	3.99	386.87	-0.44	-2.19
1972	3.01	2.58	12.29	- -	3.89	208.86	6.90	0.04
1973	4.04	3.52	12.36	- -	5.84	246.08	6.17	-0.36
1974	14.98	3.01	11.66	- -	17.96	258.87	3.88	0.57
1975	3.94	3.17	11.76	- -	4.02	338.47	1.04	-9.66
1976	10.39	3.00	11.33	- -	5.30	388.31	-0.33	-17.55
1977	2.14	2.99	9.63	- -	13.95	540.67	-6.56	-19.04
1978	2.79	2.98	8.72	4.50	7.21	581.51	-8.62	-12.56
1979	4.28	2.98	7.40	4.50	7.62	1362.99	-33.22	-11.86
1980	1.74	2.05	6.04	4.90	9.32	763.85	-9.64	-10.55
1981	-2.80	1.98	5.21	6.00	10.83	720.76	-9.07	-14.52
1982	6.79	1.91	- -	6.40	9.93	26.50	-21.93	-13.97
1983	2.38	1.83	- -	6.50	2.66	- -	- -	-8.87
1984	- -	1.74	- -	6.50	8.40	- -	- -	- -
1985	- -	- -	- -	8.00	9.27	- -	- -	- -
1986	- -	- -	- -	8.50	- -	- -	- -	- -

Notes:

Col. 1 Annual rate of increase in net real national income.

Col. 2 Annual rate of increase of population calculated from five year moving averages of population numbers.

Col. 3 Percentage of national income saved calculated from five year moving averages of total net savings and the five year moving averages of national income.

Col. 4 Nominal rate of interest.

Col. 5 Rate of increase of GDP deflator.

Col. 6 Net annual investment/annual increment of real national income, both in five year moving averages.

Col. 7 Column 3 minus Column 2 multiplied by Column 6 divided by 100.

Col. 8 Exports surplus (capital outflow; if negative, then capital inflow) as percentage of national income.

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COMMENT ON S. C. TSIANG'S

"SUCCESS OR FAILURE IN ECONOMIC TAKEOFF"

by Gregory C. Chow

This paper asks an interesting and important question, why some countries have succeeded and others have failed in achieving economic growth. It is broad in scope, covering theory, empirical analysis and policy recommendations. It attemps to give an integrated answer to the question raised. In this conference, some have proposed theoretical contributions to explain economic growth which are not ready for empirical implementation, while others have proposed more readily testable theories, but have not performed the empirical analysis. By comparison, S. C. Tsiang's paper is more integrated, drawing on the author's theory of economic growth to study the empirical evidence from fourteen countries. If one is critical of certain aspects of this paper, one should keep in mind the ambitious task that it is assigned to do. As a word on motivation, our chair Arnold Harberger has pointed out that S. C. Tsiang, together with the late T. C. Liu, has played an important role in Taiwan's successful economic development by advocating a set of policies described in this paper. It is natural for S. C. to ask whether Taiwan's successful experience can be repeated in other developing countries. This question probably has motivated this paper.

As it is well known, S. C. Tsiang's model published in Econometrica, 1964, explains an underdevelopment trap by introducing three modifications to Solow's neoclassical model of economic growth. First, besides capital and labor, land is introduced as a third factor of production which is fixed in supply. Second, the rate of population growth is assumed to depend on per capita real income, first as an increasing function and then a decreasing

function. Third, per capita saving is assumed to depend on per capita income, the marginal productivity of capital (which is equated to the real rate of interest), and the income share of the capitalists and landowners. The model consists of three equations, (1) a Cobb-Douglas production function with three factors, (2) a function explaining the rate of population growth by per capita real income, and (3) a savings function as described. It explains the rates of growth of output, labor (assumed to be proportional to population) and the capital stock. To generate an underdevelopment trap, only the second modification to Solow's basic model is needed. When real income increases, if population increases faster, per capita income will be prevented from increasing through the Malthusian mechanism.

In this conference, other significant modifications to Solow's model of economic growth have been presented. Some are directed toward explaining the sustained growth in a developed economy, by abandoning the assumption of diminishing returns to physical or human capital, or by endogenizing the rate of technological change. Others are directed toward explaining both an underdevelopment equilibrium and a sustained economic growth by endogenizing the rate of population growth and the formation of human capital. In studying the important question posed by S. C. Tsiang, one should ask to what extent these alternative theories are useful in explaining the successful or unsuccessful development experiences of a variety of countries.

Guided by his theoretical framework, S. C. examines three important statistics in his empirical analysis and considers the policies of each country which may have affected these statistics. The statistics are: (1) the savings-income ratio S/Y, (2) the ratio of income change to investment $\Delta Y/I$, and (3) the rate of population growht $\ell = \Delta L/L$. These statistics are

displayed in the table for each of the fourteen countries studied. They are contained in the key condition for economic growth

$$(13'') \qquad \frac{S}{Y} - \left[\frac{I}{\Delta Y}\right]\left[\frac{\Delta L}{L}\right] > 0$$

and the left-hand side of (13") is shown in column (7) of each table. The statistics correspond to the three equations in Tsiang's model. To appreciate the importance of condition (13"), one notes that it is equivalent to the condition

$$(13^*) \qquad \frac{\Delta Y}{Y} - \frac{\Delta L}{L} > 0$$

or the condition for the growth of per capita real income, since (13") results from multiplying (13*) by $(S/\Delta Y)$ and using the condition $S = I$ assumed in the model.

In view of the equivalence of (13") and (13*), I am puzzled by the lack of consistency of the data presented in the statistical tables for the countries examined. For many countries, we find the difference of columns (1) and (2), $(\Delta Y/Y) - (\Delta L/L)$, to be positive and column (7) to be negative. This can be due to the condition $S = I$ failing to hold with I much larger than S so that column (7) is negative while the product of $(S/\Delta Y)$ and the left-hand side of (13*) is positive. To illustrate, for the year 1956, Table 3 on Taiwan shows that the product of column (1) and column (6), or $\Delta Y/Y$ and $I/\Delta Y$, is $.0449 \times 2.24 = .1006$ which should equal I/Y. Yet the ratio S/Y in column (3) is .0483, only half as large. If saving and investment are not equal, the theory has to be modified, or the data have to be made consistent with the theoretical framework. The use of five-year moving averages in computing $\Delta L/L$, S/Y and $I/\Delta Y$ also requires some discussion, including whether it could lead to an inconsistency between (13") and (13*).

Can the model be used more explicitly to explain the data rather than merely suggesting three important variables to be examined? Would it be useful to estimate the three equations of the model for each country, or at least to insert some reasonable values for the parameters? By comparing the parameter values, one may be able to explain better the differences in growth rates of real income and of population among countries.

Concerning policy evaluation and recommendations based on the three important statistics, we are told that a government should not abitrarily enforce a low rate of interest to encourage investment for this would discourage savings. By implication, neither should the government arbitrarily raise the rate of interest for it may discourage investment. Second, to maintain a high ratio of ΔY to I, or a low $I/\Delta Y$ ratio, the policy recommendation consists of limited or no import restrictions, the encouragement of exports and of import of foreign capital to promote technological change, and the avoidance of overvaluation of the domestic currency in world trade. Third, a policy to reduce the rate of population growth should be adopted. As in the case of statistical analysis, the approach to policy analysis is informal. The role of policies in influencing the three key variables in condition (13") is not explicitly modelled.

To illustrate the use of the suggested framework, let us review the data for Taiwan in Table 3. We have found the savings ratio S/Y increasing in the 1960's and 1970's, but a satisfactory explanation for this phenomenon is absent. The real rate of interest, or the nominal rate of interest of column (4) minus the inflation rate of column (5), was actually declining from the 1950's to the 1960's and 1970's while the savings ratio S/Y was increasing. Could this be due to the effect of the interest rate on investment? With only one equation for savings and investment, how does one identify the

separate effects of the rate of interest? In Taiwan, the ratio I/ΔY increased somewhat from 1965 on, but not sufficiently to prevent real income from growing rapidly. To what extent can the slow increase in I/ΔY be attributed to the policies of export expansion and encouragement of foreign investment? As the third factor, the population growth rate declined steadily in Taiwan. To what extent and in what manner can government policy be said to have contributed to this decline?

Reviewing the stories for the fourteen countries examined, one often finds it difficult to connect government policies and the observed changes in the three important statistics. In South Korea, for example, the real rate of interest as measured by the difference between the nominal rate and the inflation rate was negative from 1972 to 1980, according to Table 4, and yet the savings ratio raised rapidly during this period. In the case of Hong Kong, with data shown in Table 5, it is hard to explain the rapid increase in S/Y from 1964 on when there was no apparent change in government policy. There was also no discernable change in government policy towards the encouragement of exports and the relaxation of import controls to influence the ratio I/ΔY. The rate of population growth remained high for most years up to 1981 because of migration from Mainland China, but the high growth rate did not prevent real income per capita from growing rapidly. In the case of Hong Kong and Taiwan, the influx of talented people from Mainland China probably contributed significantly to the successful economic development rather than serving as a drag by raising the rate of population growth. The case of Hong Kong can be used to support the thesis that a laissez-faire policy, with government providing the required infrastructure and law and order, is sufficient to promote rapid economic development, a thesis which

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cannot be contradicted without a very careful examination of the statistical evidence available.

It may be of interest to examine the three important statistics for the People's Republic of China. According to official data provided by the Statistical Yearbook of China, 1986 (p. 41), real national income increased from 1979 to 1985 by an annual rate of about 9.2 percent. With a rate of savings (or accumulation) to income of about 31 percent (p. 49), the relationship $(S/Y) = (\Delta Y/Y).(I/\Delta Y)$ implies a ratio $I/\Delta Y$ of about 3.37, or a ratio $\Delta Y/I$ of .297. As population growth was kept to about 1.2 percent per year (p. 72), real income growth per capita was about 8 percent per year. These data could be interpreted to mean than in the People's Republic of China, the savings ratio $(S/Y) = .31$ is high enough and the associated ratio $(\Delta Y/I) = .297$ is not too small to yield a product of .092 for the rate of real income growth. Is one to conclude that the policies of enforcing a high savings rate, of expanding foreign trade and technology import to keep $\Delta Y/I$ from falling, and of controlling population growth have succeeded in achieving a takeoff to economic growth?

To summarize, this paper is ambitious. It attempts to deal with an important question in an integrated fashion. It has proposed a theoretical framework. It calls our attention to the important statistics to examine. S. C. Tsiang's accounting based on these statistics can serve as a basis for more explicit model building and policy evaluation. This paper has also provided warnings to possible policy mistakes and recommended specific policy options to promote economic growth. What more can be expected of a paper? Others have proposed different theories of economic growth. It is of interest to ask how other theories can be applied to answer the important question posed in this paper.

A Comment on "Success or Failure in Economic Take-off" by S.C. Tsiang

Professor S.C. Tsiang is not only a most distinguished theorist but also one of the leading architects of the outward-oriented policies in Taiwan that have led to such spectacular results. Anything he has to say on the subject of economic development must therefore be of great value to all with an interest in this field.

He takes as his point of departure Robert Solow's celebrated 1956 paper that introduced the neoclassical growth model to the economists' tool-kit (along with the contemporaneous contribution by Trevor Swan). After contrasting this model favorably with the previous Keynesian-inspired models of Harrod and Domar, Professor Tsiang points to what he considers to be various deficiencies in the Solow model, particularly in relation to the problem of "take-off" in less developed countries. He then examines the record of a number of developing countries, particularly in Asia, and attempts to account for success (as in the case of Taiwan, Hong Kong, South Korea and Singapore) and relative failure (as in the case of India and Communist China) in terms of the nature of the economic policies that the three countries have pursued. He makes elegant and effective use of the concept of a "low-level equilibrium trap", emphasizing the role of an opening-up to foreign trade as a particularly powerful source for breaking out of stagnation.

Unfortunately, I find the statements regarding the Harrod-Domar and Solow models and the relationship between them, in the early part of the paper, inaccurate and misleading. To begin with it is stated that Harrod and Domar regarded the growth of effective demand as the engine of growth. Neither Harrod nor Domar was ever so naive and foolish as to imagine that continuous growth could be obtainedmerely by pumping up effective demand. Both of them, particularly Domar, stressed that it was thorough the expansion of productive capacity by augmenting the capital stock that investment made its contribution to economic growth. It is true that they simultaneously were concerned about the growth of effective demand, to ensure that the expanding capacity would be utilized, since otherwise the motive to keep on investing would be impaired,

precipitating a recession. When Tsiang praises Solow's model as making it clear "...that it is the expansion of the productive capacity of its factors of production that constitutes the real growth of a country. It has thus contributed greatly towards weakening the baneful influences of the Keynesian type of growth policy which seeks to stimulate growth merely by expanding effective demand" he is completely off the mark, and unfair not only to Harrod and Domar but to Solow as well, whose contribution was more subtle than merely pointing out that growth depended upon an augmentation of productive capacity.

The Harrod-Domar model introduced the simple formula.

(1) $$g = s/c$$

where g is the growth rate of national income, $\underline{s}$ is the proportion of national income that is saved and invested and $\underline{c}$ is the incremental capital-output ratio or ICOR, the ratio of investment to the increase of output. Just as in the case of MV = PT this relation (1) can be viewed as an identity or as a prediction, if $\underline{s}$ and $\underline{c}$ are independently specified. Harrod and Domar regarded $\underline{s}$ and $\underline{c}$ as exogenously given parameters.

This formula (1) was adapted for use in the development planning exercises that were so popular in the sixties. The modification was simply to write.

(2) $$\tilde{g} = s/c - p$$

where $\tilde{g}$ is the rate of growth of per capita national income and $\underline{p}$ the rate of growth of population. The typical "development plan" would specify a value of $\tilde{g}$ as a target and then derive the value of $\underline{s}$ that would be implied for given values of $\underline{c}$ and $\underline{p}$. This value of $\underline{s}$ would then have to be attained by taxation, foreign aid or other measures. Thus given $\underline{c}$ and $\underline{p}$, $\tilde{g}$ depended upon $\underline{s}$.

The implicit production function of the Harrod-Domar model was

(3) $$Y = K/c$$

Solow replaced this relation, in which output is simply proportional to capital so that the marginal (equal to average) capital-output ratio is constant, with

(4) $$Y = F(K,L)$$

where output depends on both capital and labor, which are substitutable for each other continuously at the margin. With constant returns to scale (4) can be written in intensive form as $y = f(k)$ where y is output and k is capital per unit of labor. Solow retained the assumption of an exogenously given savings propensity s. A further key parameter that he introduced was the rate of labor-augmenting technical progress. The variable $L(t)$ in the model can then be interpreted as "effective" instead of actual labor, and its growth rate defined as n which is the actual growth rate of the labor force plus the exogenously give rate of labor-augmenting technical progress.

In the "steady state" we must have

(5) $$sf(k) = nk$$

and it is readily shown that the economy will converge to a value k^* and corresponding $y^* = f(k^*)$. Note that the capital-output ratio is not simply given, as in Harrod and Domar, but is endogenously determined in the long run as s/n, as can be seen from (5).

The message for development from the Harrod-Domar model is thus that the growth rate of per capita income can be permanently raised by raising the propensity to save, lowering the ICOR, and lowering the growth rate of population. The message of the Solow model is that it is only technical progress that can permanently raise per capita income since changes in the rate of saving or population growth will only cause off-setting adjustments in the steady-state capital-output ratio, as (5) implies. Solow thus shifted the emphasis

from capital accumulation per se to technical progress as the true "engine of growth" in the long run. It is this shift, and not the spurious shift from effective demand to productive capacity as claimed by Professor Tsiang, that is the real difference between the two approaches to the theory of growth. Subsequent research on the so-called "Golden Rule", combined with the early analysis of Ramsey, clarified the issue of "optimal" savings in the context of intertemporal utility maximization.

Professor Tsiang next criticizes Solow for three assumptions of the model which are (a) neglect of fixed natural resources such as land (b) making the growth of population independent of economic variables such as the level of wages or per capita income and (c) making the propensity to save independent of the level of per capita income or the rate of interest. Professor Tsiang modifies all three assumptions in the required direction and develops a neat model of the "low-level equilibrium trap". What I find surprising is his failure to have noticed that Solow made precisely these extensions himself in the very same 1956 paper (see in particular his Section VI and Figure IX). The work of Harvey Leibenstein and Richard Nelson should also be mentioned in this regard.

Professor Tsiang uses a criterion (13") of the savings rate required for take-off to be in excess of the product of the ICOR and the population growth rate. This is identical to the savings rate required for $\tilde{g}$ to be positive in our equation (2). He gives some interesting statistics for Taiwan and other East Asian economies, showing how there have been huge increases in the savings rate and growth rates, accompanied by sharp declines in population growth. He uses the criterion (13") to date the take-offs in the sense of the beginnings of sustained growth in per capita incomes. As Gregory Chow has shrewdly observed, the statistics on real interest rates appear to go in the opposite direction from that required to elicit a positive supply response of savings. While all these favorable developments on savings and growth were accompanied by liberalization of trade and capital markets, and by population control measures the micro foundations of the relationships between these

policy measures and the favorable growth outcomes are not explored in Professor Tsiang's paper. In particular the paper does not really come to grips with the difference between level effects and growth rate effects of such measures as increases in savings and trade liberalization. Everyone (at least those represented at this conference) would agree that such measures are beneficial but it is not apparent why growth rates continue to be so high in the East Asian countries in response to measures that in principle at least should have only "one time" effects. My explanation would be the diffusion of technical change from the United States and Japan through foreign investment and other channels but Professor Tsiang does not discuss these aspects explicitly.

His stress on the virtues of productivity, thrift and population control are, in my view, entirely well taken. As I have explained, however, this fits in exactly with the prescriptions of Harrod, Domar and most practitioners of development in the fifties. Solow's demonstration that increased thrift could not permanently raise the growth of per capita income was not intended by him to denigrate the general desirability of doing this in the interest of raising living standards.

What the experience of the NIC's in the sixties and seventies has shown is the continuing importance of foreign trade as an "engine of growth", just as Marshall and Robertson had always maintained. Under the influence of the Great Depression, and perhaps also of the Soviet experience, influential development economists such as Lewis, Nurkse, Rosenstein-Rodan and Mahalanobis turned inward in their thinking, stressing the role of "balanced growth" for the domestic market instead of relying on the advantages of international specialization. Professor Tsiang is entirely right in emphasizing the crucial role of international trade as the true "engine of growth" for the modern world economy.

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Government Spending in a Simple Model of Endogenous Growth*

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Recent models of economic growth can generate long-term growth without relying on exogenous changes in technology or population. Some of the models amount to theories of technological progress (Romer, 1986), and others to theories of population change (Becker and Barro, 1988). A general feature of these models is the presence of constant or increasing returns in the factors that can be accumulated (Romer, 1988, Lucas, 1988, Rebelo, 1987).

One strand of the literature on endogenous economic growth concerns models where private and social returns to investment diverge, so that decentralized choices lead to sub-optimal rates of saving and economic growth (Romer, 1986). In this setting private returns to scale may be diminishing, but social returns—which reflect spillovers of knowledge or other externalities—can be constant or increasing. Another line of research involves models without externalities, where the privately determined choices of saving and growth are Pareto optimal (Rebelo, 1987). These models rely on constant returns to private capital, broadly defined to encompass human and non-human capital.

The present analysis builds on both aspects of this literature by incorporating a public sector into a simple, constant-returns model of economic growth. Because of familiar externalities associated with public expenditures and taxes, the privately-determined values of saving and economic growth may be sub-optimal. Hence there are interesting choices about government policies, as well as empirical predictions about the relations among the size of government, the saving rate, and the rate of economic growth.

1. Growth Models with Optimizing Households

As a background I begin with a brief sketch of the standard optimal growth model, due to Ramsey (1928), Cass (1965), and Koopmans (1965). The representative, infinite-lived household seeks to maximize overall utility, as given by

$$U = \int_0^\infty u(c)e^{-\rho t}dt \tag{1}$$

where c is consumption and $\rho > 0$ is the constant rate of time preference. Population, which corresponds to the number of consumers, is constant. I use the iso-elastic utility function,

$$u(c) = [c^{1-\sigma}-1]/(1-\sigma) \tag{2}$$

where $\sigma > 0$.

Each household-producer has access to the production function,

$$y = f(k) \tag{3}$$

where y is output per worker and k is capital per worker. I interpret $y = f(k)$ as output net of depreciation. The production function satisfies the usual properties, including positive net marginal product of capital ($f' > 0$) over some range of k, diminishing marginal productivity ($f'' < 0$), and the limiting conditions, $f'(0) = \infty$ and $f'(\infty) \leq 0$. There is no technological progress, in the sense that the function $f(\cdot)$ is time

invariant. The economy is closed, and produced net output goes either for consumption or net investment. The number of workers equals the constant number of households, and each worker works one unit of time. That is, I abstract from the labor-leisure choice.

As is well known, the maximization of the representative household's overall utility in equation (1) implies that the growth rate of consumption at each point in time is given by

$$\dot{c}/c = (1/\sigma)\cdot(f'-\rho) \tag{4}$$

Since I omitted the two standard sources of exogenous growth—population change and technological progress—the model has steady-state levels of capital, k^*, and consumption, c^*. The value k^* is determined from equation (4) by the condition, $f'(k^*) = \rho$. Since net investment is zero in the steady state, steady-state consumption is $c^* = f(k^*)$.

A recent strand of endogenous growth models, represented by Rebelo (1987), departs from the standard framework by replacing diminishing returns, $f'' < 0$, with constant returns. In the present setting, which has a single type of capital good, the modified production function with constant returns to capital is

$$y = Ak \tag{5}$$

where $A > 0$ is the constant net marginal product of capital.[1]

[1]This formulation effectively reverses Solow's (1956) extension of the Harrod (1948)-Domar(1947) model to return to a setting with a fixed capital-output ratio. However, the formulation differs from Harrod-Domar in that saving

The assumption of constant returns becomes more plausible when capital is viewed broadly to encompass human and non-human capital. Human investments include education and training, as well as expenses for having and raising children (Becker and Barro, 1988). In effect, a family can invest in human capital by improving the quality of its existing members or by deciding to have more members. In any event, while the returns to broadly-defined capital may not be precisely constant, it is hard to see why economists usually interpret capital narrowly to exclude labor input. It seems that labor services depend as much as capital services on prior investment decisions.

Of course, human and non-human capital need not be perfect substitutes in production. Therefore production may show roughly constant returns to scale in the two types of capital taken together, but diminishing returns in either input separately. The "Ak" production function shown in equation (5) can be modified to distinguish between two types of capital, and the model can be extended, along the lines of Lucas (1988), Rebelo (1987), and Becker and Murphy (1988), to allow for sectors that produce physical and human capital, respectively. In comparison with the "Ak" model, the main additional results involve transitional dynamics whereby an economy moves from an arbitrary starting ratio of physical to human capital to a steady-state ratio. This transition is particularly important in analyzing how countries that start from different initial conditions—possibly due to major disturbances such as World War II—might converge to similar levels of economic performance.

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choices are privately optimal (as in the analyses of Ramsey (1928), Cass (1965), and Koopmans (1965)).

However, for studying steady-state growth, the important element is constant returns to scale in the factors that can be accumulated—that is, the two types of capital taken together—and not the distinction between the factors.[2] Since my primary interest in this paper concerns long-term growth, I decided to use the simplest constant-returns-to-scale production function, as given by the "Ak" form in equation (5).

The analysis does assume that fixed factors are not important enough to cause significant departures from constant returns. Even with the existence of land and other natural resources, the results can go through as long as reproducible capital is a good substitute for these fixed factors. Alternatively, it may be that fixed factors become binding eventually, but not until the variable factors reach very high levels. Then the present analysis may be a good approximation over a wide range of accumulation where the returns to scale in the variable factors are nearly constant.

The concept of capital can include knowledge, accumulated through expenditures on research and development, as long as this knowledge is private property. Knowledge that is non-excludable or non-rival brings in issues of sub-optimal economic growth that have been studied by Romer (1986). My study of government as an element in economic growth turns out to parallel Romer's analysis in some respects.

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[2] Jones and Manuelli (1988) show that similar results can obtain if the marginal product of capital is diminishing but has a positive lower bound. In effect, diminishing returns can apply over a range of capital stocks, as long as roughly constant returns apply asymptotically.

The production function in equation (5) implies $f' = A$. Substituting into equation (4) then yields

$$\gamma = \dot{c}/c = (1/\sigma)\cdot(A-\rho) \tag{6}$$

where I use the symbol γ to denote a growth rate. I assume that the technology is sufficiently productive to ensure positive steady-state growth, but not so productive as to yield unbounded utility. The corresponding inequality conditions are

$$A > \rho > A(1-\sigma) \tag{7}$$

The first part implies $\gamma > 0$ in equation (6). The second part, which is satisfied automatically if $A > 0$, $\rho > 0$, and $\sigma \geq 1$, guarantees that the attainable utility is bounded.

In this model the economy is always at a position of steady-state growth where all variables—c, k, and y—grow at the rate γ shown in equation (6). Given an initial capital stock, k(0), the levels of all variables are also determined.[3] In particular, since net investment equals γk, the initial level of consumption is

$$c(0) = k(0)\cdot(A-\gamma) \tag{8}$$

[3]With a perfect capital market (and given constant returns to scale and no adjustment costs for investment), the scale of a competitive firm would be indeterminate in this model. However, the aggregates of capital stock and investment would be determined. In the model considered next, which allows for public services, the scale of an individual firm may also be determinate.

The model is a theory of endogenous growth in that changes in the underlying parameters of technology and preferences map into differences in growth rates. From equation (6) the growth rate, γ, is higher if the economy is more productive (higher A), and lower if people are less patient (higher ρ) or less willing to substitute intertemporally (higher σ).

2. The Public Sector

The contribution of the present paper is to modify the above analysis by incorporating a public sector. Let g be the quantity of public services provided to each household-producer. I assume that these services are provided without user charges, and are not subject to congestion effects (which might arise for highways or some other public services). That is, the model abstracts from externalities associated with the use of public services.

I consider initially the role of public services as an input to private production. It is this productive role that creates a potentially positive linkage between government and growth. I assume now that production exhibits constant returns to scale in k and g together, but diminishing returns in k separately. That is, even with a broad concept of private capital, production exhibits decreasing returns to private inputs if the (complementary) government inputs do not expand in a parallel manner. In a recent empirical study, Aschauer (1988) argues that the services from government infrastructure are particularly important in this context.

I assume the Cobb-Douglas form of production function,

$$y = f(k,g) = Ak^{1-\alpha}g^{\alpha} \tag{9}$$

where $0 < \alpha < 1$. In equation (9) k is the representative producer's quantity of capital, which would correspond to the per capita amount of aggregate capital. I assume that g can be measured correspondingly by the per capita quantity of government purchases of goods and services.

A number of questions can be raised concerning the specification of public services as an input to production. First, the flow of services need not correspond to government purchases, especially when the government owns capital and the national accounts omit an imputed rental income on public capital in the measure of current purchases. This issue is important for empirical implementation of the model. But conceptually, it is satisfactory to think of the government as doing no production and owning no capital. Then the government just buys a flow of output (including services of highways, sewers, battleships, etc.) from the private sector. These purchased services, which the government makes available to households, correspond to the input that matters for private production in equation (9). As long as the government and the private sector have the same production functions, the results would be the same if the government buys private inputs and does its own production, instead of purchasing only final output from the private sector, as I assume.

A second issue arises if the public services are non-rival for the users (as is true for the space program). Then it is the total of government purchases, rather than the amount per capita, that matters for each

individual. As is well known at least since Samuelson (1954), this element is important for determining the desirable scale of governmental activity. However, the present analysis can be modified to include this aspect of publicness without changing the nature of the subsequent results.

Another point is that the Cobb-Douglas technology in equation (9) implies that private activity, represented by the input k, is not a close substitute for public activity, represented by the input g. Private activity would not readily replace public activity if user charges were difficult to implement, as in the case of such non-excludable services as national defense and the maintenance of law and order. In other cases, user charges would be undesirable, either because the service is non-rival, or because external effects cause private production to be too low (as is sometimes argued for basic education).

Government expenditure is financed contemporaneously by a flat-rate income tax.

$$g = T = \tau y = \tau A k^{1-\alpha} g^{\alpha} \tag{10}$$

where T is government revenue and τ is the tax rate. I have normalized the number of households to unity, so that g corresponds to aggregate expenditures and T to aggregate revenues. Note that equation (10) constrains the government to run a balanced budget. That is, the government can neither finance deficits by issuing debt nor run surpluses by accumulating assets.

The production function in equation (9) implies that the marginal product of capital is now

$$(11) \qquad f_k = A(1-\alpha)(g/k)^{\alpha}$$

Note that f_k is calculated by varying k in equation (9), while holding fixed g. That is, the representative producer assumes that changes in his quantity of capital and output do not lead to any changes in his amount of public services.

It is convenient to substitute $g = \tau y$ in equation (9) and simplify to get

$$(12) \qquad y = k \cdot A^{1/(1-\alpha)} \cdot \tau^{\alpha/(1-\alpha)}$$

Therefore, for a given expenditure ratio, τ, y is proportional to k, as in the "Ak" production function in equation (5). An increase in τ means an increase in the relative amount of public input, and therefore an upward shift in the coefficient that connects y to k.

The ratio of the two productive inputs is

$$(13) \qquad g/k = (g/y) \cdot (y/k) = \tau \cdot (y/k) = (A\tau)^{1/(1-\alpha)}$$

where the value for y/k comes from equation (12). Substituting from equation (13) for g/k into equation (11) leads to

$$(14) \qquad f_k = (1-\alpha) \cdot A^{1/(1-\alpha)} \cdot \tau^{\alpha/(1-\alpha)}$$

Therefore, an increase in the expenditure ratio, τ, implies an upward shift in the marginal product of capital, f_k.

Private optimization still leads to a path of consumption that satisfies equation (4), except that f' is replaced by the private marginal return to capital. With the presence of a flat-rate income tax at rate τ, this return is $(1-\tau)f_k$. Therefore, substituting for f_k from equation (14), the growth rate of consumption is now

$$(15) \qquad \gamma = \dot{c}/c = (1/\sigma)\cdot[(1-\alpha)\cdot A^{1/(1-\alpha)}\cdot(1-\tau)\tau^{\alpha/(1-\alpha)} - \rho]$$

As long as τ is constant—that is, the government sets g and T to grow at the same rate as y—the growth rate γ is constant. Hence the dynamics is the same as that for the "Ak" model analyzed before. Consumption starts at some value c(0) and then grows at the constant rate γ. Similarly, k and y begin at initial values k(0) and y(0) and then grow at the constant rate γ. The economy has no transitional dynamics, and is always in a position of steady-state growth where all quantities grow at the rate γ shown in equation (15).

Given a starting amount of capital, k(0), the levels of all variables are again determined.[4] In particular, the initial quantity of consumption is

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[4]Unlike the previous model, the present setting may also determine the size distribution of competitive firms that have access to a perfect capital market. The scale of an individual firm is determined by its quantity of public services, g, or more precisely, by its share in the aggregate of public services. (Recall that, for given g, an individual producer faces diminishing returns in the private inputs.) For example, if there are N firms (which could correspond to N household-producers), and if each has property rights in 1/N of the total of public services, then each firm uses 1/N of the aggregate capital stock and produces 1/N of aggregate output. However, this argument works only if the producers effectively have property rights in designated quantities (or shares) of public services. If the public service is freely available, then the size distribution of firms is again indeterminate.

$$(16) \qquad c(0) = k(0)\cdot[(1-\tau)\cdot A^{1/(1-\alpha)}\cdot\tau^{\alpha/(1-\alpha)} - \gamma]$$

where γ is given in equation (15). The first term inside the brackets of equation (16) corresponds to $y(0) - g(0)$, and the second term to initial investment, $\dot{k}(0)$.

Figure 1 (originally drawn on a menu) shows the relation between the growth rate, γ, and the expenditure- and tax-rate, τ. A higher expenditure ratio raises f_k in equation (14) and thereby raises γ in equation (15). However, a higher tax rate means that people retain a smaller fraction, $1-\tau$, of their before-tax income, which tends to reduce γ. At low values of τ, the first force dominates and creates a net positive effect of τ on γ. (The Cobb-Douglas technology shown in equation (9) implies that anarchy is very unproductive.) However, for high enough τ, the second force dominates and therefore leads to a net negative effect of τ on γ. As τ approaches 0 or 1, the growth rate from equation (15) approaches the same negative value, $-\rho/\sigma$.

The growth rate, γ, is positive for a range of τ if the economy is sufficiently productive relative to the rate of time preference. The condition for a range with positive growth (which generalizes the condition $A > \rho$ from the "Ak" model) is $A^{1/(1-\alpha)}\cdot(1-\alpha)^2\cdot\alpha^{\alpha/(1-\alpha)} > \rho$. Also, as before, I assume that the economy is not so productive to allow the attained utility to become unbounded—the condition here is $\rho > A^{1/(1-\alpha)}\cdot(1-\sigma)(1-\alpha)^2\cdot\alpha^{\alpha/(1-\alpha)}$. As in the "Ak" model, the latter condition must hold if $A > 0$, $\rho > 0$, and $\sigma \geq 1$.

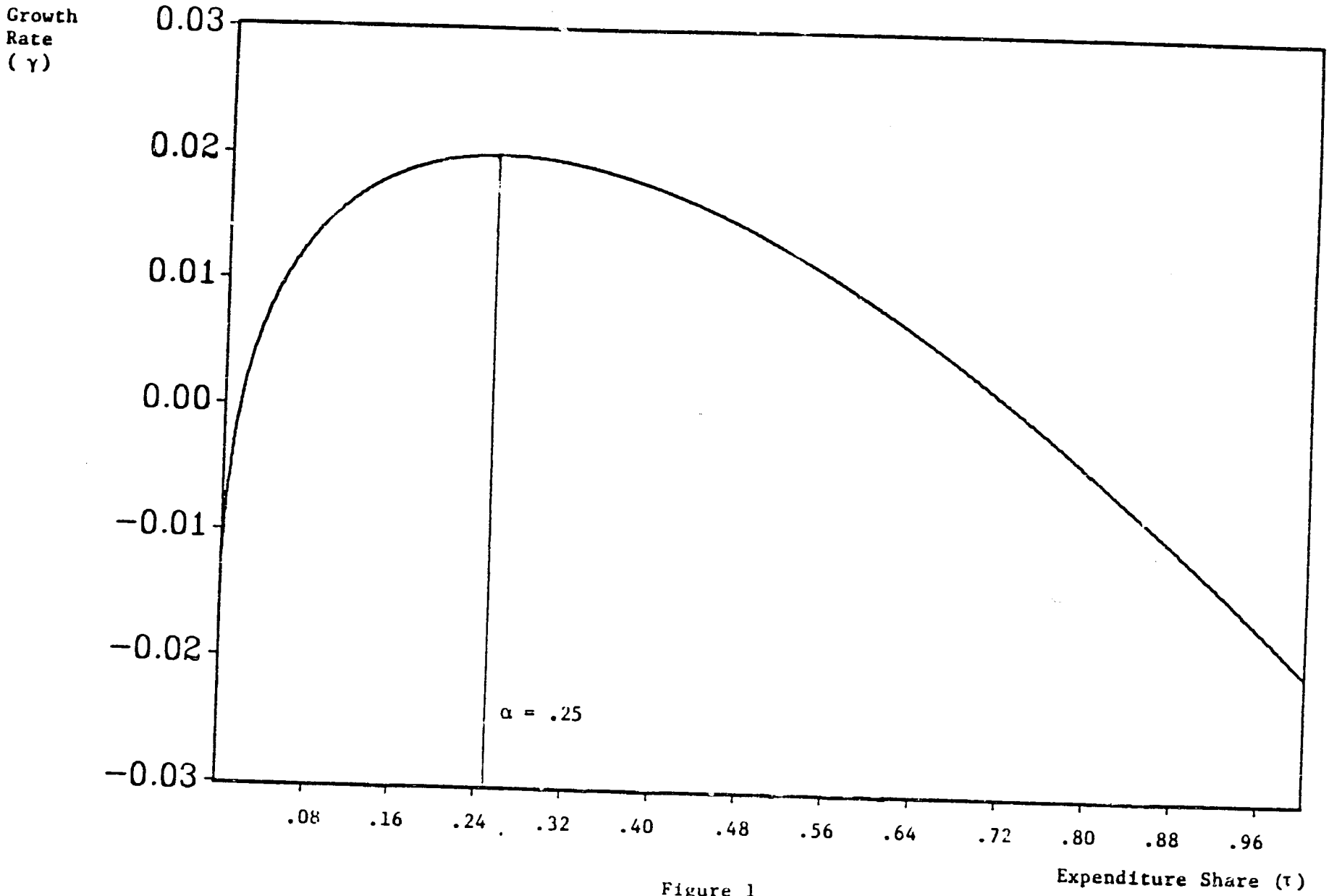

Figure 1
The Growth Rate and the Size of Government

NOTE: The curve shows the growth rate, γ , from equation (15). The parameter values are σ = 1, α = .25, ρ = .02, $A^{1/\alpha}$ = .113. These values imply that the maximum value of γ is .02.

Equation (15) shows that maximizing γ is equivalent to maximizing the expression, $(1-\tau)\cdot\tau^{\alpha/(1-\alpha)}$.[5] The solution is $\tau = \alpha$. Roughly speaking, to maximize the growth rate, the government's sets its share of GNP, $\tau = g/y$, to equal the share it would get if public services were a competitively supplied input of production. Note that the value of τ that maximizes γ depends only on the production parameter, α, and not on the preference parameters, ρ and σ. (The independence from ρ and σ follows for any constant-returns production function, and does not depend on the Cobb-Douglas form.)

The (net) saving rate is given by

$$(17) \qquad s = \dot{k}/y = (\dot{k}/k)\cdot(k/y) = \gamma\cdot A^{-1/(1-\alpha)}\cdot\tau^{-\alpha/(1-\alpha)}$$

where k/y comes from equation (12), and γ is given in equation (15). The curve in Figure 2 is a graph of s versus τ. Because k/y declines with τ, the saving rate peaks before the growth rate. That is, a value $\tau < \alpha$ would maximize s. Recall that saving and investment are broader concepts than usual in this model since they encompass accumulations of human capital (including additions to the stock of population). On the other hand, net product, net investment, and net saving are reduced by depreciation of stocks of human capital.

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[5]This result follows because the rate of time preference, ρ, is constant, and therefore does not depend on τ. In Becker and Barro (1988), the effective rate of time preference increases with the rate of population growth, which is itself determined within the model. This extension may introduce a dependence of ρ on τ, and thereby affect the choice of τ.

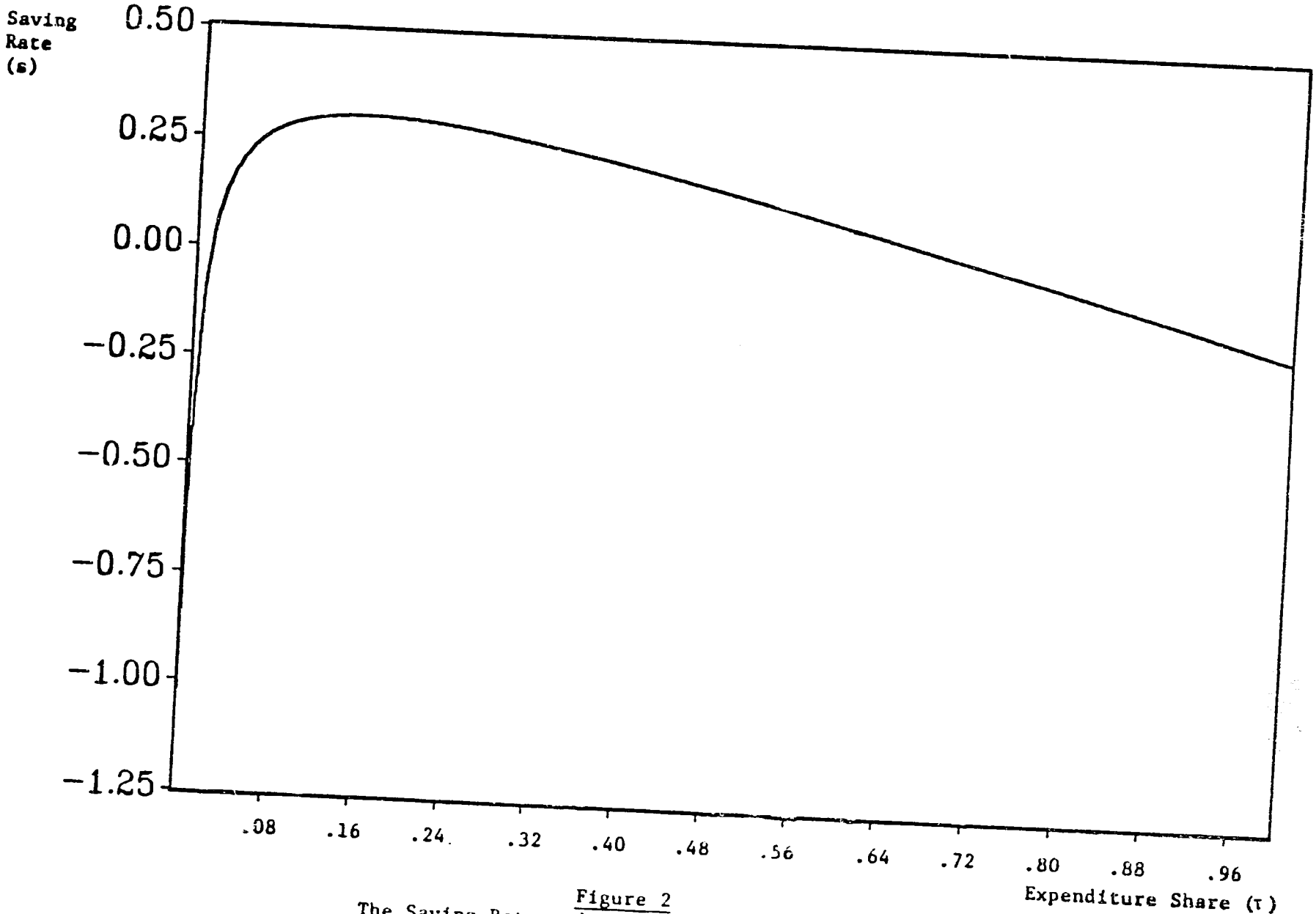

Figure 2
The Saving Rate and the Size of Government

NOTE: The curve shows the saving rate, s, from equation (17). Parameter values are indicated in Figure 1.

Presumably, there is no reason for the government to wish to maximize γ or s, *per se*. For a benevolent government, the appropriate objective in this model is to maximize the utility attained by the representative household. Because the economy is always in a position of steady-state growth, it is straightforward to compute the attained utility as a function of τ, as long as τ is constant over time.[6] With γ constant, the integral in equation (1) can be simplified to yield (aside from a constant),

$$U = \frac{[c(0)]^{1-\sigma}}{(1-\sigma)[\rho - \gamma(1-\sigma)]} \tag{18}$$

The condition that utility be bounded, mentioned before, ensures that $\rho > \gamma(1-\sigma)$.

Equations (15) and (16) determine γ and c(0), respectively, as functions of τ. Hence, these formulas can be used to determine the value of τ that maximizes U in equation (18). To see the nature of the results, it is useful to note that equations (15) and (16) imply that c(0) can be written as a function of γ (with τ not appearing separately),

$$c(0) = [k(0)/(1-\alpha)]\cdot[\rho + \gamma\cdot(\sigma+\alpha-1)] \tag{19}$$

Substituting into equation (18) yields a relation between U and γ,

[6] I show later that a constant τ (equal to α) is an equilibrium in this model, in the sense of being time-consistent.

$$U = \frac{[\rho + \gamma(\sigma+\alpha-1)]^{1-\sigma}}{(1-\sigma)[\rho - \gamma(1-\sigma)]} \tag{20}$$

It can then be shown that the effect of γ on U in equation (20) is positive for all values of $\sigma > 0$ and $0 < \alpha < 1$, as long as utility is bounded, which ensures $\rho > \gamma(1-\sigma)$. (This result follows although an increase in γ need not raise c(0) in equation (19).) Therefore the maximization of U corresponds to the maximization of γ. It follows that $\tau = \alpha$ is the tax rate that delivers the maximum of attained utility.

3 A Planning Problem for the Government

The result $\tau = \alpha$ is the solution to a second-best policy problem. Because of familiar externalities implied by public expenditures and taxation, the decentralized choices of saving turn out to generate outcomes that are not Pareto optimal. In fact, the departures from Pareto optimality are analogous to those in Romer's (1986) growth model, which relied on the public-goods nature of privately-created knowledge.

In the present model the easiest way to assess the external effects is to compare the decentralized outcomes with those from a planning problem. Suppose that the government chooses a constant expenditure ratio, τ, and can then dictate each household's choices for consumption over time. (It is straightforward to show that a constant τ is optimal in this planning problem.) Given the value of τ, the government picks the consumption path to maximize the representative household's attained utility, where the expression for utility is again given in equations (1) and (2). The

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resulting condition for the planned growth rate of consumption turns out to be

$$(21) \qquad \gamma_p = \dot{c}/c = (1/\sigma)\cdot[A^{1/(1-\alpha)}\cdot(1-\tau)\cdot\tau^{\alpha/(1-\alpha)} - \rho]$$

In equation (15), the expression within the brackets and to the left of the minus sign was the private marginal return on capital, $(1-\tau)f_k$. In contrast, the corresponding term in equation (21) is the social marginal return on capital, <u>given that the expenditure ratio, τ, is constant</u>. Equation (12) shows that the marginal effect of k on y, for fixed τ, equals $A^{1/(1-\alpha)}\cdot\tau^{\alpha/(1-\alpha)}$. However, to maintain τ, an increase of y by 1 unit requires an increase in g by τ units. Since the increase in g comes out of current output, the effect of k on y is adjusted by the factor, $1-\tau$, to calculate the net social return on capital in equation (21). Hence, the difference between the private choice in equation (15) and the planning solution in equation (21) is the presence of the term, $1-\alpha$, in the former.

Figure 3 shows how τ affects the planning growth rate, γ_p, and the decentralized growth rate, γ. It is clear from a comparison of equations (21) and (15) that γ_p exceeds γ for all values of τ. That is, the decentralized choices involve too little growth. (The insufficiency of growth corresponds to too low a saving rate—see the comparison of saving rates in Figure 4.) Moreover, since equation (21) differs from equation (15) only by the absence of the term, $1-\alpha$, it follows that the shape of the graph of γ_p versus τ is the same as that of γ versus τ. In particular, the maximum of γ_p also occurs at the tax rate, $\tau = \alpha$. (The result $\tau = \alpha$ is the solution to almost all problems in this paper.)

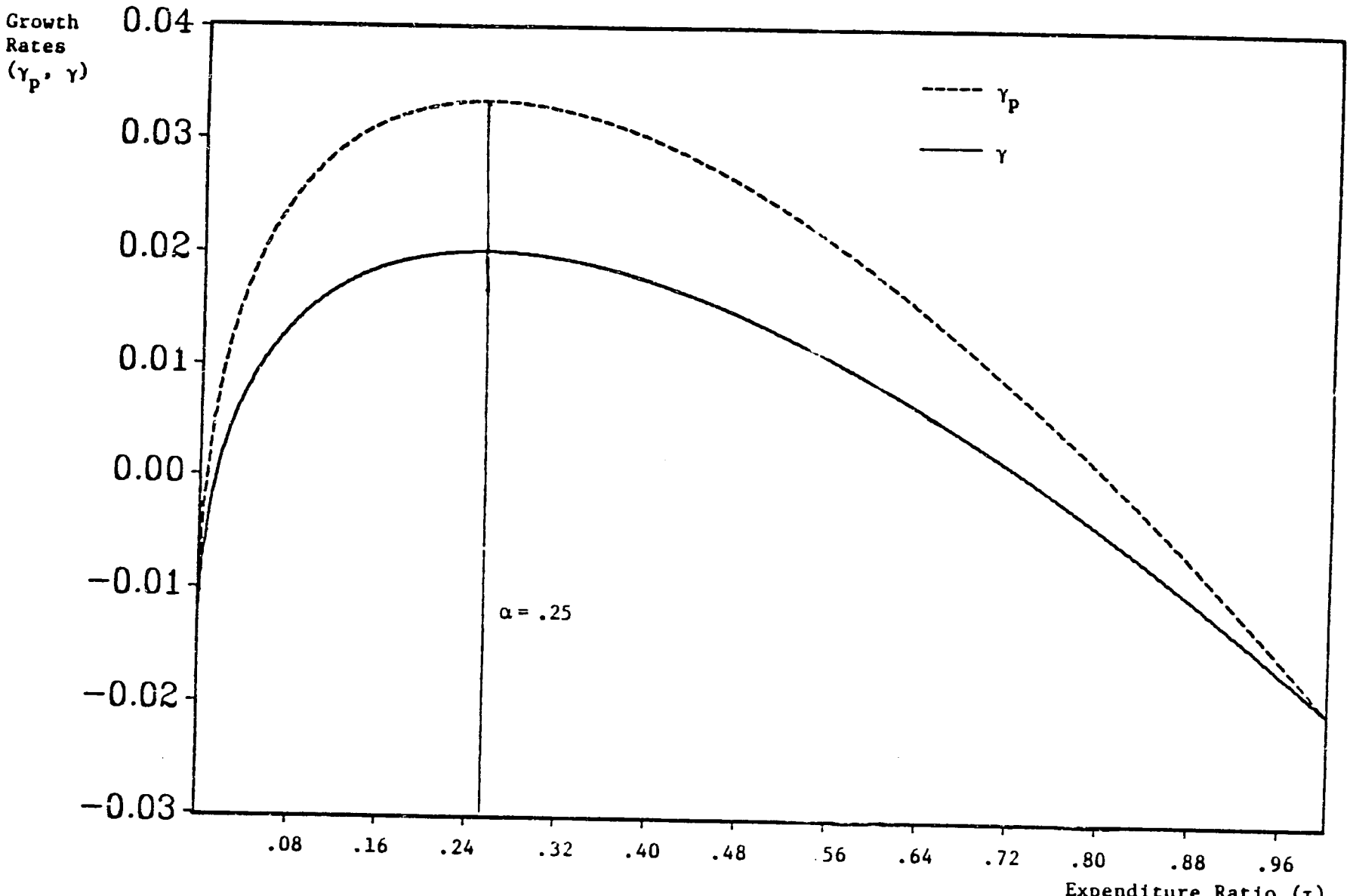

Figure 3

The Planning Growth Rate (γ_p) and the Decentralized Growth Rate (γ)

NOTE: γ_p comes from equation (21) and γ from equation (15). Parameter values are given in Figure 1.

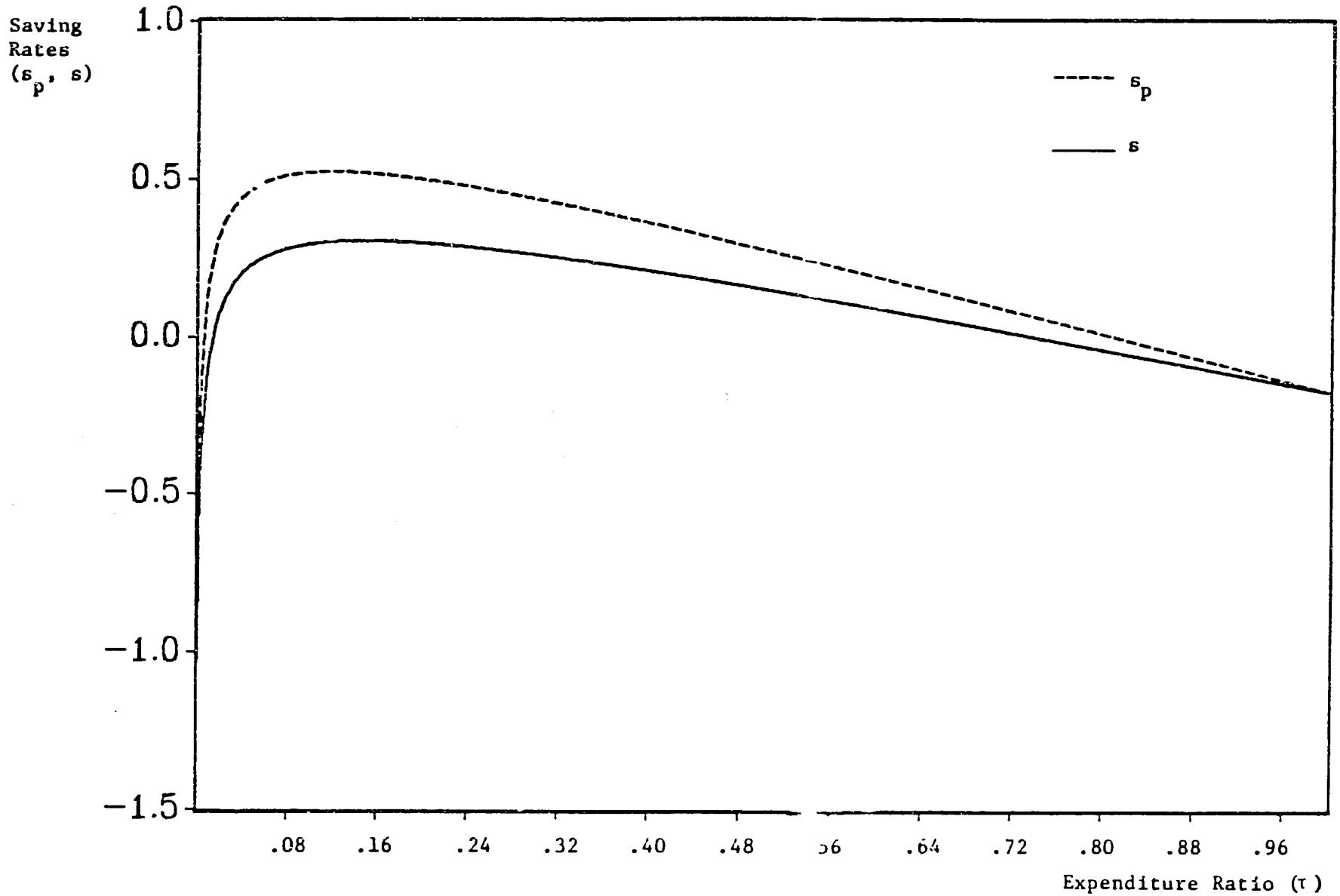

Figure 4

The Planning Saving Rate (s_p) and the Decentralized Saving Rate (s)

NOTE: $s_p = \gamma_p \cdot (k/y)$, where γ_p is given in equation (1[illegible]) and k/y in equation (12). s is given in equation ([illegible]). Parameter values are as in Figure

It is straightforward to show, following the procedure used for the decentralized case, that the planner who desires to maximize the utility attained by the representative household would choose the value of τ that maximizes the growth rate, γ_p. But this growth-maximizing expenditure share is again the value a. Hence the government selects the expenditure share, $1 - a$, in two circumstances: first, if it uses an income tax to finance spending in an environment of decentralized households, and second, if it has the power to dictate each household's saving behavior. The growth rate, saving rate, and level of attained utility are all lower in the first environment than the second. But the share of government in GNP is the same.

It is natural to consider whether the command optimum can be implemented by replacing the income tax with a lump-sum tax in an environment of decentralized households. (In this model, which lacks a labor-leisure choice, a consumption tax would be equivalent to a lump-sum tax.) With lump-sum taxes, the private marginal return on capital is f_k, rather than $(1-\tau)f_k$. Therefore, instead of equation (10), optimizing individual households would choose the growth rate of consumption,

$$(22) \quad \gamma_L = \dot{c}/c = (1/\sigma)\cdot[(1-a)\cdot A^{1/(1-a)}\cdot\tau^{a/(1-a)} - \rho]$$

Thus, γ_L differs from γ by the absence of the term, $1-\tau$, inside the brackets.

Figure 5 graphs γ_L, along with γ and γ_p, as a function of τ. As is apparent from equation (22), γ_L is monotonically increasing in τ. That is because a higher τ means a higher expenditure share, which shifts upward the marginal product, f_k. With a lump-sum tax, households respond to the higher

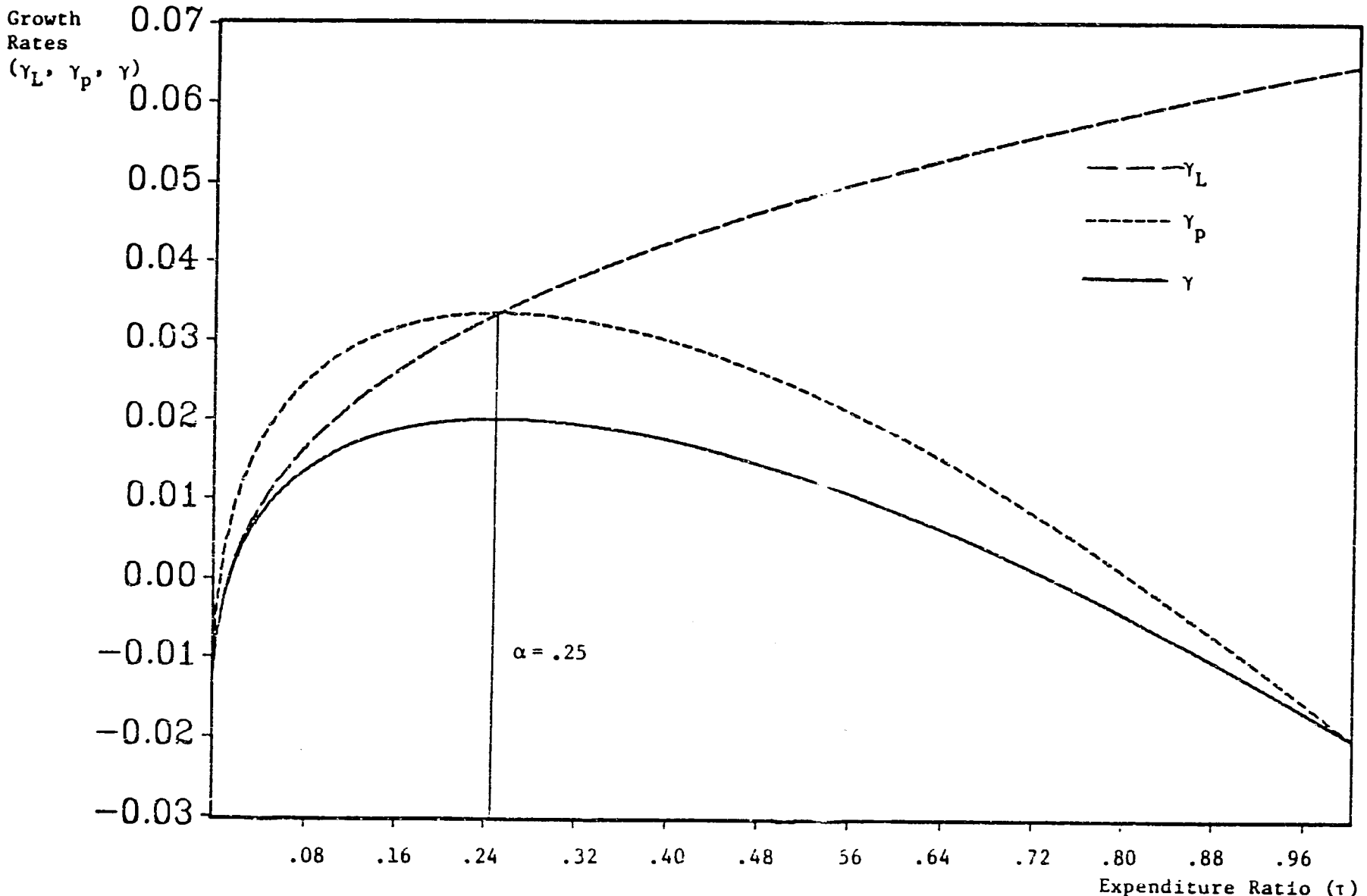

Figure 5
The Growth Rate in Three Environments

NOTE: γ_L is from equation (22), γ_p from equation (21), and γ from equation (15). Parameter values are given in Figure 1.

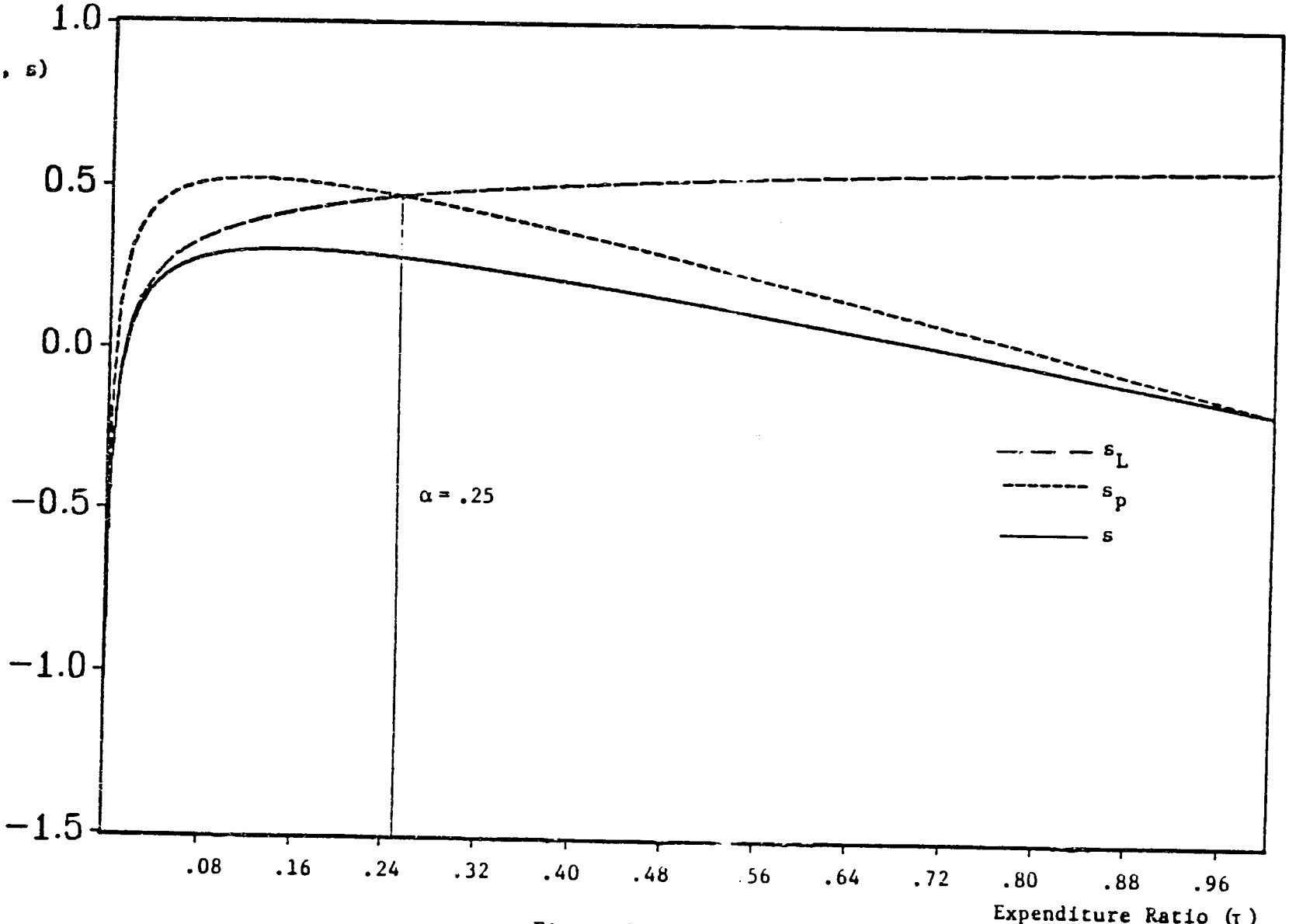

Figure 6
The Saving Rate in Three Envi nments

NOTE: $s_L = \gamma_L \cdot$ ·/y and $s_p = \gamma_p \cdot k/y$, where γ_L is fro equ tion (22), γ_p from equation (21), and k/y from equation (12). s is from equation (17) Pa ameter values are given in Figure 1.

f_k by choosing a higher growth rate for consumption (and a higher saving rate—see Figure 6).

A comparison of equations (21) and (22) indicates that γ_p contains the term, $1-\tau$, where γ_L contains the term, $1-\alpha$. At the point, $\tau = \alpha$, which was already shown to correspond to the command optimum, the two terms coincide. Note from Figures 5 and 6 that the growth rates, γ_p and γ_L, and saving rates, s_p and s_L, are equal at this point. These results mean that lump-sum taxation supports the command optimum if the expenditure share is set at the optimal value, $\tau = \alpha$.[7]

If the expenditure share is set non-optimally, $\tau \neq \alpha$, then the planning solution for consumption—contingent on this incorrect choice of τ—does not coincide with the solution under lump-sum taxation. This result indicates that the income tax is not the only distortion in the model. I am uncertain

[7]This result under lump-sum taxation underlies the time consistency of the solution, $\tau = \alpha$, under income taxation. Suppose that future governments will set the income-tax rate, $\tau(t) = \alpha$, for all $t > 0$. Then, for given $k(0)$, the current income-tax rate, $\tau(0)$, is effectively a lump-sum tax. In particular, the current choice affects neither past investments (which cannot be undone) nor expected future tax rates (which matter for current and future investment). If the government could run budget surpluses and thereby accumulate assets, it would be attractive to choose a very high value of $\tau(0)$ and use the proceeds to finance future spending (which otherwise would require distorting income taxation). However, the balanced-budget constraint in equation (10) rules out this possibility. Therefore, the government selects the current expenditure ratio, $\tau(0)$, as it would under lump-sum taxation. But the solution to that problem is $\tau(0) = \alpha$. In the absence of the balanced-budget constraint, the government would have the usual incentive to effect capital levies, so that $\tau(t) = \alpha$ would no longer be time consistent. (Private investors would also anticipate these levies and act accordingly.) The result $\tau(t) = \alpha$ would then hinge on the government's ability (starting from time $t = -\infty$) to commit itself to a constant tax rate. However, in cases where the income tax is not distorting—as discussed below—the problem of time consistency does not arise.

whether the other distortion is economically interesting, but I will now explain what it is.

An individual producer computes the marginal product, f_k, while holding constant the quantity of public services, g, that he receives from the government. This assumption is appropriate for some types of public services, and I maintain this assumption for now. But, if the government sets a given expenditure ratio, τ, then an increase in national product by one unit induces the government to raise the aggregate of its public services by τ units. Thus, when an individual producer decides to raise his individual k and y, he is indirectly causing the government to increase its aggregate spending. The effect on that individual's public services, which entered into his production function, would be negligible (under my assumption about how public services are provided), and can therefore be ignored. But it is nevertheless true, with τ fixed, that an individual's decision that raises national product by 1 unit causes the total of government purchases to expand by τ units. The effects depend on whether the size of the government is optimal. If so—namely, at the point $\tau = \alpha$—a marginal change in government expenditures is just worth its cost. Hence there is no distortion and the lump-sum tax result replicates the planning optimum, as noted before. But suppose that the government is too large, $\tau > \alpha$. Then the induced expansion of government expenditures constitutes a negative externality. On this count, each individual has too much of an incentive to expand individual output; in particular, in this model, each individual has too much incentive to save. Hence, $\tau > \alpha$ implies $\gamma_L > \gamma_p$ in Figure 5, and $s_L > s_p$ in Figure 6. Analogously, the incentive to expand

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individual output is too low when the government is too small, $\tau < \alpha$. Hence, $\gamma_L < \gamma_p$ and $s_L < s_p$ apply in this range.

Figures 5 and 6 also allow a comparison between lump-sum taxes (which could be consumption taxes in this model) and income taxes. At the point $\tau = \alpha$, the lump-sum tax generates the command optimum and is therefore superior to the income tax. For $\tau < \alpha$, the lump-sum tax comes closer than the income tax to the command optimum; therefore, the lump-sum tax would also be preferred here. However, for $\tau > \alpha$ the comparison becomes ambiguous, because the lump-sum-tax choices, γ_L and s_L, are too large, while the income-tax choices, γ and s, are too small. For very large governments (that is, τ well above α), the outcome under income taxes can be superior to that under lump-sum taxes. The reason is that the income tax is an imperfect way to get individual producers to internalize the distortion described above. With $\tau > \alpha$, people have too great an incentive to expand output by an additional unit because the government is thereby induced to increase its expenditures by τ units. If government spending were worthless, then the way to internalize this distortion would be to tax the individual's income at rate τ. As τ gets well above its ideal value, α, the social return from more government spending diminishes—that is, it becomes more nearly accurate that government spending is worthless at the margin. Therefore, the income tax becomes more nearly the right way to offset the negative externality, and the value γ in Figure 5 gets steadily closer to the value γ_p. Similarly, in Figure 6, s and s_p converge as τ approaches 1.

4. Tax Systems and Property Rights

Within the framework of an income tax, the (average) marginal tax rate, τ, can vary for a given expenditure ratio, g/y. For example, differences in the degree of graduation or in enforcement policies could generate these variations in τ. If τ decreases, for a given g/y, the response is a movement in the direction from the solid to the dashed curve in Figures 3 and 4. Hence, for given g/y, the rates of growth and saving increase.

From the standpoint of investors, enhanced property rights look like reductions in marginal tax rates. Therefore, an improvement in rights also generates a shift in the direction from the solid to the dashed curve in Figures 3 and 4. Hence, the rates of growth and saving again increase.

Many functions of government, such as maintenance of law and order and national security, help to sustain property rights. (Others, including some regulatory and legislative activities, have opposing effects.) An increase in spending, g, in areas that enhance property rights causes a reduction in the effective value of τ, rather than a direct effect on the production function (as in equation (9)). However, the effects on growth and saving are similar to those for the productive government expenditures considered before. In particular, the relation of growth and saving rates to the amount of government expenditure devoted to the enforcement of property rights would resemble the curves shown in Figures 1 and 2.

5. An Alternative Specification for Public Services

I assumed so far that each individual held fixed his quantity of public services, g, when considering a change in his quantity of capital, k, and output, y. This setting is appropriate for some public services, but not for

others. For example, for police and fire protection, and perhaps for national defense, the amount of public services that an individual receives is roughly proportional to the amount of property that the person has to protect. (Thompson, 1974, argues that an increase in an individual's appropriable property makes the home country more attractive to foreign aggressors, and thereby increases the home country's overall burden for providing national security.) These cases can be approximated by assuming that each individual holds constant his ratio of public services to output, $\tau = g/y$, rather than his level of public services.

With a flat-rate income tax at rate τ, the individual's optimization problem now coincides with the planner's problem considered before. Hence (for the case where public services appear directly in the production function), the decentralized choices lead to the growth rate, γ_p, shown in Figure 3, and the saving rate, s_p, shown in Figure 4. The private choices lead to a Pareto optimum because the income tax at rate τ works like a user fee to internalize the effect of an individual's choices on his level of public services. In particular, a decision to raise y by 1 unit (by an increase in k) leads to increases in own public services and taxes by τ units. Since individuals are effectively paying for the services they receive, a Pareto optimum results.

It is also possible to combine the present specification for public services with a lump-sum tax, which could be a consumption tax. The growth rate in this case equals the planning growth rate γ_p, shown in equation (21), except that the term, $1-\tau$, is removed. Equivalently, the growth rate equals γ_L, shown in equation (22), except that the term, $1-\alpha$, is removed. Hence the growth rate now exceeds γ_p and γ_L for all values of τ. Diagrammatically, the

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growth rate has the same shape as γ_L in Figure 5, but is displaced upwards. Analogously, the saving rate exceeds s_p and s_L for all values of τ, and can be represented as an upward displacement of the curve s_L shown in Figure 6.

Savings, and hence growth, are now too high because individuals do not internalize the effects of their choices on the quantity of public services that they receive. An individual's decision to raise k and y brings that individual more public services, which—with a lump-sum tax—he does not have to pay for. Hence, individuals have too much motivation to invest and produce goods.

6. Government Consumption Services

I now return to the setting where each individual holds constant his level of public services. But, suppose that the government's expenditures also finance some services that enter into households' utility functions. I assume that total spending per household is g+h, where the quantity h represents the government's consumption services. The utility function for each household is now

$$u(c,h) = \frac{(c^{1-\beta} \cdot h^{\beta})^{1-\sigma} - 1}{(1-\sigma)} \tag{23}$$

where $0 < \beta < 1$. The household's overall utility is still given by equation (1), except that u(c,h) replaces u(c) in the integral.

I still assume a flat-rate income tax, so that the government's budget constraint is

$$T = (\tau_g + \tau_h) \cdot y \tag{24}$$

where $\tau_g = g/y$ is the government's expenditure ratio for productive services, and $\tau_h = h/y$ is the ratio for consumption services.

Households' decentralized choices for consumption and saving (taking g and h as givens) now lead to the growth rate

$$\gamma_h = (1/\sigma) \cdot [(1-\alpha) \cdot A^{1/(1-\alpha)} \cdot (1-\tau_g-\tau_h) \cdot (\tau_g)^{\alpha/(1-\alpha)} - \rho] \tag{25}$$

This expression modifies equation (15) in a straightforward manner: $(1-\tau_g-\tau_h)$ replaces $(1-\tau)$, and $(\tau_g)^{\alpha/(1-\alpha)}$ replaces $\tau^{\alpha/(1-\alpha)}$. The dotted curve in Figure 7 shows the relation between γ_h and the share of productive government spending, τ_g, taking account of the positive value of τ_h. The growth rate lies uniformly below the value γ, shown by the solid curve, that would have been chosen if $\tau_h = 0$. Figure 8 shows the corresponding saving rates, s_h and s.

For a given τ_h, it is easy to show that the value of τ_g that maximizes γ_h in equation (25) is $\alpha(1-\tau_h)$. In other words, the growth-maximizing share of productive government spending is smaller if the government is also using the income tax to finance other types of spending. However, this choice of τ_h turns out not to maximize the utility attained by the representative household.

Suppose that each household's utility function is given by equation (23), and that τ_g and τ_h are set to maximize the overall utility attained by the representative household in the form of equation (1). (I again restrict attention to tax rates that are constant over time.) The effects of the tax

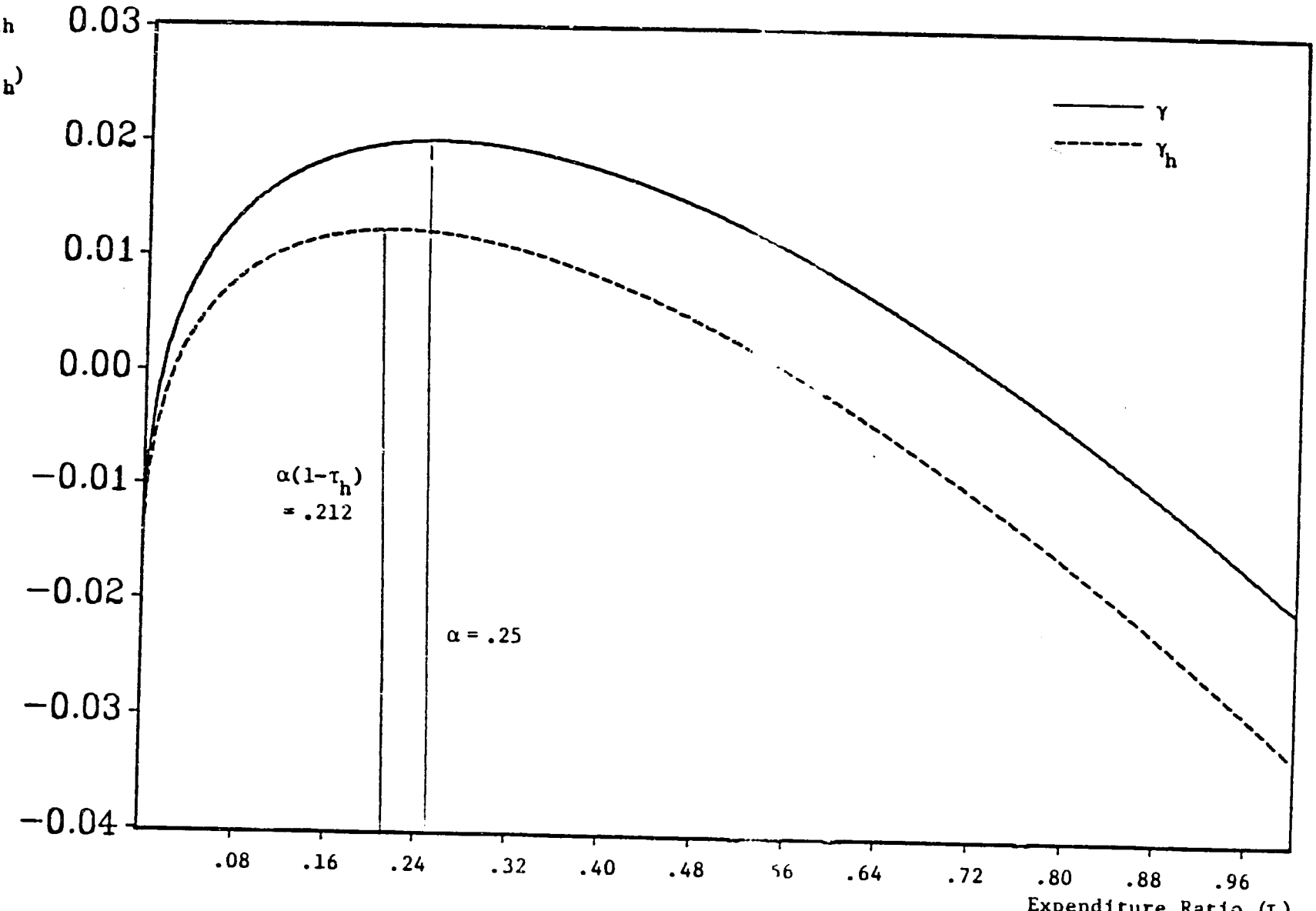

Figure 7

Growth when the Government also Provides [illegible]ption Services

NOTES: γ is from [illegible]uation (15) and γ_h from equation (25 [illegible] graph of γ_h assumes τ_h = .15. Other paramete values are from Figure 1.

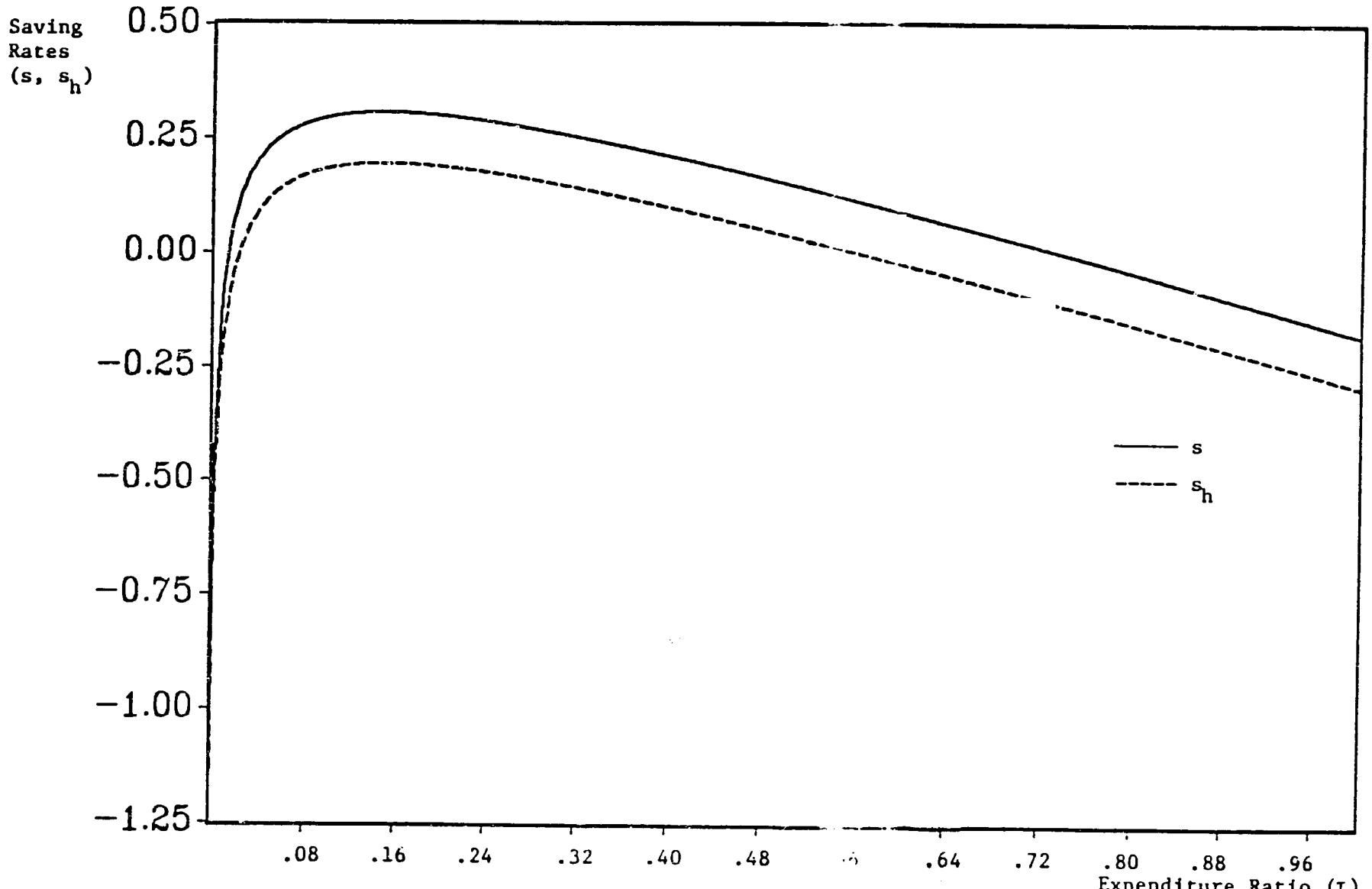

Figure 8

The Saving Rate when the Government also Prov onsumption Services

NOTE: s is from equation (17). $s_h = \gamma_h \cdot k/y$, where γ_h m equation (25), and k/y from equation (12). $\tau_h = .15$. Other parameter values are in Figure 1.

rates on γ_h are shown in equation (25). As before, it is possible to determine the initial level of consumption, c(0), and thereby calculate the entire path of consumption as $c(t) = c(0)\cdot e^{\gamma_h t}$. The path of the government's consumption services is given by $h(t) = \tau_h \cdot y(t) = \tau_h \cdot y(0)e^{\gamma_h t}$. Using these results, it is feasible to relate the attained utility, U, to the tax rates, τ_g and τ_h. There are then two first-order conditions corresponding to the maximization of U. Combining these conditions leads to the familiar result: $\tau_g = \alpha$. That is, as long as τ_h is also chosen optimally, the optimal ratio for productive government expenditures, τ_g, is the same as before. In particular, the choice depends again only on the productivity parameter, α, and not on aspects of preferences (including now the parameter β, which determines households' preferences for private consumption, c, versus government consumption services, h).

[illegible]

[illegible] government was benevolent and therefore sought to maximize the utility attained by the representative household. I now consider the alternative that the government is run by an agent who has no electoral constraints and seeks to maximize his own utility.

Return to the setting where all government expenditures, g, serve as productive inputs for private producers. The government still uses a flat-rate income tax, but instead of automatically balancing the budget, the government can earn the net revenue,

$$c_g = (\tau - \epsilon)y \tag{26}$$

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where the expenditure ratio, $\epsilon = g/y$, can differ from the income-tax rate, τ. The government agent uses his net revenue to purchase the quantity of consumer goods, c_g. (The results would not change if the agent were allowed to hold capital, and perhaps owned a nonzero quantity of capital at time 0.) The agent receives utility from consumption in the same manner as any household—that is, the flow of utils is $u(c_g)$ from equation (2), and the overall attained utility, U, is given by the integral in equation (1). In particular, the government agent has the same discount rate, ρ, as each household.

Assuming constant values for τ and ϵ, the privately determined growth rate is now

$$(27) \quad \gamma_\epsilon = (1/\sigma)\cdot[(1-\alpha)\cdot A^{1/(1-\alpha)}\cdot(1-\tau)\cdot\epsilon^{\alpha/(1-\alpha)} - \rho]$$

This result is a straightforward modification of equation (15) when $\epsilon \neq \tau$. The government agent's consumption is $c_g(t) = (\tau-\epsilon)\cdot y(0)e^{\gamma_\epsilon t}$. Therefore, using the same procedure as before, it is possible to write the agent's attained utility as a function of τ and ϵ. The two first-order conditions for maximization of utility then lead to the results

$$(28) \qquad \tau > \epsilon = \alpha$$

The optimal expenditure rate, ϵ, equals α, as in previous models. This choice is basically one of efficient production, which means that the self-interested government chooses the same value as the benevolent government. Basically, the government agent sets $\epsilon = \alpha$ in order to maximize

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the tax base that he has to work with. Then he is also in the position to set $\tau > \epsilon$ in order to secure the net flow of revenue, c_g.

The results in this section parallel those in the preceding one. In effect, the government agent's consumption, c_g, plays the same role that the government's consumption services, h, played in the previous model. In both cases the presence of these consumption flows does not upset the conditions for productive efficiency, which imply that the government's productive expenditures are the fraction α of total output. However, the ratio of government revenues to output exceeds α in both cases; in one case to provide consumption to the government agent, and in the other to provide government consumption services to each household.

8. Some Empirical Implications

The theory has implications for relations between the size of government and the rates of growth and saving. Since the analysis applies to steady state growth paths the actual empirical application would be to differences in average performance across countries over long periods of time.

As is usual in empirical investigations, the hypothesized effects of government policy are easier to assess if the government's actions can be treated as exogenous. That is, the results are simple if governments randomize their actions and thereby generate useful experimental data. In this case, variations in the share of productive government expenditures in GNP, g/y, affect growth and saving rates, γ and s, as shown by the curves in Figures 7 and 8, respectively. (These curves apply with a proportional income tax, and in settings where individuals treat their own allocations of

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public services, g and h, as givens.) As suggested before, productive government spending would include the resources devoted to property-rights enforcement, as well as activities that enter directly into production functions. Countries could be arrayed along the horizontal axes by the size of g/y, and the responses of γ and s would be non-monotonic, as shown in the figures.

An increase in the share of non-productive government expenditures, say h/y in the model of section 6, leads to the types of shifts shown by the movements from the solid to the dashed curves in Figures 7 and 8. For a given value of g/y, an increase in h/y lowers the growth and saving rates. These effects arise because a higher h/y has no direct effect on private-sector productivity, but does lead to a higher income-tax rate. Since individuals retain a smaller fraction of their returns from investment, they have less incentive to invest, and the economy tends to grow at a lower rate.

predictions are similar for any other differences across countries that imply that private investors get to retain a smaller fraction of their returns from investment. For example, if g/y is held fixed, an increase in the average marginal tax rate—resulting, say, from a difference in the tax system—would tend to lower the growth and saving rates.

Aside from problems of measuring public services and the rates of growth and saving, the empirical implementation of the model is complicated by the endogeneity of the government. Within the theoretical model, the government sets the share of productive expenditures, g/y, to equal α. Therefore, instead of being arrayed along the horizontal axes in Figures 7 and 8, each government would operate at the same point, g/y = α. Within this framework

of optimizing governments, cross-sectional variations in g/y arise only if α differs from country to country.

The parameter α, which measures the productivity of public services relative to private services, could vary across countries for a number of reasons. These include geography, the share of agricultural production, urban density, and so on. For present purposes it is unnecessary to predict how any specific element would affect α, and therefore g/y for an optimizing government. As long as the variations in α are independent of the overall level of productivity (measured by the coefficient, $A^{1/(1-\alpha)}$, which connects y to k for a given τ in equation (12)), the model predicts how the induced variations in g/y will correlate with differences in γ and s. Using equations (15) and (17), substituting $\tau = \alpha$, and holding constant $A^{1/(1-\alpha)}$, the model implies that a rise in α, and hence in g/y, will reduce γ and s.[8] Therefore, the theory predicts that these types of endogenous variations in productive expenditures will be inversely correlated with γ and s. In other [illegible] the data [illegible] show an inverse association between the size of government and the rates of growth and saving, even though the true relations are those in Figures 1 and 2, and the government operates at the point of maximum growth.

The literature includes a number of empirical studies on the relationship between government and economic growth. Kormendi and Meguire (1985) studied 47 countries in the post-World War II period, using data on total government "consumption" expenditures and other variables from *International Financial*

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[8]The result for s uses the condition $\gamma > 0$, which implies $\rho < A^{1/(1-\alpha)} \cdot (1-\alpha)^2 \cdot \alpha^{\alpha/(1-\alpha)}$.

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Statistics. This measure of government spending, used by many authors because of the availability of the data, excludes public investment and transfers from overall public expenditures. Although the category is called consumption, it does not necessarily follow that these public services enter mainly into utility functions, rather than production functions. Using data for each country averaged over roughly 20-year periods, Kormendi and Meguire found (p. 147) no significant relation between average growth rates of real GDP and average growth rates or levels of the share of government consumption spending in GDP.

Grier and Tullock (1987) extended the Kormendi-Meguire form of analysis to 115 countries, using data on total government consumption and other variables from Summers and Heston (1984). This extension was a pooled cross-section, time-series analysis, using data averaged over 5-year intervals. They found (Tables 1 and 2) a significantly negative relation between the growth of GDP and the growth of the government share of GDP, [illegible] derived from the [illegible] countries.

Landau (1983) studied 104 countries on a cross-sectional basis, using an earlier form of the Summers-Heston data. He found (Table 1) significantly negative relations between the growth rate of real GDP per capita and the level of government consumption expenditures as a ratio to GDP. However, Landau's regressions held constant a measure of investment in education, which would be one component of an economy's broadly defined saving. Since the negative effect of more government on growth in my model works through a reduced incentive to save, the interpretations are very different if saving rates are held constant.

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Barth and Bradley (1987, Table 1) found a negative relation between the growth rate of real GDP and the share of government consumption spending for 16 OECD countries in the period, 1971-1983. They also found that the share of government investment in GDP had a statistically insignificant effect on growth, although the point estimate was positive. However, the last estimate applies when the ratio of private investment to GDP is held constant.

Ram (1986) looked at 115 countries using the Summers-Heston data. He reported (Table 1) positive effects of the growth of government consumption spending on the growth of GDP. However, there are two problems with the results. First, they hold constant the ratio of investment (private plus public) to GDP, which eliminates the channel in my model for the negative effect of government on growth. Second, the results amount to a positive coefficient in a regression of the growth rate of GDP on the growth rate of government consumption expenditures. This regression would pick up the reverse effect of income on government consumption; that is, it probably amounts to a demand function for public services.

The literature contains a number of additional empirical studies, with results similar to those reported above. In my planned empirical work, I will consider these results in more detail, as well as carrying out new research along the lines suggested by my theoretical analysis.

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Discussion of Barro

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Robert Barro's paper looks at some important public finance questions in the setting of an endogenous growth model. The government does not contribute to growth by financing the accumulation of knowledge or by correcting externalities. Instead, government has an important role in production itself. In the model, government commandeers a fraction of output and recyucles it immediately as a government-provided input. The government has no intertemporal functions; it cannot run a surplus in early years and use the proceeds to finance later provision of its productive input. The government's contribution to growth is entirely through its influence on output.

The footnote on pp. 10-11 (ms.) provides the only hint about the relationship between the government and producers in the model. Apparently there is a group of claimants who receive arbitrary free allocations of the government input, g. They bid for capital in a free market and achieve the efficient allocation of capital to g. Behavior of this type is all too common among governments. For example, the U.S. government gives away landing slots at crowded airports to well-placed airlines. The airlines are then free to allocate slots to aircraft efficiently. The inefficiency in the process arises, in Barro's model, only from the distortionary tax needed to finance the free goods distributed to producers. The model does not consider a potentially more important inefficiency arising from the rent-seeking activities of those who would like to receive the free goods. The paper is about the "Harberger triangle" created by the tax, not the "Posner rectangle" created by rent-seeking activities.

The lucky recipients of the free government input earn rents from

their control of g. These rents are exactly enough to pay for g, when the government is conducting itself according to Barro's prescription. Intelligent options available to the government to avoid the excess burden of taxation are:

1. Auction g to the highest bidders.
2. Sell g at the efficient price or user fee, which is 1 in goods units.
3. Put a 100 percent tax rate on pure rents, measured as revenue y less the service cost of capital, rk.
4. Allocate g in proportion to capital, k.

Any of these achieves the first-best optimum. Instead, the model assumes, realistically, that the government stupidly puts a distortionary tax on output. The tax drives a wedge between the private return on capital and its marginal product. The economy with the tax grows too slowly because future consumption is taxed more heavily than is current consumption.

Barro's central finding is that the ratio of government input to output is the same in the first-best and the second-best situations. One might have reasoned along the following lines: Given that taxation has a rising marginal excess burden, the government should hold the level of g below its first-best optimum if g has to be financed by distortionary taxes. Barro's finding that the government should push g all the way to the point of production efficiency seems to contradict that reasoning. In fact, however, the finding is exactly consistent with the reasoning. At the outset, the supply of capital and hence the supply of output is completely inelastic. The tax on initial output is non-distorting and hence the fully efficient level of g should be provided. In subsequent periods, the supply

of capital and output is elastic and the tax is distortionary. The *level* of g should be lowered to the point where the marginal benefit of diverting output equals the marginal excess burden of the tax. At the second-best optimum, both y and g are below their first-best levels, to an extent governed by the intertemporal elasticity of substitution, σ^{-1}. But under Barro's assumptions about the technology, the proportional depression of y and g are the same, so the ratio of g to y remains at its first-best level. Barro's result on the ratio should not be confused with statements about the levels of the variables.

The equi-proportional depression of the two variables is a special feature of the Cobb-Douglas technology. With a different technology, it remains true that maximizing welfare amounts to maximizing growth, but it is no longer true that production efficiency maximizes growth. The key growth equation, (15) can be written

$$\gamma = \frac{1}{\sigma} [(1 - \alpha(\tau)) h(\tau) - \rho]$$

Here $\alpha(\tau)$ is g's factor share stated as a function of the ratio of g to output, $h(\tau)$ is output net of recycled g, and ρ is the rate of impatience. For the Cobb-Douglas technology, $\alpha(\tau)$ is a constant, so maximizing $h(\tau)$ is equivalent to maximizing growth, γ. For any other technology, $\alpha(\tau)$ varies with τ, so production efficiency does not maximize growth.

The primacy of production efficiency also arises in the fiscal problem posed by Peter Diamond and James Mirrlees ("Optimal Taxation and Public Production: I—Production Efficiency," *American Economic Review* 61: 8-27, March 1971.) However, Barro's setup is different from

theirs—he does not permit a different tax rate for each time period and he excludes the accumulation of government assets that is implicit in the application of Diamond-Mirrlees to the intertemporal problem. At the conference, Kenneth Judd pointed out the importance of these restrictions in Barro's model in connection with the problem of time-consistency.

There is a question in my mind whether the problem considered in Barro's paper has any practical significance. Government provision of sewers clearly fits the model, but I am not convinced that the types of governments that are responsbile for sewers are departing from the first-best as dramatically as the model says. Construction of sewers is generally financed by levies in proportion to anticipated use, so the tax comes closer to a user fee than does Barro's hypothesized tax on output. Law enforcement is another service generally provided free to businesses, but, as Barro shows, if the benefits are in proportion to capital, then income taxation provides the first-best result.

Government purchases of goods and services are predominantly for education at the state and local level and for defense at the national level. Barro makes no claim that his model has anything to do with education. He does note Earl Thompson's point that defense is, in effect, a business input that increases the expected output given inputs. But, viewed in that light, defense is allocated in proportion to capital, so income taxation yields the first-best allocation. The purchaser of capital buys free defense along with the capital. Therefore, it is optimal to put a tax on capital's earnings, because it has the same effect as a user fee for defense.

Barro's paper raises some important and interesting questions in public finance, but I believe they are essentially static. The relation

between fiscal efficiency and growth arises in the model only because the model embodies a general relation between the level of activity and the growth rate. The paper is silent on how the government should lift the economy out of the low-growth equilibrium described in other papers at this conference.

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Comments by Daniel Gros on

Government Spending in a Simple Model of Endogenous Growth

by Robert J. Barro

In preparing my discussion of this excellent and provacative paper, I had to face the problem that I am not an expert in public finance or growth theory. I, therefore, choose to follow closely the structure of the paper and to focus on two points:

1. What is the real life counterpart of the production government services that are central to the analysis of this paper?

2. How would a change in the functional form used to describe the contribution of government services to overall productivity, change the main result of the paper; namely that the optimum size for the government is the same for the social planner and the second best equilibrium?

Before discussing these two points, I would like to make some preliminary remarks.

The purpose of this paper is to explore the role of the government in growth. Growth and the actions of the government become endogenous in this framework in the sense that actual growth rates interact with government actions because of the reaction of the private sector to government expenditures and taxes. The important contribution of this paper is to break away from the approach taken by growth theory so far, in which the government was usually absent or its actions were treated as exogenous to the growth process. This paper also makes a welcome break from standard treatments of growth in that it contains no

complicated intertemporal optimization problems that have to be solved explicitly, instead, by using some clever building blocks, the author suceeds in keeping the technical complexity of the analysis to a minimum.

The approach taken by the author differs from standard growth theory in that he argues that some government servies are necessary for the private sector to be productive at all, the main result of the paper could therefore be summarized quite simply by the statement: "Government services are essential for the private sector, but the government has to finance its expenditure; it follows that there must be an optimum size for taxes and expenditure since at zero expenditure (and taxes) there is no growth and at confiscating (100 percent) taxes there is no growth either; the optimum is somewhere in between." A careful reader of the paper might object that in this framework government services are necessary for production (in this period) not for growth per se; I will come back to this point later.

The main thrust of my comments, however, is not directed at the above proposition, which is reasonable, but at the way the author models the contribution of government services to the productivity of the private sector.

1. What are productive government services?

The innovation of this paper is contained in the production function, equation (9):

$$(9) \quad y = f(k,g) = Ak^{1-\alpha}g^{\alpha}$$

where k denotes human and physical capital and g denotes government services. A first comment on the specification is that it is the assumption of constant returns to sale in k and g together that transforms equation (9), which describes production at one point in time, into a growth story; government services do not make a direct contribution to growth, for example in capital accumulation. Presumably the main results of the paper concerning the optimal shares of government expenditure and taxes would still go through in model which exhibited decreasing returns to scale. The only difference would be that government expenditure and taxes would affect the steady state level of output, instead of its growth rate. While the choice of constant or decreasing returns to scale is a difficult one to make on a priori grounds, it is difficult to imagine why doubling the (physical and human) capital per capita and the amount of government services should lead to a doubling of output. The assumption of constant returns to scale in the per capita terms g and k implies of course increasing returns in the three factors government services, capital, and population.

However, since the main innovation of the paper lies this specification of the contribution of government services to productivity, the author should explain more fully, as he did in his oral presentation the nature of the government services that are supposed to be represented by g. One way to get a better idea of what g might represent is t ook at Table 1 which contains a crude breakdown

of actual government expenditure for a group on countries with widely differing growth rates: Argentina, Korea, and the United States. 1/

The data in Table 1, which refer to the consolidated central government show that the biggest item for the U.S. and Argentina is "Social Security and Welfare," which does not seem to represent an essential service for the private sector. The only important items that might correspond to the g in equation (9) would be the classic ones of external security and economic services (i.e., infrastructure). However, security is a typical service that is "non-rival" in the sense that one person can use more of this service without affecting the amount of service received by others, even at a given supply. The author claims (page 8) that his analysis could be modified to include this aspect without changing the nature of the results. However, I would doubt this claim since, except for Section 4, the analysis of the paper is based on the assumption that each household/producer receives an amount of g that is fixed in the sense that his or her actions cannot change this amount. This is not an appropriate assumption for public goods like security, as the author acknowledges in the section dealing with an alternative specification for public services. Indeed, if, as assumed in that section, the amount of public services consumed is proportional to wealth or income, the income tax is just an efficient pricing mechansim for these services. But even the specification of Section 4 does not seem to take into account the non-rival nature of public goods like security.

1/ The data is from the IMF publication Government Financial Statistics.

This leaves economic services (i.e., infrastructure) as the main candidate to represent g. But since a large part of the infrastructure (like roads, ports, canals, etc.) consists of services that could be subject to user fees, it is not clear whether a large part of the services could not just be treated as other intermediate inputs provided by the private sector. It is also interesting to note that economic services amount to only about 4 to 5 percent of GDP in the three countries considered here (20 percent to total expenditure which in turn is roughly 20-25 percent of GDP).

One might be tempted to assume that education would represent g since a higher level of education should raise productivity. But this would contradict the assumption that the variable k represents both physical and human capital. A change in the resources devoted to education should then affect the growth rate of k directly, which is not possible in this model.

It would therefore be crucial for the author to show more precisely which of the public services actually provided by the government has the characteristics of his variable g. For the empirical part, this would then allow him to see why Korea grows so much faster than Argentina; because it has a better infrastructure, a better legal system, or better security?

A better identification of the nature of g would also allow the author to discuss the implications of his framework for growth accounting exercises. Taken literally, his ananlysis suggests that the observed residual is due to government services which are not properly accounted for. This would mean that the share of government services in

GDP, α, should be large. But intuitively, this is not very convincing. It seems unrealistic to argue that todays physical and human capital is so much more productive simply because the infrastructure is so much better or because property rights are better enforced.

Casual observation suggests that not all governments are equally efficient in transforming a given amount of tax revenue in productivce services. One way to incorporate this into this framework would be by assuming that the output of g is related to tax revenue by:

$$(10') \qquad g = \tau y B$$

where B represents a parameter that indicates how many units of g the government can produce with one unit of output it obtains through taxes. One could imagine B as being determined by the nature of g and the *efficiency* of the government. Viewed in the latter perspective a government that is an inefficient producer of g would have a low value of B. An increase in B would act just like an increase in the overall productivity parameter t as can be seen by substituting (10') back into (8), which yields:

$$(12') \qquad y = A^{\frac{1}{1-\alpha}} B^{\frac{\alpha}{1-\alpha}} k \, \tau^{\frac{\alpha}{1-\alpha}}$$

The value of B will, therefore, not affect the optimal size of the government since it affects the effect of τ on growth rates proportionally. The value of B will, however, affect the actual growth

rates associated with the optimal choice $\alpha = T$. 1/ Figure 1 shows that a drop in the efficiency of the government to one half ($B = 0.5$) would actually lead to negative growth rates for the parameter values chosen in the paper itself.

In his discussion of empirial work, the author mentions that cross-country differences in the productivity of the government could be expressed by different values of α, however, it might be more realistic to assume that B varies, as were, that is, some governments provide more services for the same tax revenue, as others.

In the framework of this paper, private production of output, y, is subject to decreasing returns to scale in the private factor, k. In contrast, the government production of services, g, is subject to constant returns to scale in the resources the government collects through taxes, τy. This asymmetry is necessary for the model to remain a growth story, since if there were diminishing returns to scale in the production of government services, there would also be overall diminishing returns to scale. This can be illustrated by assuming that g is produced by the government via:

$$(10'') \quad g = (\tau y)^{\delta}$$

with $\delta \leq 1$. Substituting this relationship into equation (9) to obtain the "reduced form" production function yields:

$$(12'') \qquad y = A^{\frac{1}{1-\alpha\delta}} k^{\frac{1-\alpha}{1-\alpha\delta}} \tau^{\frac{\alpha\delta}{1-\alpha\delta}}$$

1/ I have to thank the author for pointing out an error which had led me to believe that the value of B would affect the optimal tax rate.

It is apparent that with $\delta < 1$ there are overall diminishing returns to scale. 1/ The assumption of diminishing returns to scale in the production of g has some intuitive appeal if one considers that the productive services provided by the first road or by the first policeman should certainly be higher than the marginal increase in the services provided by an additional road in a country which already has a lot and the additional policeman in a country with a large policy force. This observation should not be taken as a criterium since the model would still lead to an interesting discussion of the optimal size of the government. It only suggests that the comparative advantage of this model might not be an analysis of the relationship between government size and growth, but rather an analysis of the optimal size of government per se.

2. Sensitivity of the results to the functional form

Standard growth models "work" with very mild restrictions on the functional form of the production and utility functions. Since the main contribution of this paper is to introduce the role of government in production, it would be interesting to see whether the spirit of the results survives in a slightly more general specification of the production function. given that the author uses a Cobb-Douglas

1/ Compare this to equation (12) in the paper which is linear in k.

specification, it seems natural to go to a CES function; equation (9) could then be written as: 1/

$$(1) \quad y = A[(1-\alpha)k^{\theta} + \alpha g^{\theta}]^{1/\theta}$$

Using the budget constraint (10), the "reduced form" production function is then given by:

$$(2) \quad y = A(1-\alpha)^{1/\theta} k\ [1 - \alpha(A\tau)^{\theta}]^{-1/\theta}$$

It can then be shown that the socially optimal planning solution for the tax rate is: 2/

$$(3) \quad \tau_p = \alpha^{1/(1-\theta)} A^{\theta/(1-\theta)}$$

This equation shows immediately that there exists a solution inside the interval [0, 1] only for certain combinations of α, θ, and A. This implies that under a slightly more general specification there might be no equilibrium, and in general the optimal tax rate depends on a host of different factors. This result comes from the feature of the CES function that the government is not essential for production; $y > 0$ is possible even if $g = 0$. Using the CES specification, the optimal tax in a second best world would be given by: 3/

1/ The limiting case of $\theta = 1$ gives equation (9) in the paper. The CES function, per se, does not satisfy the Ianada conditions. However, the Ianada conditions cannot be used in this context since the "reduced form" production function, equation (12) in the paper is linear in k and therefore requires restrictions on A.

2/ See Appendix.

3/ See Appendix.

$$(4) \quad \tau = \alpha^{1/(1-\theta)} A^{\theta/(1-\theta)} [\theta(\tau-1) + 1]^{1/(1-\theta)}$$

It is apparent that this tax rate is different from the planning tax rate. The result that the optimal planning and second best tax rates are equal is therefore definitely a special feature of the Cobb-Doublas functional form of the production function. Figure 3 shows the optimum and second best growth rates for two values of θ, $\theta = 0.5$, and $\theta = -0.5$, it is apparent, that for $\theta = -0.5$ (which corresponds to an elasticity of substitutions of 2/3) the optimal planned and second best growth rates diverge dramatically.

In conclusion I would like to say that the author has produced a thoughtful, elegant, and stimulating paper, just what one has come to expect from him. Most of the comments I have been able to offer could be viewed just as attempts to indicate where the analysis might be amended to convince even the skeptical reader.

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Appendix

The optimal tax rates with the CES production function can be computed easily for the social optimum since the "reduced form" production function (2) implies that the net social marginal product of k is given by:

$$\text{(A.1)} \quad (1-\tau)\, f_k = (1-\tau)\, A(1-\alpha)^{1/\theta}[1 - \alpha(A\tau)]^{-1/\theta}$$

The planning growth rate, γ_p, is the equal to:

$$\text{(A.2)} \quad \gamma_p = \frac{1}{\sigma}\,[(1-\tau)A(1-\alpha)^{1/\theta}[1 - \alpha(A\tau)^{\theta}]^{-1/\theta} - \rho]$$

The F.O.C. for a maximum of γ_p with respect to τ implies that:

$$\text{(A.3)} \quad 0 = -[1-\alpha(A\tau)^{\theta}]^{-1/\theta} + (1-\tau)[1-\alpha(A\tau)^{\theta}]^{-((1-\theta)+1)}\,\alpha A^{\theta}\tau^{\theta-1}$$

which can be transformed into equation (3) by rewriting it as:

$$\text{(A.4)} \quad 1 - \alpha A^{\theta}\tau^{\theta} = (1-\tau)\,\alpha A^{\theta}\tau^{\theta-1}$$

To calculate the second best growth rate, γ, it is first necessary to calculate the private marginal product of capital:

$$\text{(A.5)} \quad f_k = A(1-\alpha)\,[(1-\alpha) + \alpha(g/k)^{\theta}]^{(1-\theta)/\theta}$$

To calculate the term g/k, use the relationship $(g/k) = (g/y)(y/k)$ as in Barro's paper, this implies:

$$\text{(A.6)} \quad (g/k) = \tau\,[A(1-\alpha)^{1/\theta}][1 - \alpha\,(A\tau)^{\theta}]^{-1/\theta}$$

After substition of this relationship into equation (A.5) and some simplifications γ can be shown to be determined by:

$$\text{(A.7)} \quad \gamma = \frac{1}{\sigma} \{[A(1-\alpha)^{1/\theta} (1-\tau)[1 - \alpha(A\tau)^{\theta}]^{(\theta-1)/\theta} - \rho\}$$

The F.O.C. for a maximum of γ with respect to τ then implies:

$$\text{(A.8)} \quad 0 = -[1 - \alpha(A\tau)^{\theta}]^{(\theta-1)/\theta} - (1-\tau)(\theta-1)[1 - \alpha(A\tau)^{\theta}]^{((\theta-1)/\theta)-1} \alpha A^{\theta}$$

This can be simplified again by transforming it to:

$$\text{(A.9)} \quad 1 - \alpha (A\tau)^{\theta} = (1-\tau)(1-\theta) \alpha A^{\theta} \tau^{\theta-1}$$

from which equation (4) can be obtained easily.

Table 1. Government Expenditure by Function 1/

(In percentage of total)

	United States 2/		Argentina 3/	Korea
General public services	5.2	(8.1)	7.1	10.5
Defense	24.9	(16.8)	5.2	29.7
Education	1.8	(13.7)	6.0	18.4
Health	11.3	(11.5)	1.3	1.4
Social security and welfare	29.1	(24.6)	32.6	5.7
Housing and community amentities	2.5	(...)	0.4	1.0
Other community and social services	0.3	(0.1)	0.5	1.1
Economic services	8.3	(6.4)	18.5	17.5
Other purposes	16.7	(15.3)	24.9	14.7
Memorandum item: Ratio of total expenditure to GDP	24.6	(36.5)	23.7	17.7

1/ All data are taken from Government Financial Statistics and refer to Table B, Expenditure by Function, Consolidated Central Government, for the year 1985.

2/ Data in parentheses for the United States refer to general government.

3/ The total of 96.4 percent is due to an additional item called "Adjustment to Cash Expenditure."