How do National Policies Affect Long-run Growth?

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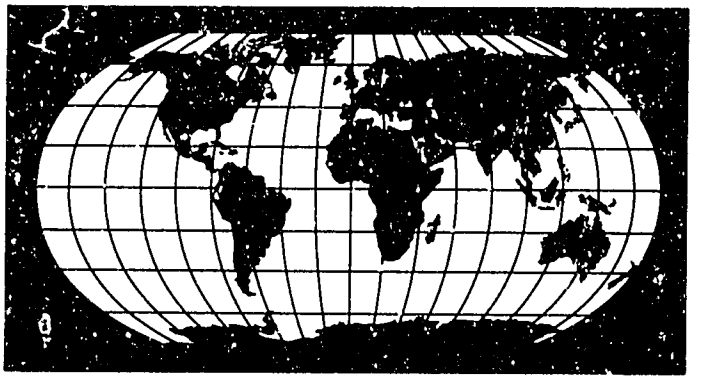

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"Idea Gaps and Object Gaps in Economic Development"

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Idea Gaps and Object Gaps in Economic Development

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To keep track of the wide range of existing explanations for persistent poverty in developing nations, it helps to have two extreme views in mind. The first is based on an Object Gap: Nations are poor because they lack valuable objects like factories, roads, and raw materials. The second interpretation invokes an Idea Gap: Nations are poor because its citizens do not have access to the ideas that are used in industrial nations to generate economic value. These explanations are not mutually exclusive. A developing nation can suffer from both gaps at the same time. Moreover, distinguishing between the two gaps is not important for reaching some policy conclusions. According to either explanation, a functioning legal system, stable monetary policy, and effective support for education, will all be desirable policy goals.

Nevertheless, each gap imparts a distinctive thrust to the analysis of development policy. The object gap highlights saving and accumulation. The idea gap directs attention to

the patterns of interaction between a developing country and the rest of the world. In particular, it suggests that there is a special role for multinational corporations as the conduits that let productive ideas flow across geographical regions and national boundaries. Because their implications differ, economists must make an accurate assessment of the relative importance of idea gaps and object gaps before they can provide comprehensive guidance on development policy. The essence of the argument presented in this paper is the claim that progress toward a consensus on this issue will require both the abstract theorizing characteristic of one tradition in economics and the attention to a very broad range of qualitative evidence characteristic of other traditions.

One of the chronic temptations in economic analysis is to reduce a two-gap vision of the world to a single, all encompassing gap that somehow captures everything about the stages of development. To see why this is dangerous, it helps to have a concrete example in mind that illustrates how the two gaps differ. Suppose that you are an experienced writer, familiar with word processing on personal computers. An impoverished colleague comes to you with a 1000 page, hand-written manuscript and asks for your advice about how to produce a typed version on a word processor. If he has neither a computer nor any experience with word processing software, he suffers from an object gap. He lacks both the piece of physical capital (the computer) and the human capital (knowledge of how to use it) necessary to type the manuscript himself.

Now suppose that a second colleague, who has a computer and knows how to use word processing software, comes to you because she has accidentally issued the command that deletes the computer file containing the only copy of her just completed, 1000 page

manuscript. She asks you if there is any feasible way to recover the information stored in this file. Because you are knowledgeable about computers, you know that there are inexpensive, easy to use utility programs that will recover the deleted computer file. Because your colleague does not know this, she suffers from an idea gap.

A correct, and important assertion made by those who emphasize the importance of object gaps is that human capital -- measured the way that a labor economist would measure it, in years of schooling or experience -- is one of the most important objects that an economy, or a person, can lack. To be excruciatingly literal, the object in question is a brain. A brain that has had its neural connections rearranged by education and experience is more valuable than one that has not. A prerequisite for careful thinking about the two gaps is to understand that human capital (a brain with connections that store the commands for using a computer) is more like the computer in the example of the two writers than the piece of information you possess about the existence of file recovery procedures.

The abstract or formal reasons for making a distinction between objects and ideas in economic analysis have been elaborated elsewhere. (Romer, 1993.) A preliminary goal in this paper is to suggest why mainstream economists seem to have been more comfortable dealing with objects than ideas, and why there are other kinds of economists who have concluded, on the basis of a broad range of qualitative evidence, that idea gaps are of decisive importance. The ultimate goal of the paper is to combine the formal mathematical models and statistical evidence characteristic of mainstream macroeconomic analysis with the broad reading of the evidence characteristic of these other intellectual traditions, using both to support the claim that idea gaps are crucial for understanding the experience of developing

countries.

There are no easy solutions to an object gap. If you want to help your first colleague get his manuscript entered into a computer file, you can buy a computer for him and teach him how to use it. Alternatively, you can tell him he must save up his money, buy his own computer, and go to school to learn how to use it. Either way, the costs will be high and it may take a long time for him to catch up with you. Recent work emphasizing object gaps has therefore lent a pessimistic, almost Calvinistic tone to policy advice. "These countries are poor because they consumed too much in the past and did not accumulate lots of objects like the rest of us did. To achieve a better standard of living, they must tighten their belts, reduce their current standard of living, accumulate more capital, and pay for a better system of public education." Bad policy may be identified as the cause of the previous failure to save, but once policy impediments are removed, countries that are already poor face the grim prospect of still further cuts in current standards of living to achieve a better future.

Idea gaps, in contrast, are easy to solve, at least in principle. You can tell your colleague with the deleted file to leave the computer alone, buy program X, and follow its instructions for emergency file recovery. At the cost of a few seconds of your time, you can save her thousands of hours of work. This disparity between the small costs to the supplier of an idea and the large benefits to the recipient are characteristic of idea gaps. The large potential surplus or gain from trade arises from the defining characteristic of ideas as economic goods. An idea is something that you can give to someone else yet still retain for your own use.

The idea gap explanation for persistent poverty therefore offers a more optimistic

picture of the potential for rapid development, but it also possesses a dark side that has influenced the political economy of development. The large surplus created by trade in ideas raises difficult issues about how the surplus is or should be distributed. Instead of explaining about file recovery software, you could tell your second colleague that you will recover the file for a fee of, say, $10,000. If she is desperate and in enough of a hurry, she might agree. If she did, she would presumably be better off than if she had not met you and had used her disk in a way that made file recovery impossible. But once she learns how simple and inexpensive file recovery is, she will no doubt experience intense emotional distress. Economists sometimes argue, in effect, that how hard or expensive it is for you to recover the file should not affect how she feels about the transaction. But economists also argue that we do not have any business telling people how they should feel about different outcomes. Experience suggests that feelings about the division of the gains from trade are very important in relationships between colleagues, and also in the politics of development.

Without denying that objectives are important, this paper points to a wide variety of evidence suggesting that an important fraction of worldwide poverty may be due to an idea gap that can, at least in principle, be reduced relatively quickly and at relatively low cost. Cross country regression evidence on the role of machinery imports and direct foreign investment, historical accounts of the transmission of technology, and case studies of individual country performance and individual industries all point to the important role played by international flows of ideas. This paper also relates this claim both to other evidence presented at this conference -- for example the high apparent returns to equipment investment identified by De Long and Summers, the role of macroeconomic instability

studied by Stanley Fischer, and the variability of growth rates over time noted by Easterly et al -- and to previous evidence pointing to the importance of human capital in fostering growth and to the possibility that poor countries can sometimes catch up rapidly with developed countries. All this evidence makes more sense in a world characterized by both idea gaps and object gaps than it does in a world characterized by object gaps alone.

To anticipate part of this discussion, if the finding by De Long and Summers of extremely high returns on equipment investment is interpreted in the context of an object gap model, the very large apparent spillovers from investment in physical capital are difficult to reconcile with what we know about production and investment at the level of the firm. In world of objects, these findings would also seem to endorse, or at least be consistent with, a government policy program of autarky, closed borders, and aggressive domestic capital accumulation. On the basis of other evidence (for example, the experience in the former Soviet Union), De Long and Summers acknowledge that this kind of policy would be unwise, but in a theoretical framework that implicitly allows only for objects, it is hard to be precise about why this is so. Once their results are interpreted in the context of a world with idea gaps, the findings make perfect sense at the micro level and lead to policy prescriptions about openness that are more consistent with the general pattern of development. In a world with objects and ideas, equipment investment serves two functions. It gives an economy additional objects used in production. It also brings into local use the new ideas that are embedded in the designs contained in a steady flow of new types of capital goods.

The optimistic fact emphasized by the idea gap approach to economic development is that the industrial nations of the world already possess all of the knowledge needed to

provide a decent standard of living for everyone on Earth. The citizens of the poorest countries of the world can benefit enormously from this knowledge if they can gain access to it. It is true that many countries lack important objects, but these object gaps create the usual opportunities for gains from trade that arise whenever objects are more scarce in one region than another. We can lend them the nonhuman objects that they need to our mutual benefit. And for the human capital they lack, crucial pieces of specialized, highly trained human capital can be put to work domestically by inviting in managers or technicians from abroad, and more human capital can be acquired through on-the-job training than a narrow emphasis on schooling would suggest.

The optimistic view of the potential for development suggested by idea gaps is consistent with the experience of a few, very rapidly growing economies. In fact, idea gaps offer the best way to explain these cases of dramatic success. But if the potential for rapid development is so great, why is poverty still so common?

Part of the answer is suggested by other papers presented in this conference. If the local government does not provide the basic institutional infrastructure required for market exchange -- for example, if the financial system fails to offer an effective payments system or to match borrowers and lenders, if market prices are distorted by an unstable monetary and exchange rate regime, if the government neither provides basic physical infrastructure nor lets the private sector provide it, and if, in extreme cases, property rights flow from the barrel of a gun -- it is no surprise that the gains from trade in ideas cannot be realized.

In the face of evidence of massive governmental failure, economists have little to say except to avoid it if possible. There is, however, another difficulty that economic analysis

may be more helpful in resolving. The poorest countries face the same difficulty in their dealings with the developed world that confronts your colleague with the deleted computer file in her dealings with you. She must give you an incentive to put your ideas to work for her, even though she knows that there is a risk that she is exposing herself to opportunistic or exploitative behavior. For a developing country, one of the most important and easily implemented aspects of policy for a minimally functional government is to ensure that ideas flow readily from the rest of the world. Economists can encourage governments to tolerate or support this flow by making it clear how very costly it is in terms of domestic welfare if a nation indulges its taste for preventing more affluent foreigners from benefiting in any way from the nation's position as a late comer in the development process.

Access to the ideas available in the rest of the world comes partly through free flows of the capital goods that are produced in the industrialized nations of the world and that embody new ideas. For the very poorest nations, this surely is the lesson from the De Long and Summers evidence about the importance of equipment investment. But successful development also requires a mechanism for ensuring adequate flows of the large quantity of disembodied ideas that are used in production. The government of a poor country can therefore help its residents by creating an economic environment that offers an adequate reward to multinational corporations when they bring ideas from the rest of the world and put them to use with domestic resources. There may be other mechanisms for tapping into these disembodied ideas -- sending students abroad for advanced education or giving incentives for individuals with special skills and knowledge to migrate into the economy. There may also be important complementary investments that the government must make --

in infrastructure, a legal system, or in the general level of education. But for developing economies, local productive activities by multinational firms offer the quickest and most reliable way to reduce the idea gaps that keep them poor.

I. Intellectual Background on Ideas and Objects

The basic assertions made in this paper about the importance of idea gaps in economic development will ultimately be accepted or rejected on the basis of the strength of the empirical evidence that can be produced to support them. Economists do not, however, evaluate evidence in a vacuum. Discussions about evidence and its interpretation take place in the context of a long history of debate. Each paper, and each person, comes into one of these extended intellectual conversations in the middle.

This section reviews part of the larger intellectual background in the economics profession as a whole that bears on the issues at hand. It identifies two broad traditions in economics, the mainstream or neoclassical tradition that has generally pushed objects into the foreground, and a dissenting tradition that emphasizes ideas. Understanding the strengths of both of these traditions and the gulf that exists between them is important because this paper tries to take advantage of elements from both. It supports the mainstream tradition of using highly abstract mathematical models because models can facilitate communication and understanding. It also tries to adopt, or at least suggest the value of, an open-minded evaluation of the large body of qualitative evidence that bears on the questions at hand.

I. A. The Rise of Price Taking and the Fall of Ideas

There is nothing new or original about the assertion that ideas and objects are both important in the creation of wealth. Adam Smith emphasized that it is the objects used as inputs in production, not monetary tokens, that constitute the true wealth of a nation. Yet Smith, and every economist since, also understood that these objects are of no inherent value as inputs without knowledge of how to combine them in ways that generate valuable outputs. Economists have used different terms -- invention, innovation, discovery, technological change -- but they always recognized that changes in the stock of an intangible factor representing something like knowledge or ideas was a crucial input in creating high, and rising, standards of living.

If it takes both stocks of physical objects and stocks of ideas about how to use them to produce economic output, it follows that countries that produce less output per capita have smaller per capita stocks of ideas, objects, or both. What has varied is the relative importance that economists attribute to these two fundamental classes of inputs, both in explanations of long run economic growth in the leading economies of the world, and in explanations of the variation in output per capita across nations at a point in time.

Over time, the economics profession has moved toward ever greater reliance on mathematics as the language of intellectual discourse. As it did, objects took precedence over ideas for purely technical reasons. The operation of the invisible hand is relatively easy to formalize in a world of objects. Objects lend themselves readily to analysis in terms of convex opportunity sets and price-taking competition. In this framework, all of the

mathematical machinery of convex optimization comes into play, including the suggestive duality between quantities and shadow prices, or equivalently, between optimization and equilibrium. Ideas, however, are inherently associated with fixed costs or nonconvexities, and are therefore inconsistent with price-taking. Ideas, like Smith's closely related discussion of specialization and the division of labor, were pushed aside as the mathematics of convexity took on greater importance in economic reasoning.

In Marshallian analysis at the level of firm or industry, it had been possible to consider both the price-taking behavior of a competitive firm and the price-setting behavior of a monopolist. But as economists, especially macroeconomists, pushed the analysis to the level of a general equilibrium in the economy as a whole, there was no way to maintain this symmetry. The mathematical description of an entire economy could only be undertaken in the context of perfect competition. Joan Robinson ( ) and Edward Chamberlain ( ) tried, without much success, to keep the profession from following what Paul Krugman has called the "path of mathematical least resistance" towards ever greater reliance on perfect price-taking competition.

In the three decades following WWII, the mathematical program for the economics profession laid out in Samuelson's Foundations of Economic Analysis came into full fruition. In the 1950s and 1960s, the analysis of macroeconomic fluctuations was temporarily set aside and subjected to an entirely different form of analysis, but in all other areas of aggregative or economy wide analysis, perfect competition reigned supreme. And with the emergence of real business cycle theory in the 1980s, even macro fluctuations were brought under the domain of perfect competition. In trade theory (following

Samuelson), growth theory (following Solow), and welfare economics (following Arrow and Debreu), our understanding was built on a foundation of price taking in perfect markets (and of course a long list of caveats sufficient to justify any policy intervention deemed to be worthwhile.)

Economists are often accused of having an ideological belief in laissez faire that skews their modeling preferences toward perfect competition, but this diagnosis has it backward. In the profession as a whole, we have an aesthetic or technical preference for perfect competition, and have nevertheless been able to rationalize extensive forms of intervention. Ironically, the formal advocates of perfect competition may in fact have substantially underestimated the advantages of markets, advantages of the kind suggested by Schumpeter or Hayek that go far beyond getting tangency conditions right. These advantages may have been better appreciated by economists such as Richard Nelson ( ) who explicitly rejected the standard elements in the defense of markets -- price taking and individual optimization.

With the application of computable, aggregate models of perfect competition to questions in areas as diverse as economic history and tax policy, and with the development of the modern theory of efficient financial markets, price-taking models of perfect competition invaded all of the most important areas in aggregate economic analysis and dominated most of them. Along the way, ideas got lost because their intrinsic nonconvexities were inimical to an analysis in terms of price-taking. Much of the lip service that economists offered about why ideas were different from objects focused on incomplete property rights, but these are quite easy to include in a price-taking model. This is precisely what price-taking models

with external effects or spillovers do. Economists also pointed to the risks associated with the invention or discovery of new ideas, but in a time when the theory of finance showed that competitive equilibrium theory could easily accommodate risk and when accumulating evidence suggested that financial markets performed better than many economists had suspected, the risks inherent in the production of new ideas could hardly have been the decisive difference separating ideas from objects. The fundamental difficulty, immediately obvious in the analysis of patents, was the one that Schumpeter (1942) had emphasized. Any degree of property rights over ideas leads inevitably to price-setting and market power, concepts that are technically difficult to add into a aggregate, equilibrium model.

As a result, ideas suffered not from hostility but rather from neglect. The development of growth theory after Solow (1956,1957) is illustrative. No one really thought that technological change was exogenous, and everyone presumably expected that this provisional assumption, made only for analytical convenience, would subsequently be abandoned in a second round of theorizing. Yet despite a variety of early theoretical efforts at understanding technological change at the macro level (Kaldor , Arrow 1962, Shell 1966, Nordhaus 1967) and despite a body of micro level empirical and theoretical work on technological change that is far to large to begin to catalog here, aggregate growth theory stayed close to the formulation adopted by Solow, and a whole generation of macroeconomists came to view exogenous technological change less as a provisional theoretical crutch and more as a reasonable description of how the world works.

An extremely important contribution to the vision of competitive behavior that developed in the post-war era was the articulation in labor economics of human capital

theory. To restate their case in the starkest (and most dehumanizing) terms possible, economists like Gary Becker ( ) showed that human capital could be understood in exactly the same way that we understand the canine capital of a seeing-eye dog. In each case, costly resources are invested to make a durable object (the brain of a person or dog) a more valuable input in production. Production in this sense is just like the production that takes place when a press bends metal. For institutional reasons, we use rental contracts and prices for human capital instead of the sale prices and contracts used for canine capital and steel, but the basic elements of competitive analysis are the same.

Technically, human capital theory was an analytical success precisely because it stayed so close to the emphasis on objects inherent in the rest of economic theory. Nevertheless, our everyday experience with education, the most important investment activity in human capital theory, suggested that human capital was somehow connected to ideas. By embracing human capital theory, one might have hoped that economic analysis could somehow get closer to capturing the elusive role of ideas in economic production. A fundamental claim of this paper is that this hope was largely mistaken. As important as human capital theory is as an extension of the economics of objects, it does not capture the essential aspects of the economics of ideas. Human capital theory gets it right when it explains why the writer with no experience with word processing software faces large costs in learning to type a manuscript. It also gives us the correct framework for thinking about the equilibrium rental price for the time of someone who knows how to use word processing software and who sells his services on the market. But it entirely misses the essence of the transaction between someone who knows about file recovery software and the writer with the

deleted file who does not.

I. B. Dissent from the mainstream position

Many parallel lines of dissent emerged in response to the trend in mainstream analysis toward ever greater reliance on mathematics and therefore, on perfect price-taking competition. These dissenting positions range from the Austrians on the right to the post-Keynesians on the left. For the analysis of questions pertaining to development, one important group developed around the study of technology, both in a historical context (e.g. David, 1992, Rosenberg , Mokyr, 1991) and in a modern industrial context (as exemplified by the work of the Science Policy Research Unit at the University of Sussex or at MERIT at the University of Limburg in the Netherlands.) In addition to work on science policy and technology, a closely related line of work, which traces its recent origins to the work of Nelson and Winter (1982), emphasized an evolutionary approach to economic analysis that required neither price-taking nor explicit maximization in its description of market outcomes. Both of these overlapping lines of inquiry distinguish themselves from mainstream analysis in large part by placing ideas at the center of the analytical framework. For example, Dosi, Pavitt, and Soete (1990) treat trade theory along these lines and Dosi, et al (1992) for a similarly motivated discussion of development and catching up. Both of these studies position themselves in opposition to mainstream theory by dismissing, or at least down

playing, the importance of conventional object related issues like factor endowments or capital accumulation.

Because of the technical difficulties intrinsic in giving a mathematical representation of ideas as economic goods (and in capturing other complicated aspects of economic behavior such as the limited mental capacity for memory storage and calculation possessed by people) the theoretical work in these traditions has until recently relied primarily on what Nelson and Winter call "appreciative theory": theory that is less abstract, more descriptive, more verbal, and closer to practice and to real world context. (Work in this vein is beginning to supplement this kind of verbal theory with computer simulation, following the lead suggested by Nelson and Winter did more than 10 years ago, but it is too early to tell whether this style of theory on the computer will finally take hold.) The appreciative theory was able to sustain contact with the analysis of an economist such as Joseph Schumpeter to a much greater extent than could the formal mathematical analysis of mainstream economic growth theory, which for many years lost all contact with concepts such as market power or creative destruction. At the same time, the growing divergence in styles of theory made communication between these groups and mainstream theorists more difficult.

The key elements in the appreciative theory of economic development are the gap between the level of technology in a developing country and in the rest of the world and the social absorption capability of the developing country. In this branch of theory, the notion of a idea gap is referred to as a technology gap. (Authors working in this tradition cite Veblen, 1915, or Schumpeter, 1934, as important early statements of this view. Early historical accounts of development, e.g. Gerschenkron, 1962, made use of this concept. Nelson and

Phelps, 1966, give a formal description of how human capital increases absorption capability.) Technology is taken as a largely undefined primitive, but as something that differs from objects in the crucial sense that it can be replicated and used all over the world. Technology in use in one place can be converted into a communicable form (possibly at a cost) and sent to another place. There, it can be put to use if the recipients have the capacity to receive or absorb this information. Absorption capability is a characteristic of an economy or society as a whole. It depends in an expected fashion on ordinary inputs like a level of human capital adequate to make use of information from somewhere else, but also on the larger institutional framework, the national innovation system, present in the economy. The educational system, firms, and research institutions -- both public and private -- all contribute to this institutional framework. The tension in this theory arises from the fact that a technology gap presents an opportunity for rapid growth through technology flows, but a reduced absorption capability makes it more difficult for a country to take advantage of this opportunity. Because a poor developing economy will typically suffer from both a large technology gap and a reduced absorption capacity, the prediction about the correlation between the initial level of income and the rate of growth ambiguous. However, high indicators of absorption capacity (for example, a higher level of education in the population) imply a faster rate of growth for a country facing a given technology gap.

The notion of an idea gap invoked in this paper includes the concepts that previous authors have had in mind when they speak of a technology gap, but it is intended to suggest something broader. The word technology invokes images of manufacturing, of things that happen in factories, but most economic activity takes places outside of the manufacturing

sector. Ideas include the innumerable insights in areas such as marketing, distribution, inventory management, corporate organization, information systems, supervision, quality control, and worker motivation that all combine to make an modern economy function. If one looks carefully at the details of a corporation such as Frito-Lay, one sees that there are as many subtle ideas involved in supplying potato chips as there are in computer chips, and that the ideas involved in supplying the potato chips are probably more important for successful development in the poorest countries.

II. Endogenous Growth Theory

During the 1980s, mainstream growth theory entered a phase of renewed activity. This work was clearly in the mainstream tradition in its style of modeling -- simple abstract mathematical models that make extensive use of optimization and foresight. It was therefore flawed from the point of view of the dissenting lines of work, but it did begin to move part way toward the emphasis in that work on the role of ideas. To do this, it had to depart from the usual reliance on price-taking with perfect competition. In so doing, it was following a trajectory that in retrospect appears to have been inevitable. Following developments in many other areas of analysis (most notably in trade theory), growth theorists first freed themselves from the constraints imposed by perfect price-taking competition by introduced increasing returns that were external to the firm. This let the analysis introduce increasing

returns while still retaining the assumption of price-taking. This style of formal analysis -- price-taking with external effects -- followed closely along the lines of the existing analysis of dynamic models.

The use of external increasing returns to understand long run economic progress goes all the way back to Marshall's introduction of a downward industry sloping supply curve. (This, after all, was why he introduced external effects in the first place. Smoke and bees came later.) Arrow (1962) gave the first explicit dynamic analysis of equilibrium with external increasing returns, in his case emphasizing knowledge spillovers that were associated with investment in physical capital. I published a model (1986) with spillovers from private investments in the production of pure knowledge. Lucas (1988) made the first explicit connection between human capital accumulation and spillovers.

In retrospect, these models were correct in emphasizing that knowledge was intimately related to a form of aggregate increasing returns. Indeed, this had been evident ever since the 1960s at least. Once one writes a production function for firm j in the form $Y_j = A\,F(K_j,L_j)$ or $Y_j = F(K_j,AL_j)$, and assumes that the function F is homogenous of degree one, one is confronted with the fact that output exhibits increasing returns as a function of both the objects K and L, and the ideas, A. The telling, and crucial fact about the ideas represented by A is that they have no index j. They can be used by all firms in the economy at the same time. (For an extensive discussion of why this aspect, this attribute of nonrivalry or simultaneous use is the crucial characteristic that distinguishes ideas from objects, see Romer 1993. For a formal discussion of why this aspect is unavoidably linked to nonconvexities and aggregate level increasing returns, see Romer 1990.)

There first round models were inadequate in the sense that they did not fully capture the notion that private property rights over ideas lead inevitably to monopoly pricing. At least some small degree of control, secrecy or property rights over ideas is required if we are to understand why economic agents devote resources to discovery, invention, refinement or diffusion of ideas. But as Stiglitz and Dasgupta ( ) have observed, the assumptions needed to make price-taking with external increasing returns theoretically consistent have a knife edge character. If a firm can capture for itself even a tiny amount of the knowledge that its other activities creates as a side effect, then an equilibrium with price-taking and many firms breaks down. Consequently, there is no way to capture any of the interesting economic implications of ideas in a model that tries to preserve price-taking.

A second round of growth models subsequently made the leap to equilibrium models of monopolistic competition -- that is, to models with price-setting behavior but also with free entry. Patents, ex post market power, product cycles, and innovation that destroys the rents captured by others could finally be brought back into the discussion of aggregate growth. As was the case for the external increasing returns models, there was at least one important precedent in the 1960s, Nordhaus (1967). Subsequently, the formal model of monopolistic competition developed by Dixit and Stiglitz ( ) greatly simplified that mathematical analysis of these models, and has been used in much of the subsequent work. Explicit dynamic model of the aggregate effects of patents and invention by Judd ( ) and Shleifer ( ) illustrated how aggregate analysis could still take place in a model with monopoly power, and both of these models showed how nonconvexities and market power at the micro level could have important, and surprising aggregate effects. With a lead of several years,

trade theorists had also made the switch from models with external increasing returns to models with monopolistic competition. (See the discussion in Krugman,) Given all of these developments, it was inevitable that fully dynamic models of persistent growth resulting from intentional research activities would follow along these lines, and they did. (Some of the early examples were Aghion and Howitt 1992, Grossman and Helpman 1990, Romer 1987, 1990, and Segerstrom et al .)

The lasting contribution, if any, from these second round or neo-Schumpeterian models will come from their ability to let mainstream economists look at the world and to see ideas where we previously failed to see them. One can hope that on the other side, they may add to the appreciative discussion of ideas by clarifying some of the subtleties of, say, the distinction between weak property rights and nonconvexities, or by emphasizing logical connection between nonconvexities and property rights on the one hand, and public and private goods on the other. Ideally, these models may help economists from both traditions see the restrictive and misleading nature of assumptions we implicitly have made in the past, for example that a divergence between social and private marginal products arises if and only if there are spillovers of some kind. (This point is elaborated below in the discussion of the De Long and Summers evidence on equipment investment.)

At the same time that one branch of work in endogenous growth theory was working its way along the well worn path from perfect price-taking competition to price-taking with external increasing returns, then proceeding on to internal increasing returns and monopolistic competition, another branch made the case for retaining the framework of perfect price-taking competition. This work made the logically correct point that persistent

or "endogenous" growth could take place in a world in which there are no increasing returns, no nonconvexities. To oversimplify the contribution of a complicated and rich set of models (in particular, Becker and Murphy, Jones and Manuelli , and Rebelo), one can observe that it is possible as a matter of pure theory that output is proportional to the stock of some object-like capital good that can nevertheless be accumulated without bound. In particular, it is possible to write down mathematical models with object-like (i.e. convex) technologies and therefore to make use of perfect competition as the equilibrium concept. This logical possibility -- growth without anything resembling technological change or discovery -- seemed empirically irrelevant when the only capital stock variable that could be accumulated was physical capital. In light of the fact that the elasticity of substitution between physical capital and labor seemed to be rather small, the prospects for persistent growth through physical capital accumulation alone seemed quite dim. However, once economists emphasized that human capital could be accumulated along with physical capital, this kind of assertion was could no longer be dismissed as being obviously false, especially if one did not distinguish carefully between human capital and the stock of ideas.

III. Recent Mainstream Empirical Work

Given the theoretical developments that took place during the last half of the 1980s, one might have hoped that empirical work would play a decisive role in resolving the fundamental issue in growth and development: Is variation in the stock of ideas an important

explanatory variable in understanding both long run growth and cross country patterns of development? As the story of the two writers in the introduction is intended to suggest, much turns on the answer. Unfortunately, mainstream empirical work has so far had almost nothing to say about this question.

This is not to say that this empirical work has been of no value. Cross country regression analyses motivated by recent work on growth have established two key facts about cross country patterns of growth. (The most influential papers in this large and rapidly growing empirical literature are by Robert Barro 1991, and Greg Mankiw, David Romer and David Weil, 1992.) The first fact that has emerged from the cross country analysis is that holding the right additional variables constant, poor countries seem to grow faster then rich countries. Among developing countries as a whole, there is no simple correlation between the level of initial income and subsequent development, but if one holds constant other explanatory variables, countries that start from a lower level of income seem to grow faster.

The second fact about which there is wide consensus is that for data averaged over moderately long periods of time (e.g. 10 to 25 years), growth in income per capita is correlated with the share of GDP devoted to investment. This correlation is robust in the sense that it holds regardless of the other variables that one partials out. For example, in a regression of growth rates on the investment share and a variety of other variables, the coefficient on the investment share is significantly different from zero with almost any choice of other included regressors. This finding is also robust in the sense that it is evident in any reasonably large sample of countries, regardless of the particular countries in the sample.

Despite the widespread sense that "we knew this all along," this was not the accepted wisdom even 5 years ago, at least not among mainstream macroeconomists. (When I presented one of the early papers demonstrating this correlation in the cross country data at the annual NBER Macroeconomics conference in 1987, I was confidently told that there is no correlation between investment and growth in developing countries.) Now that the correlation is accepted as being present in the data, it is still far from clear what causal interpretation should be attached to it. It could be that exogenous variation in investment rates causes variation in the growth rate. It could be that exogenous variation in the growth rate causes variation in the investment share. Or it could be that exogenous variation in some omitted variable affects both growth and the investment share. To anticipate the interpretation that will be stressed in the discussion of the De Long and Summers findings, microeconomic theory and evidence suggests that new ideas cause increases in investment by creating new investment opportunities, and that these ideas together with the subsequent investment both cause increases in the rate of growth. But whatever causal interpretation eventually emerges, the correlation between investment and growth is a highly pertinent fact. Many different models of growth would need to be rejected, or at least modified, if no such correlation existed.

Although the recent work has established these and other useful facts, it has not helped us come to any sense of the relative importance of idea gaps versus object gaps, nor even recognized this the key issue. The tendency in this literature -- one that seems to be characteristic of much of modern, theoretically based empirical work -- has been to rely on a strict interpretation of positivist methodology, posing precise hypotheses and trying to falsify

them. In this approach, a pure object gap model relying on perfect competition is typically taken as the null hypothesis. A frequent, and not very surprising, finding is that is not possible, on the basis of cross country regressions alone, to reject this null model. For example, the paper by Mankiw, D. Romer, and Weil fails to reject the hypothesis that output in different countries is characterized by a model of the form $Y=AF(K,L,H)$ and in which the level of the technology A is the same for all countries in the world.

The problem with a narrow positivist approach to the data is that cross country regressions have extremely limited power to reject any meaningful hypotheses. There are many different causal structures, and many entirely different interpretations of the world that are consistent with the correlations and partial correlations that one uncovers by running cross country regressions. Take for example, the interpretation of the finding that the growth rate is negatively correlated with the initial level of income. This has generally been interpreted as evidence in favor of pure object gap model. This correlation is interpreted as a sign of diminishing returns associated with physical capital accumulation along a transition to a steady state. (Barro and Sala i Martin , MRW) However, the presence of an object gap, with its associated signs of diminishing returns to physical capital accumulation, does not rule out the presence of an idea gap. Moreover, the fact that poor countries grow faster can with equal justice be interpreted as a sign of the importance of large idea gaps. Countries that initially make little use of the productive technologies available in the rest of the world can grow rapidly once these technologies are put to use within their borders. (Fagerberg, 1987, is an early example of a regression analysis that interprets a negative coefficient on initial income in this way.)

Some of the early models that tried to capture a role for ideas assumed that national borders were impermeable to flows of ideas. These models implied that being a latecomer in development conferred no advantage, or implied a strict disadvantage relative to advanced countries. (See for example my paper in 1986 or Lucas, 1988.) The evidence of a negative partial correlation between initial income and subsequent growth provides evidence against these particular models and is useful for this reason. (As indicated below, there also is abundant qualitative evidence that this strong assumption about national borders is wrong.) The regression evidence does not, however, shed any light on the broader question of whether there are important idea gaps, and whether economic incentives are an important determinant of the rate at which these gaps are exploited and narrowed.

A disadvantage of a narrow positivist approach to empirical work is that it encourages an excessively classical approach to statistical inference. It lets us treat identifying assumptions (e.g. that investment causes growth instead of vice versa) as reflecting prior knowledge that is certain, when in fact these assumptions are often dubious in the extreme. It also lets us treat null and alternative hypotheses asymmetrically, implicitly letting theoretical fashion or preference dictate which model gets preferential treatment as the null. In a body of data that can support many different identifying assumptions and in which the statistical power to reject any hypothesis is weak, the freedom to select the null hypothesis and the identifying assumptions is tantamount to freedom to guarantee acceptance. In addition, an emphasis on falsification tends to focus attention on a narrowly specified body of data that admits explicit quantification. A more natural Bayesian approach would weigh all of the available evidence in the process of attaching posterior probabilities to different

interpretations of observed events.

The association between increased theoretical reliance on perfect competition and a narrow interpretation of positivist empirical work has been noted before, most recently in discussions of economic fluctuations. For example, in his evaluation of real business cycle theory, Greg Mankiw (1989) objects to the kind of procedure used by real business cycle theorists of treating a model with prefect competition and exogenous productivity shocks as the null hypothesis and then failing to reject this model. As Prescott (1986) demonstrates, if you treat perfect competition as the null and calculate a growth accounting residual, one indeed finds large procyclical productivity shocks. Mankiw observes that there is much other evidence that bears on the presence of absence of large aggregate productivity shocks, evidence that is not captured in explicit statistical time series. To put this evidence to use in a scientific debate, Mankiw is forced to make use of rhetorical devices that invoke the readers own exposure to diverse information about what happens over the course of the business cycle. "My own reading of the newspaper does not, however, lead me to associate most recessions with some exogenous deterioration in the economy's productive capabilities" (p. 85) and presumably, so too does the readers reading of the newspaper and of many other pieces of evidence. (Another rhetorical device that serves the same function is a thought experiment.)

While we disagree about the role of idea gaps in economic development, Mankiw and I agree on the importance of making use of all of the available data in coming to conclusions about important policy questions. I have used exactly the same kind of argument in reference to the question of whether ideas are important for understanding growth, saying

that this question is one of the few that "can be resolved (in the affirmative) using logic and the kind of evidence reported in the newspaper" (1990, p.). It is ultimately to this diffuse, qualitative information about the world that we must turn when we make causal inferences. Much of the time the role of this data is hidden. It is the basis for the priors we use to evaluate new pieces of data and to judge the plausibility of the untested and unsupported identifying assumptions inherent in a particular argument. But there is no reason why this kind of data could not be explicitly discussed, debated, and challenged in much the same way that we now treat formal quantitative evidence.

IV. Alternative Types of Empirical Evidence

The suggestion made in the last section is that low power positivism tends to be invoked as a methodological defense of models based on perfect competition that would not survive a symmetrical horse race against other models that makes use of all of the available data. This is certainly how the explicit discussion of positivism entered economic discourse, with Milton Friedman's famous defense of price-taking ( ). (It is revealing that this was intended in no small part as a response to assertions by Chamberlain and Robinson price-setting was ubiquitous.)

If this suggestion about the correlation between narrow positivism and mainstream economic theory is correct, one would expect that economists working outside the

mainstream would be relatively unconstrained and would be willing to make use of a much broader range of evidence than mainstream economists. They would evaluate all of the evidence in a Bayesian fashion, assigning a weight to each piece of data in proportion to its reliability and precision, and aggregating it to generate posterior probabilities for alternative explanations.

This does seem to be a reasonably accurate description of the empirical work undertaken by students of technology and by the evolutionary theorists. Some of this work is explicitly statistical, for example, the paper cited above by Fagerberg, 1978. Also, as noted above, the historical accounts of growth and technology already cited fit precisely in this mold, as does most economic history. And there are many case studies of industrial development. To cite only a few recent examples, a volume edited by Nelson and Rosenberg (1993) collect 15 different studies of the national innovation systems in a variety of industrial and newly industrializing countries. This comprehensive effort at summarizing qualitative data stands in sharp contrast to the kind of statistical variables (e.g. secondary school enrollment rates) used as indicators in regression analyses (including the ones reported below.)

By augmenting this more detailed, but qualitative evidence with familiar statistical series, Dahlman and Nelson (1992) compare the record of development in a handful of countries (Singapore, Korea, Hong Kong, Taiwan, China, Hungary, Brazil, Yugoslavia, Israel, Mexico, India, and Argentina.) At a more detailed level, there are a very large number of detailed industry case studies. For example, the studies conducted in the Industry and Energy Department of the World Bank cover industries ranging from footwear to steel

mini-mills. And publications such as the World Investment Report for 1992, published by the Transnational Corporations and Management Division of the United Nations, document the extensive patterns of direct foreign investment, cross national alliances, and other means of technology transfer that operate between industrial and developing nations.

The cumulative persuasive effect of all of this kind qualitative evidence probably exceeds the effect of all of the formal statistical analysis and growth accounting that has been done in the economics profession. For example, there is enough flexibility in how one constructs growth accounting residuals that one could no doubt drive the technology residual to zero. (Grilliches and Jorgenson, , came close, and Jorgenson's current estimates are not far off.) If economists had been willing to believe the results, we would certainly have driven this nuisance term out of existence, but our knowledge of economic history, of what production looked like 100 years ago, convinces us beyond any doubt that discovery and technological change have been of overwhelming importance in the course of the last century, and even of the last 30 years.

Most mainstream economists have far less contact with the corresponding information about cross national patterns of development, but the people who do have no doubt that the determinants of cross national flows of ideas about production are of decisive importance in influencing aggregate outcomes. It is not possible, for example, to read the story of how Taiwan moved from a position with essentially no industrial base to become the fourth largest producer of synthetic fibers in 1981 (Wade, 1990) without being impressed by the importance of the joint ventures and licensing agreements undertaken with firms from the United States and Japan. Similarly, the development of the electronics industry in Taiwan

was decisively influenced by government's decision to induce foreign electronics firms to set up assembly operations in a free trade zone opened specifically for this purpose. Moreover, it is no surprise that firms in India (a country with large quantities of highly skilled human capital but which placed suffocating constraints on the activities of foreign firms) failed to develop comparable industries. In the face of this kind of evidence, the assumption that all technological knowledge is broadcast like short wave radio transmissions to every country in the world seems as inappropriate as the assumption that there has been no technological innovation in the last 30 or 100 years.

To cite another instance in which knowledge of the details can change ones view of aggregate outcomes, consider China. The superficial take on developments in China is that movement to an undistorted market system has unleashed large increases in output, by changing factor supplies or by changing the proportions in which different factors are used. This view (especially with respect to labor supply) no doubt helps explain much of the early success in agricultural reform, but it does not fit the recent, spectacularly successful development of the special economic zones in the costal provinces. First, China continues to be far from a model of an undistorted market economy with strong property rights. As reported by Bateman and Mody (1991) "even a casual reading of World Bank reports on China would give the impression of an economy suffering from rigidities and complexities in its labor, capital and input markets, in its provision of education and infrastructure, and in its enterprise structures. These descriptions create the impression of an economy more distorted than, say, the India economy." Second, the notion of a purely domestic response to policy reform misses the enormous flows of direct foreign investment that China has received

since the last half of the 1980s and specifically of the importance of proximity to Hong Kong. (Mody and Bateman observe that the best one variable explanation for development in China, even if one restricts attention to the special economic zones, is geographic distance from Hong Kong.) Investors from Hong Kong provided more than 60% of all of the DFI in China. Beyond this, entrepreneurs and traders from Hong Kong have also acted as intermediaries with investors from other countries. In both capacities, they have supplied crucial expertise in areas such as marketing, management, training, and technology acquisition.

The decisive role played by flows of ideas that are controlled by multinational corporations becomes most evident when one descends further, to the level of the industry. Three illustrative examples can only be briefly summarized here. A recent World Bank study of the bicycle industry shows how firms from United States, Hong Kong, and Taiwan, are in the process of rapidly converting the bicycle industry in China from a low technology, low quality producer of bikes for the domestic market into the world's largest exporter of bicycles. (Mody et al, 1991). The new firms or joint ventures produce high quality bikes using modern techniques such as total quality control. Assembly operations are now attracting local manufacturing facilities from Taiwanese producers of key components such as chains and derailleurs.

The large scale cross national study of productivity in automobile assembly plants conducted by the MIT International Motor Vehicle Program (and summarized in Womack, Jones, and Roos, 1990) clearly demonstrates the role of multinational firms in transmitting fundamental discoveries about production across national boundaries. This is clear in the

early years after Henry Ford's refinement of the techniques of mass production, with direct investments by Ford, and then GM in Europe. These episodes help demonstrate how very long the full diffusion of techniques of production can take. (Two wars and the economic disruptions of the interwar years constituted a particularly difficult time for industrial development, but the authors' estimate that it took about 50 years for European auto makers to fully absorb the manufacturing techniques developed in Michigan.) The project also documents in much greater detail the process whereby the techniques of lean production developed in Japan have been transmitted back to producers in North America, through local production by Japanese firms, and by joint ventures such as that between Ford and Mazda. or Toyota and GM. This account also makes clear that national borders are not necessarily strong impediments to flows of ideas, and that it is possible for a foreign firm to setup a world class production facility in a middle income, newly industrializing economy. They report that on the basis of their detailed measurements, the Ford assembly plant in Hermosillo, Mexico had the highest quality of any volume (i.e. non-luxury car) assembly plant in the world, better than the best performing Japanese plants and the best transplants in North America. The Hermosillo plant assembled a Japanese designed car (a variant of the Mazda 323). The plant has developed by Ford after it had gone through a period of crisis in the early 1980s and learned how to restructure its manufacturing operations along Japanese lines through an equity stake that it had acquired in Mazda. In the mid 1970s, Mazda had reconfigured its production facilities in Hiroshima as a close copy of Toyota's operations after it had gone through a period of crisis after the failure of its cars built around the Wankel engine.

Finally, there are few countries small enough so that a case study of an industry is equivalent to a case study of the nation as a whole, but Mauritius comes close. Events in Mauritius went through three main phases during the 1970s and 1980s. (This account is drawn primarily from Gulhati and Nallari, 1990. For additional details, see also Romer, 1993.) In 1970, after a policy of encouraging a import substituting manufacturing sector had clearly reached its limits, the government in Mauritius adopted a policy of export promotion centered around an export processing zone (EPZ). This "zone" was in fact an administrative arrangement that gave a number of incentives to firms that produced exclusively for export. These included tariff free imports of capital goods, intermediate inputs, and raw materials, tax concessions, advantageous financing, unrestricted repatriation of profits, and special flexibility in discharging workers. During the years from 1970 to 1975, the government also adopted a policy of wage restraint for the island as a whole. During this period, the island experienced a rapid increase in sugar prices (the main export commodity), which generated both large quantity of domestic saving that was invested in the EPZ (accounting for about one half of all capital investment there) and less fortunately to strong pressures for the government to overspend. As sugar prices declined in the second half of the 1970s and oil price increase, the government continued the switch from a policy of austerity and wage restraint to accommodation. By 1979, wage rates had increased by roughly 40-50% in real terms and the currency had appreciated. In the last half of the decade, government spending grew by 18% per year. From 1979 to 1982, the current account deficit and the government budget deficit each averaged about 12% of GDP. During this second phase, foreign and domestic investment in the EPZ declined dramatically.

From 1979 to 1982, the government, in consultation with the IMF and the World Bank, adopted a stringent program of macroeconomic stabilization that included depreciation of the currency, declining real wages, spending restraint. It subsequently increased the incentives for manufacturing firms, primarily by substantially cutting corporate tax rates and simplifying permit and certification procedures. In response these measures, investment in the EPZ resumed and output and employment in the EPZ grew very rapidly, as did GDP for the island as a whole (at about 6% per year from 1982 to 1989.) By the end of the 1980s, employment in the EPZ accounted for one third of all employment on the island and two thirds of the total increase in employment between 1970 and 1990.

The first salient fact from this account are that foreign investors were crucial to the success in the EPZ and for the island as a whole, not because of the financial resources that they brought to the island, but rather because of the knowledge they possessed about the garment industry, some of it specific to production, but much of it having to with marketing. The second salient fact is that participation by foreign investors was highly responsive to both direct costs (e.g. tax rates and wage rates) but also to the perceived indirect costs associated with macroeconomic instability and its associated political instability. This suggestion, that macro instability effects a developing economy at least partly through its effects on foreign direct investment and other kinds of links by multinational corporations, offers one mechanism that can help explain the correlation noted in the paper by Stan Fischer between bad macro performance and slow growth. If one looks narrowly at direct, domestic effects of, say, inflation on growth, it may be hard to justify why the negative effects should be important, but if flows of ideas from foreigners is sensitive to the perception of

macroeconomic instability (and the associated political instability) and if these flows are important for growth, a large effect is easy to understand. Again, one should be able to uncover direct qualitative evidence in support of this link. To quote from another World Bank report from the Industry and Energy division, "the main operating concern [for Japanese firms engaged in direct foreign investment] is macroeconomic stability, followed by host country restrictions on operations."

V. Cross Country Regressions Revisited

The advantage of micro level evidence (e.g. the specific role played by the foreign firms in setting up bicycle production in China) or of case study evidence (e.g. the sequence of events in Mauritius) is that one can confidently resolve mechanisms of action and causal chains. It is quite clear that foreign bicycle firms taught the Chinese firms about the kinds of bicycles that would sell on foreign markets, undertook much of the design work, and taught workers specific skills such as quality control. It is also quite clear that foreign investors brought to Mauritius a specific set of ideas, and that equipment investment (funded by the foreigners and domestic firms that began to supply them) followed in response, caused by their arrival.

The disadvantage with the micro evidence is that it is difficult to know how to add it all up, and how to judge whether an experience is typical or idiosyncratic. If one is willing

to consider cross country evidence in light of the mechanisms of action and patterns of causality revealed in the micro data, they can help put order-of- magnitude estimates on the size of aggregate effects and give some indication of how general they are. In particular, if the cross country regressions convincingly suggest that there is no aggregate level trace of the kinds of effects suggested by the other evidence, this should at least serve as a caution about how seriously one takes the qualitative evidence.

If the claims made above are correct -- that there are important ideas gaps and that these can be exploited by importing equipment from industrial economies and by inviting in direct foreign investment -- one would hope to be able to find some sign of this in the aggregate data. Blomstrom, Lipsey, and Zejan (1992) report results consistent with this view. They consider a regression of per capita income growth rates on a set of right hand side variables that includes the share of investment in GDP, the share of machinery and transportation equipment imports in GDP, and direct foreign investment as a share of GDP. They find that foreign direct investment (FDI) has a strong association with the rate of growth. In panel estimates over 5 year time intervals, they also report that FDI seems to lead, rather than lag, income growth. Holding constant the FDI variable, the imported equipment variable did not seem to have an independent effect in their growth regression.

Because their specification uses a different functional form from that used in several others empirical studies in the literature, and because their sample includes Singapore, a data point that is highly influential in any regression equation that includes FDI or equipment imports as a share of GDP, tables 1 and 2 consider regressions using different specifications and that exclude Singapore. (A case study of Singapore is very revealing about the large

potential role of FDI and including Singapore strengthens the results reported here. Nevertheless, letting the results be heavily determined by this one point alone is counter to the spirit of the exercise here.) Equation 1 in table 1 reports a standard growth regression equation using a minimal set of explanatory variables:

$$\hat{Y} = c + \beta_1 \frac{I}{Y} + \beta_2 Y_{1960} + \beta_3 Sec.$$

Here I is the usual national income accounts measure of total investment, and Sec is the secondary school enrollment rate in 1960. This equation is estimated on a sample of 76 developing economies that are listed in Appendix A. For comparability with equation 2 below, this sample consists of all countries for which the data on the included variables and the measure of equipment imports are available, with the exception of Singapore, which is excluded for the reasons noted above.

As usual, the investment share and the secondary school enrollment rate have positive coefficients, and initial income has a negative coefficient. To interpret these coefficients, write output as Y = AF(K,H), take the derivative with respect to time, and divide through by Y to get an expression that relates the rate of growth of output to the marginal product of capital:

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \frac{\dot{K}}{K}\frac{\partial F}{\partial K} + \frac{\dot{H}}{H}\frac{\partial F}{\partial H}.$$

Then substitute in the expression for the rate of growth of capital in terms of investment I and depreciation δK, to get

In principle, if the rate of technological change is a constant across different

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \frac{I}{Y}\frac{\partial F}{\partial K} - \frac{\delta K}{Y}\frac{\partial F}{\partial K} + \frac{\dot{H}}{H}\frac{\partial F}{\partial H}.$$

economies, and if the investment share, the capital-output ratio, and the rate of growth of human capital are exogenously determined, then in a regression of growth on a constant, the investment share, the capital-output ratio and the rate of growth of human capital, the coefficient β_1 on the investment share will give an estimate of the marginal product of capital. In practice, we do not observe the capital output ratio. Because it will be correlated with the investment share, the resulting omitted variable bias should drive the coefficient on the investment share down towards zero. In fact, across steady states, the prediction of the Solow model is that the coefficient β_1 is zero in a regression that omits the capital-output ratio. If, however, we assume that the capital-output ratio is negatively correlated with the initial level of income (as we should expect if there are diminishing returns to K), then including initial income partly corrects for this bias. The negative coefficient on initial income is consistent with this interpretation, and as indicated above, this kind of finding has been interpreted as being consistent with diminishing returns to physical capital. This equation as a whole can be interpreted as being consistent with the pure object gap interpretation of cross country patterns of development.

Equation 2 in this table offers a different perspective on the same data. It estimates a regression equation that can be described as follows. Let EM denote machinery and equipment imports. It is used here as a measure of interaction with the rest of the world with the advantage that it is available for a relatively large number of countries. The regression takes the form

$$\hat{Y} = c + \beta_1 \frac{I}{Y} + \beta_2 \left(\frac{I}{Y} * Y_{1960}\right) + \beta_3 Y_{1960} + \beta_4 Sec * \frac{EM}{Y}.$$

The estimates for this equation find significant, positive estimates for β_1, β_3, and β_4, and a significant, negative coefficient for β_2. To interpret these results, recall from the derivation above that it implicitly assumed that the marginal product of capital was the same in all countries. Suppose instead that we allow this marginal product to vary with the level of income, with the expectation that a higher level of income will be associated with a lower marginal product of capital. This is the interpretation suggested by the negative estimate for β_2. The interpretation here is the same as the one suggested for the usual negative coefficient estimate on initial income. One can equally well interpret this as saying that the advantages to starting from a low level of development accrue in proportion to the amount of investment that a nation undertakes. Either way, it can be interpreted as a sign of diminishing returns to physical capital accumulation, i.e. as being consistent with an object gap.

The positive coefficient on initial income alone then suggests that there is something about the level of development that makes it easier for a richer country to growth. In the case of an idea gap model, this would presumably reflect the fact that the ability to take advantage of the ideas available in the rest of the world is higher for countries that have higher initial income. Finally, the positive coefficient on the product of the secondary school enrollment rate and equipment imports as a share of GDP is consistent with the view that a country benefits from interaction with the rest of the world in proportion to the level of

human capital that it possess. Consistent with the technology gap interpretation of development, rapid growth is a function of both access to foreign technology and a domestic capability for using it.

It is worth emphasizing that the estimate effects here are large. An increase in initial income of $1000 reduces the implied marginal product of capital by 9% (e.g. from 19% to 10%). An increase in the secondary school enrollment rate by 0.1 increases the implied return on equipment imports by 6.5%. (To do these calculations, one must be told that annual growth rates are measured as percent, i.e. that an average annual growth rate of 2% gives a data point recorded as 2. The investment share, the equipment import share and the enrollment rate are all fractions between 0 and 1. Income in 1960 is the Heston and Summers estimate of income in thousands of 1985 dollars.)

The other regressions in table 2 test allow for the inclusion of other cross products or additional terms and show that none of them add anything to specification 2. In particular, there is no evidence of an interaction between national investment and the secondary school enrollment rate, and no evidence that equipment imports divided by GDP (which are already included in total investment divided by GDP) have a direct effect on output that is different from the effect of investment itself.

If one were to judge purely by the size of the R^2, the second equation, the one with the cross terms (but the same number of included variables) would dominate over the first, but this is a weak basis for reaching any definitive conclusions about idea gaps versus object gaps. The point emphasized here is rather that this kind of evidence is equally consistent with an interpretation that there are both idea gaps and object gaps as it is with the standard

interpretation, which emphasizes only the presence of an object gap.

For comparison, table 2 reports equations analogous to equations 1, 2, and 6 for the smaller sample of 39 countries for which a direct measure of FDI is available (from the IMF.) The comparison between equations 1 and 2 is the same, and the indications about which variables to include are the same, and the estimated coefficients are of the same order of magnitude. Because of the much smaller sample size, the standard errors are larger and the t-ratios are smaller. (P-values are reported because there is no reason to retain an artificial, fixed significance level of 5% in a comparison with very different sample sizes.) A key finding implicit in this table is that the measure of DFI did not appear to have any independent affect in a growth regression that already controls for investment. It also does not enter if it is used in an interaction term with secondary school enrollment. (One should note that most observers believe that DFI numbers are inherently difficult to measure and that the numbers from the IMF are presumably noisy signals of what is actually taking place. It is also relevant that important observations such as China, Taiwan and Hong Kong are excluded from this regression because of lack of data, as is Singapore, for the reasons noted above.)

Table 3 reports evidence that the DFI measure is still related to other variables of interest. Equations 10-12 show that a larger ratio of FDI to GDP is associated with a substantially larger ratio of Exports and Imports to GDP. For example, in equation 12, an increase in the FDI ratio by .05 is associated with a quite large increase in the trade ratio of 0.6. The machinery import share (which by definition is part of the trade share) also has an independent effect that is larger than the direct effect. One interpretation of these results is

that a large trade share is indicative of success in development, and that increases in DFI and equipment imports help cause this success.

Equations 13 and 14 emphasize, however, that this correlation could be given a different causal interpretation. It could be that an open economy is most attractive to FDI, so the trade share causes increases in the FDI share. Equation 14 emphasizes that an explanation that FDI merely chases after countries with fast growth does not find any support. Income growth has no independent explanatory power for the FDI share when the Trade share is included.

Equations 15 and 16 show that one can either conclude that increased FDI leads to increased equipment imports, or that an increased trade share directly increases equipment imports. (Interpretation of this result is complicated by the fact that equipment imports are part of total imports, which is part of the definition of the trade share.) Finally, equations 17 and 18 suggest that FDI may have an effect on total investment that is bigger than 1 (i.e. bigger than its direct effect), inducing some domestic investment in addition to the foreign investment. (Recall that this was precisely the case in Mauritius.) However, once again, it is not possible to disentangle the possibility that it is the trade share, not FDI, that causes the increased investment.

A caricature of one previous interpretation of the cross country regression results is that there is nothing in the data will force someone who wants to believe in an object gap model to abandon it. The point of this section is that one can claim with equal justification that there is nothing in these data that will force someone who wants to believe that idea gaps are important as well to abandon this position. This is why the additional evidence (and the

theory presented below) are so important for reaching a consensus.

Although they are not decisive, these regression exercises still have some value. For example, the overall pattern of results is difficult to reconcile with a view that there are no object gaps (or even that there are object gaps but that there are constant returns to physical capital accumulation.) The direct negative effect of initial income and its negative interaction with physical capital are both suggestive of diminishing returns to physical capital accumulation and object gaps.

VI. Models of Ideas in Production

So far, this paper has damned mainstream analysis at least by faint praise, and in some senses by explicit criticism. If mathematical models bias how we look at the world and how we approach evidence, and if verbal or appreciative theory is just as productive in suggesting what the key issues are to look at, then what use do the models of mainstream analysis have? This last section suggests that they can be useful for clarifying complicated concepts and for linking findings in one area (e.g. aggregate level analysis) to another (the microeconomics of production, investment, and capital goods.)

This section will reveal one of my biases, however. Once one understands complicated mathematical models, one should be able to explain the basic ideas simply,

perhaps even in the same verbal terms as an appreciative theorist. This is not to say that the mathematics is useless. Rather, it is a claim that it is intermediate product.

One of the key remaining challenges in lending credence to the two gap interpretation of the regressions given in the last section and to the regression results of De Long and Summers is to reconcile the potentially very large returns on investment in equipment that each approach reports. De Long and Summers (1991) report coefficients that imply a marginal product for equipment investment of 30%. Equation 2 above, when evaluated at the mean values of Y_{1960} and the secondary school enrollment rate, implies a marginal product of equipment investment equal to 17%, and is equal to 37% when Y_{1960} is one standard deviation below its mean and when Sec is one standard deviation above its mean.

The key to explaining these apparently high social returns to investment without invoking spillover effects for which we see no micro level evidence is to allow for fixed costs and price setting behavior. This is the essence of the neo-Schumpeterian growth models, but a very simple version of a model with many different types of capital goods is sufficient to illustrate the point.

Suppose that output is a function of human capital H and a single type of domestically produced capital good K_1:

$$Y=L^{(1-\alpha)}K_1^{\alpha}.$$

Now suppose that imports are permitted for a new type of capital good K_2. When this good is used in production as well, output takes the form

$$Y=L^{(1-\alpha)}[K_1^{\alpha}+K_2^{\alpha}].$$

This is a perfectly well behaved constant returns to scale production function. The only departure from standard assumptions is to that K_1 and K_2 are not forced to be perfect substitutes in production (as would be true under the usual practice of adding them together into a single aggregate.) The essence of the assumption that the second type of good is new or different is precisely that it is not a perfect substitute for some quantity of the existing capital good.

Now suppose that the second capital good is supplied to this economy by a monopolist who charges the monopoly price for it. The demand this monopolist faces from the competitive domestic industry that produces output Y is

$$p_2(K_2)=\alpha L^{(1-\alpha)}K_2^{\alpha-1}.$$

The profit maximizing level of K_2 chosen by the monopolist will depend on other parameters such as the marginal cost of producing each unit of good 2. Without specifying these parameters, we can calculate the net increase in output for this economy after subtracting its payments to the monopolist:

$$Surplus=L^{(1-\alpha)}K_2^{\alpha}-\alpha L^{(1-\alpha)}K_2^{\alpha}.$$

Because the output producing industry is competitive, it follows that this entire surplus or increase in total output accrues as increases in wages paid to labor. Since the monopolist captures only a fraction α of the increase in total output that it creates in this economy, the ratio of the increase in output to the cost of the capital goods is $1/\alpha$. If α, which is equal

to the share of capital in total compensation, is equal to a conventional value such as 1/3, then the social value of the units of capital good 2 that are imported will be 3 times the private value paid by the buying firm and captured by the monopolist. When new capital investment takes this form, the introduction of new goods rather than an increase in the quantity of the kind of capital good that already exists in the economy, it is quite possible for social returns to exceed private returns by a factor of 2 or 3, even though there are no technological spillovers in the model. (If one wants, it is possible to think of this as a pecuniary spillover induced by the monopoly pricing. As an aside, it is also an interesting exercise to verify that it is impossible for the monopolist to extract any more than the simple monopoly profit unless it completely takes over all production in this economy and keeps the benefits from the introduction of the new capital goods from spilling over to the workers. That is, the monopolist cannot make use of two part pricing or price discrimination to extract the full value that it creates. For details, see Romer 1993b.)

If this simple story is extended to allow for the introduction of a continually expanding list of new kinds of capital goods being developed in the rest of the world (as for example in Romer 1987 or 1990), it is easy to see how one can distinguish in principle between investment that only adds objects to an economy (i.e. in this example that increases the existing stock of K_1) and investment that brings both ideas and objects. One then sees why massive domestic capital accumulation (i.e. of only the existing capital goods) runs into the standard problem of rapidly diminishing returns, whereas a program of continual imports of new kinds of equipment from industrial nations can succeed and persistently generate social returns that are higher that private costs, and that accrue as increases in wages.

VII. Conclusions

The basic claim in this paper is that both mainstream macroeconomic work (both theoretical and empirical) and the less restrictive approach to theory and evidence characteristic of some non-mainstream lines of work will be necessary to make progress in evaluating the importance of idea gaps. The implied directions for additional work should be clear. First, mainstream theory has yet to provide a simple abstract model that shows how disembodied ideas, ideas that are free from any connection with a piece of equipment, can affect production. Once this has been done, the theory needs to show how corporations are able to keep control over this kind of idea, and show why international operations by corporations can channel ideas all over the world better than arms length market transactions using royalties or licensing fees. (The transactions cost approach to the firm will presumably be useful here.) This work will also need to explain the wide and rapidly growing variety of joint venture or collaborative arrangements that firms use for exchanging ideas or sharing the risks in producing them.

What the economists working outside the narrow confines of macroeconomic theory could most usefully provide is attempt at synthesizing or aggregating all of the diverse evidence that is known about these issues and coming to at least a qualitative assessment of how important the idea related economic transactions are, especially between multinational firms and developing countries. One might also hope for additional evidence at the most detailed microeconomic level. For example, it would be very helpful to have a complete

picture of how one set of ideas (e.g. about modern bicycle production) actually made there way into the Chinese economy from Hong Kong and steadily diffused throughout its productive structure, somewhat along the lines of the work done on machine tools in the early United States by Nate Rosenberg ( ). This kind of detailed, almost epidemiological account analogous to the spread of a disease would help elucidate the variety of mechanisms whereby ideas are spread, and might give a better sense of how far reaching international flows of ideas can be and about how better to model them.

Table 1: Full Sample of Developing Countries

Dependent Variable: Per Capita Income Growth

Eq.	1.	2.	3.	4.	5.	6.
Constant	-1.1 (.61) [.08]	-2.3 (.86) [.008]	-2.2 (.87) [.01]	-2.4 (.88) [.008]	-2.4 (.87) [.007]	-2.4 (.87) [.008]
I/Y	13.1 (3.1) [.000]	19.3 (4.20) [.000]	20.8 (4.40 [.000]	19.7 (4.3) [.000]	20.0 (4.3) [.000]	20.0 (4.3) [.000]
(I/Y) x Y_{1960}		-8.9 (3.4) [.01]	-8.8 (3.4) [.01]	-9.7 (.88) [.01]	-9.0 (3.5) [.01]	-5.2 (5.4) [.35]
Y_{1960}	-0.51 (.22) [.02]	1.6 (.78) [.05]	1.5 (.78) [.06]	1.8 (.88) [.05]	1.7 (.79) [.04]	.73 (1.3) [.57]
Sec (Secondary School)	5.8 (1.9) [.003]			-1.9 (3.4) [.57]		10.7 (11.7) [.37]
(Machinery Imports)/Y			-9.6 (7.6) [.21]			
Sec x (Mach. Imp./Y)		65 (17) [.000]	80 (21) [.000]	81 (33) [.02]	92 (36) [.01]	99 (37) [.009]
(I/Y) x Sec					-14 (16) [.39]	-61 (54) [.26]
R^2	.34	.41	.43	.42	.42	.43

Notes: Standard errors in parentheses under coefficient estimates. P-values (i.e. the marginal significance level of a two tailed test of the hypothesis that the coefficient is equal to zero) are given in square brackets under the standard errors. For all six regressions, there are 76 observations. See Appendix A for the countries in the sample. See appendix B for a description of the data.

Table 2: Small Sample with Data on FDI

Dependent Variable: Per Capita Income Growth

Eq.	7.	8.	9.
Constant	1.5 (.87) [.10]	.83 (1.3) [.53]	-.86 (1.3) [.52]
I/Y	4.2 (3.6) [.25]	7.5 (5.7) [.19]	7.5 (6.0) [.22]
(I/Y) x Y_{1960}		-3.8 (3.4) [.28]	-1.9 (7.4) [.80]
Y_{1960}	-0.74 (.20) [.001]	.19 (.81) [.81]	-.26 (1.8) [.89]
Sec (Secondary School)	4.2 (2.1) [.05]		5.1 (17) [.77]
Sec x (Mach. Imp./Y)		44 (21) [.04]	46 (38) [.24]
(I/Y) x Sec			-23 (76) [.76]
R^2	.29	.33	.33

Notes: Standard errors in parentheses under coefficient estimates. P-values (i.e. the marginal significance level of a two tailed test of the hypothesis that the coefficient is equal to zero) are given in square brackets under the standard errors. For all three regressions, there are 39 observations. See Appendix A for the countries in the sample. See appendix B for a description of the data.

Table 3

FDI, Investment, and the Trade Share

Eq. No and Dependent Variable	Const.	FDI Share	Mach. Import Share	I/Y	Trade Share	Income Growth	R^2
10. Trade Share	.36 (.05) [.000]	17.8 (3.3) [.000]					.45
11. Trade Share	.17 (.08) [.03]	13.3 (3.3) [.000]	3.8 (1.3) [.005]				.56
12. Trade Share	.06 (.13) [.66]	12.3 (3.4) [.001]	3.5 (1.3) [.01]	.68 (.64) [.30]			.57
13. FDI Share	-.0027 (.0028) [.33]				.025 (.005) [.000]		.45
14. FDI Share	-.003 (.003) [.32]				.024 (.004) [.000]	.00029 (.0009) [.75]	.45
15. Machinery Import Share	.05 (.005) [.000]	1.18 (.39) [.004]					.20
16. Machinery Import Share	.03 (.008) [.001]	.23 (.46) [.61]			.053 (.017) [.005]		.36
17. Investment Share	.19 (.01) [.000]	2.17 (.77) [.008]					.17
18. Investment Share	.17 (.02) [.000]	1.1 (1.0) [.30]			.062 (.038) [.11]		.23

Notes: Standard errors in partheses, p-values in square brackets. Nobs=39. See appendix A and B for countries and variable definitions.

Description of the Data

Growth	Average annual rate of growth of per capita income from 1960 to 1989. From Levine and Renelt (RYGDP60) Mean = 1.8
I/Y	The share of investment in GDP. From Levine and Renelt, (INV6089). Mean = .22
Y_{1960}	Initial income in 1960, from Summers and Heston, 1985. Mean = 1.2.
Sec	Secondary school enrollment rates, from Barro, 1990. Mean = .14
Mach.Imp.	Average for 1960-1985 of imports of machinery and transport equipment (SITC 7) to GDP. From Blomstrom, Lipsey, and Zejan (1992) Mean = .065.
FDI	The ratio of current dollar foreign direct investment to current dollar GDP. FDI data from the IMF. GDP data from the World Bank. Mean = .01

Countries included in Regression Samples

("X" = Included)

Sample Size:	76	39
1	ALGERIA	X
2	ANGOLA	
3	ARGENTINA	X
4	BANGLADESH	
5	BARBADOS	X
6	BENIN	
7	BOLIVIA	X
8	BOTSWANA	
9	BRAZIL	X
10	BURMA(Myanmar)	
11	BURUNDI	
12	CAMEROON	X
13	CENTRAL AFR.R.	
14	CHAD	
15	CHILE	X
16	COLOMBIA	X
17	CONGO	X
18	COSTA RICA	X
19	CYPRUS	
20	ECUADOR	X
21	EGYPT	X
22	ETHIOPIA	
23	GABON	X
24	GAMBIA	
25	GHANA	
26	GUATEMALA	X
27	HAITI	
28	HONDURAS	X
29	HONG KONG	
30	INDIA	X
31	INDONESIA	X
32	IRAN	
33	ISRAEL	
34	IVORY COAST	X
35	JAMAICA	X
36	JORDAN	
37	KENYA	X
38	KOREA,SOUTH(R)	X
39	LIBERIA	
40	MADAGASCAR	
41	MALAWI	
42	MALAYSIA	X

43	MALI	
44	MALTA	
45	MAURITANIA	
46	MAURITIUS	X
47	MEXICO	X
48	MOROCCO	X
49	NICARAGUA	X
50	NIGER	
51	NIGERIA	X
52	PAKISTAN	X
53	PANAMA	
54	PAPUA N.GUINEA	X
55	PARAGUAY	X
56	PERU	X
57	PHILIPPINES	X
58	RWANDA	
59	SAUDI ARABIA	
60	SENEGAL	
61	SIERRA LEONE	X
62	SOMALIA	
63	SUDAN	
64	SURINAME	
65	SWAZILAND	X
66	SYRIA	
67	TANZANIA	
68	THAILAND	X
69	TOGO	
70	TRINIDAD&TOBAG	X
71	TUNISIA	X
72	UGANDA	
73	URUGUAY	X
74	VENEZUELA	X
75	ZAIRE	
76	ZIMBABWE	