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# ECONOMIC ISSUES IN COST-BENEFIT ANALYSIS OF FAMILY PLANNING PROGRAMS

A Report on Phase I of the Penn State-USAID Population Project

"Cost-Benefit Analysis and Evaluation of

Family Planning Programs"

Contract No. AID/ead-1884

by

Warren C. Robinson
Project Director

and

David H. Horlocher
Research Associate

The Pennsylvania State University
Department of Economics
University Park, Pennsylvania

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## SECTION I

### Introduction

This paper represents a report on Phase I of the Penn State-USAID Population Project (USAID Contract No. AID/ead-1884, "Cost-benefit Analysis and Evaluation of Family Planning Programs").

> Phase I--This phase shall involve a sorting-out of the methodological problems connected with application of cost-benefit analysis to family planning as follows:
>
> (a) The contractor shall review the existing literature on cost-benefit analysis as applied to social and economic problems.
>
> (b) The contractor shall develop a workable cost-benefit model for future use in evaluating the impact of family planning programs.

This report does not review the literature on relationships between population growth and economic development. The literature in this field is vast, covering theoretical, historical and empirical material, and much of it is already very familiar to students of development. Nor does it review the several recent efforts to set down in a more purely descriptive way possible interactions between fertility reduction and development in general and in particular countries.[1] Rather it focuses on the problem of evaluating in

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[1] Among the most useful of these are the general papers by Gavin Jones ("The Economic Effect of Declining Fertility in Less Developed Countries," to be published shortly by the Population Council); Simon Kuznets, "Economic Aspects of Fertility Declines in Less Developed Countries," in Fertility and Family Planning: A World View, University of Michigan Sesquicentennial Celebration Volume, 1967; Richard Easterlin, "Effects of Population Growth on the Economic Development of Developing Countries," Annals of the American Academy of Political and Social Science, Vol. 369, January 1967. There exist country studies for: Kenya (Kenya, Ministry of Economic Planning and Development, Family Planning in Kenya, a report submitted to the government of Kenya by an advisory mission of the Population Council of the United States of America, 1967); Thailand (U.S. Agency for International Development, U.S. Operations Mission to Thailand, Effects of Population Growth on Economic and Social Development in Thailand, Bangkok, 1967); Turkey (Baran Tuncer,

The Impact of Population Growth on the Turkish Economy, Institute of Population Studies, Hacettepe University, Ankara, Turkey, 1968).

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quantitative terms the benefits of fertility reduction to society. Part One consists of a review, with primary emphasis on methodology, of the efforts made thus far to evaluate "benefits" of fertility reduction. In general these efforts can be characterized as falling into one of three approaches: (a) an investment model approach in which the implication of each birth prevented now is estimated in the future in terms of consumption needs foregone, and the increase in government and private savings per capita; (b) a measurement of benefits in terms of projected per capita income with and without fertility reduction; (c) a reconciliation or "mixed" model using both approaches.

In the last part of this report a new model is advanced which we feel successfully blends techniques and insights contained in several of the existing approaches. The model is intended to be operational and in later phases of the overall project it will, in fact, be applied to at least one country case study.

We now turn to the review of past studies.

## SECTION II

### Approach I: Investment Models

#### A. Stephen Enke

In the mid-1950's Stephen Enke had become convinced that the economic development of "backward countries" required that the rate of population growth be reduced. In his article "Speculations on Population Growth and Economic Development" he pointed out that maintenance of a constant capital-labor ratio was not possible at then current rates of population growth and capital formation.[2]

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[2] S. Enke, "Speculations on Population Growth and Economic Development, Quarterly Journal of Economics, Volume 71, February 1957, pp. 19-35.

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He proposed two alternative investment policies, the first called for urbanization with industrialization which would have as a byproduct the reduction of birth rates and land reclamation which would not have this side effect. Using a model of a "not atypical mythical" underdeveloped country he finds that consumption per head is initially higher under the latter policy, but ultimately it becomes higher under the former and the gap continued to widen with the passage of time. According to Enke "the main reason for the difference in per capita consumption trends, occasioned by these two investment policies lies, of course, in the different population growth."[3]

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[3] S. Enke, Ibid., p. 31.

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In summarizing this article he pointed out prophetically the direction of his future thinking. "If there are kinds of investment that will restrain population, they may prove to have a very high social net product, but it is these kinds of investments that private capital will normally not make. In seeking investments of this kind government economists will have to join other social scientists."[4]

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[4]S. Enke, Ibid., p. 35.

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In 1960 Enke published two articles which outlined just such investments.[5] He argued for investment in birth control schemes. In theory a

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[5]S. Enke, "The Gains to India from Population Control: Some Money Measures and Incentive Schemes," Review of Economics and Statistics, Volume 42, May 1960, pp. 175-180; and "The Economics of Government Payments to Limit Population," Economic Development and Cultural Change, Volume VIII, July 1960, pp. 339-348.

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policy of maximizing per capita income would call for balancing the returns from all forms of investment at the margin.

A basic input to such an analysis would be a calculation of the economic value of preventing one birth. His first calculation called for estimating the lifetime product and the lifetime consumption of a marginal birth. He calculated that total consumption would exceed total product by 6,000 rupees.[6]

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[6]S. Enke "The Gains to India from Population Control: Some Money Measures and Incentive Schemes," Review of Economics and Statistics, Volume 42, May 1960, p. 176.

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Enke then refined his calculations by introducing a rate of discount. He selected 10% and pointed out that since the newly born individual will

not begin producing for 15 years the discounted present value of his production is almost zero. However, he will begin consuming immediately and therefore the present discounted value of his consumption will not be negligible. Enke estimated it to be approximately 690 rupees. The value of a birth prevented would be even higher for lower rates of discount.

The basis of this argument is that children should be considered a special type of social investment, and that the advantages and disadvantages of additional births should be calculated by comparing the expected lifetime production and consumption streams for a person born now, both streams discounted back to the present in order to judge present costs and benefits.

The concept of discounting future economic magnitudes so as to make a present judgment deserves perhaps a bit of amplification at this point. Generally speaking, economic analysis assumes that consumption now is always preferred to consumption in the future. That is, a hundred dollars next year is "worth" less to a person than a hundred dollars today. Given a free choice, with all other factors equal, a person will always prefer income (or goods) now to income (or goods) tomorrow. Future income must consequently be reduced (or "discounted") when being compared to present income. The prevailing market rate of interest is a measure of what annual rate of return on savings (or on non-consumption of current income) a person can command. It is also a measure of that rate of return which does induce people to save some current income (to postpone their consumption of it to some specified point in the future). The interest rate is thus a measure of the inferiority of future goods to present goods and can be used as the rate by which future income (or benefits) are reduced to convert them into present values.

Enke further refined his calculations by introducing the possibility that these funds may be reinvested with a capital output ratio of 4 over a ten-year period. The result is to increase the present discounted value of a prevented birth to 1,000 rupees.

However, Enke felt that investment was likely to be exogenously determined and the 690 figure was the most realistic as well as most conservative.

Enke maintained that the size of the bonus need not be calculated accurately since it is merely a transfer payment.

"The real criterion of whether a bonus is too high or too low is its effectiveness as an 'inducement.'"

In fact Enke proposed that the bonus not be paid but kept in trust by the government until the registrant had "a baby in the bank," in the sense that she had accumulated 500 rupees in the bank which she would lose if she had a baby.

To sum up his argument, Enke maintained, "Even in money terms, if per capita consumption is the criterion, government might find bonuses ten times as productive as conventional investments for development.

The fundamental economic "trade off" is far more staggering because this must be concerned not with money costs but with resource costs. As regards per capita consumption, resources devoted to population control would then be 500 times as rewarding as resources of equivalent value invested in traditional development projects such as industry, transportation or irrigation.[7]

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[7] S. Enke, Ibid., p. 181.

In another article published later in the same year Enke made the same point in a slightly different way. He began with the assertion that births were excessive if the present discounted value of infants born that year was negative. This value would be computed as described above.[8]

[8] S. Enke, "The Economics of Government Payments to Limit Population," Economic Development and Cultural Change, Volume VIII, July 1960, pp. 339-348.

A negative value could be due to three causes. First many children do not survive to working age, hence they merely consume. Second, the marginal product of the additional worker may be considerably less than the average product and thirdly consumption is based on average rather than marginal product. Lastly production is more heavily discounted than consumption, since the latter begins at birth whereas the former begins years later.

Enke then suggests that a rate of discount be calculated which would equate the stream of production with the stream of consumption. This is much like the concept of the marginal efficiency of capital. If it is lower than the rate of return on capital, then births are excessive. Enke argues that in many of the less developed countries this must be negative.

In this article he recognized that though these bonuses are transfer payments the government must obtain the money to pay them. He argued that these can be paid for by increased taxes. As before he admitted that if dollars spent on bonuses are diverted from traditional development projects, then resource costs will equal money costs, but he argued that this type of investment still has an advantage by a factor of ten.[9]

[9] S. Enke, Ibid., p. 348.

In 1966 Enke wrote an article for The Economic Journal which treated the issues of the costs of reducing births in greater detail.[10] In this

[10] S. Enke, "The Economic Aspects of Slowing Population Growth," The Economic Journal, Volume LXXXVI, March 1966, pp. 44-56.

article he introduced an important new concept to the analysis of the relative effects of various types of investment on per capita income. Assuming the same amount is devoted to either investment in capital goods or birth control, then the latter will be superior if it reduces population by a greater percentage than a corresponding investment in capital goods will raise output. The ratio of these percentages Enke called "the Superior Effectiveness Ratio" and this is equal to:

$$\frac{\% \Delta P}{\% \Delta Y} = \frac{P \Delta Y}{Y \Delta P}$$

This ratio will vary inversely with the rate of return on capital and directly with the fertility of women practicing birth control.

B. Criticisms of Enke's Model

In a highly critical comment, Paul Demeny accepted the fact that the value of a prevented birth was substantially as set forth by Enke.[11] However,

[11] P. Demeny, "The Economics of Government Payments to Limit Population: A Comment," Economic Development and Cultural Change, Volume IX, July 1961, pp. 641-644.

he charged that Enke had grossly exaggerated the effectiveness of the bonus scheme in raising per capita income.

Specifically, Demeny challenged Enke's assertion that the transfer is simply "a monetary operation." If the bonus scheme is to be financed

by taxation, then Enke cannot assume the effect of the tax to be neutral. The propensities to save of the beneficiaries may be different from the propensities to save of the taxpayers.

Demeny's main point was that if the government had the power to tax for this scheme, it had the power to tax for alternative investment projects. "Once the government has succeeded in reducing the consumption of certain segments of the population by taxation, real savings have been mobilized and there is a choice between channeling these savings into productive investments or distributing them under bonus schemes."[12]

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[12] P. Demeny, Ibid., p. 643.

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The same type of arguments can be made when the program is financed by borrowing. In either case bonus payments have an opportunity cost: "the gain foregone when abstaining from alternative investment projects."

In a rejoinder to Demeny's argument, Enke sought to answer his first point that taxes were non-neutral by showing how the net effect on the propensity to save may be positive.[13] But he failed to address himself to

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[13] S. Enke, "A Rejoinder to Comments on the Superior Effectiveness of Vasectomy-Bonus Schemes," Economic Development and Cultural Change, Volume IX, July 1961, p. 645.

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Demeny's main point "that there is an opportunity cost in the sense of traditional investment projects foregone."

An entirely different attack was made on Enke's argument by Anne Krueger and Larry Sjaastad.[14] They held that per capita income should not

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[14] A. O. Kreuger and L. A. Sjaastad, "Some Limitations of Enke's Economics of Population," Economic Development and Cultural Change, Volume X, July 1962, pp. 423-426.

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be the sole welfare criterion and that if the family chose to pay the costs of having a child, that nothing was gained from a social point of view by bribing them not to do so.

Enke replied that the population as a whole has an economic interest in reducing the number of births.[15] "Briefly, potential parents may wish

[15] S. Enke, "Some Misconceptions of Krueger and Sjaastad Regarding the Vasectomy-Bonus Plan to Reduce Births in Overpopulated and Poor Countries," Economic Development and Cultural Change, Volume X, July 1962, pp. 427-431.

to behave in ways that are anti-economic and society through government can deter them with a bonus."[16]

[16] S. Enke, Ibid., p. 428.

His main point of disagreement is with the contention that the incidence of the extra child falls almost exclusively on the parents. He considers what will happen when the children of these parents grow up and seek out their own sustinence. "The prolific families will not stay on their own subsistence landholdings; some of their young men desperate to earn will compete as industrial workers and indirectly use other factors of production. Thus the improvidence of one set of parents will disadvantage more careful parents."[17]

[17] S. Enke, Ibid., p. 429.

In 1967 Enke's thesis was again subjected to penetrating criticism, this time by Goran Ohlin.[18]

[18] G. Ohlin, Population Control and Economic Development, Paris: OECD Development Center, 1967.

Ohlin agreed with Enke that the birth of a child may be viewed as the start of an investment project in which resources are devoted to rearing the child, this is then followed in turn by a productive period and finally another period of dependency. When these streams are discounted to their present value, a negative result would imply a positive value for preventing a birth.

However, serious problems arise when one attempts to determine what is the appropriate rate of discount and what is the appropriate measure of consumption and production.

Ohlin said that Enke erred in using such a high rate of discount (10 to 15%). He pointed out that if a child involves a constant annual expenditure and then after age 15 he would make a constant contribution to production, this level of production would have to be almost ten times as large as annual consumption in order to bring up the capitalized value of his life to zero. This is because the present value of one unit of consumption per annum over 65 years is 6.7 and the present value of one unit of output from 15 to 65 years hence is .67 assuming a 15% rate of discount.

Ohlin suggested that current rates of interest in underdeveloped countries which largely measure marginal rates of time preference not be used as the discounting factor. Instead he argued for the use of the rate of return on alternative available uses of resources. "If at that discount rate, the present value of a prevented birth is positive, this simply means that the resources spent on rearing additional children would be more profitably employed in some other type of investment."[19]

[19] Ohlin, Ibid., p. 113.

If one does not assume labor to be entirely in surplus and hence marginal product is zero, then with rather reasonable assumptions it can be shown that the value of a prevented birth would be zero at a 4% rate of interest. This then is the internal rate of return of an investment in a new birth. At a 6% rate of discount the present discounted value of a birth prevented becomes twice per capita income which is in line with Enke's estimates. This can be doubled if we consider the second generation effects of such a prevented birth.

Ohlin agreed with Enke that the appropriate measure of product per birth prevented is marginal product but he criticized Enke for failing to recognize that it is not current marginal product which is relevant but rather marginal product fifteen to sixty five years hence when such relevant matters as technology, capital stock and population itself will have changed. Thus these estimates must be tenuous guesses at best.

C. Richard Meier

In 1959, Richard L. Meier published his Modern Science and the Human Fertility Problem.[20] In it he reviewed Coale and Hoover's earlier work

[20] R. L. Meier, Modern Science and the Human Fertility Problem, New York: John Wiley & Sons, 1959.

(supra pp. 20ff.) and points out that, "In carrying out the above projection no allowances were made for the special cost of a fertility reduction program."[21] Meier argues that a society which engages in development planning

[21] R. L. Meier, Ibid., p. 74.

"must be in a position where it can compare an investment which has a demographic impact with one which has other effects."[22]

[22] R. L. Meier, Ibid., p. 76.

Rather than utilize the Coale and Hoover data based on India, Meier chose a framework developed by Dublin and Lotka in the mid 1940's.[23] The

[23] L. I. Dublin and A. J. Lotka, The Money Value of a Man, 2nd edition, New York: Ronald Press, chs. 1, 4.

procedure is to follow a cohort or age class through its life cycle examining its consumption, production and mortality.

He then considered two populations. "Population A which exhibits the features normally associated with a per capita income level of $100 per year" and Population B which exhibits features normally associated with an income of $250 per capita per year.[24]

[24] R. L. Meier, Ibid., p. 77.

In describing Population A, Meier maintained that the costs of being brought into the world are very small. And children began productive work at age five.

Meier proceeded to compute the reasonable cost of a program of family limitation by reversing the methods one would use in calculating the benefits of a public health program designed to reduce infant mortality. "The appropriate procedure would be to discount the loss to society back to the

time at which the public health measure that caused the increase in the age class was put into effect."[25]

[25] R. L. Meier, Ibid., p. 83.

He concluded that "it would pay Population A to spend up to $2,500 per year (for an age class containing 1,000 births) for a program of limitation with an 'equal and opposite' effect"[26] (of a reduction in infant

[26] R. L. Meier, Ibid., p. 83.

mortality from 10% to 8.87).

Thus, allowing for mortality, the benefit of preventing one birth would be about $20 per year in the case of Population A. In the case of Population B he found that a program which reduced births by 20% would have the effect of benefiting society by $600 per birth prevented.[27]

[27] R. L. Meier, Ibid., p. 86.

Meier came to the following conclusions as a result of his study:

(1) The net value of a prevented birth varies directly with per capita income.

(2) The value of medical innovation which reduced infant mortality would be negative in underdeveloped countries.

(3) The economic value of an effective program of family limitation is much greater for more developed societies. They can use the gains to invest in human resources and elsewhere.

Though Meier's technique was developed independently of Enke's it is quite similar. Both measure the net worth of preventing a birth in terms

of the net discounted value of the expected stream of production less the expected stream of consumption. But there are important differences. Enke limited himself largely to the case of India whereas Meier used a more general model. Meier assumed production begins at age 5 whereas Enke assumed production begins at age 15. Lastly Enke used the marginal product as his measure of output whereas Meier used the average product of the cohort. These differences largely explain why Meier's estimates of the value of a birth prevented are lower than those of Enke.

D. George C. Zaidan

Under the direction of Professor Harvey Leibenstein, Dr. Zaidan wrote a doctoral dissertation on the "Benefit and Costs of Population Control with Special Reference to the U.A.R."[28] The principal conclusions of this study

[28] G. Zaidan, "Benefits and Costs of Population Control with Special Reference to the U.A.R." Unpublished dissertation, Harvard University, 1967.

were summarized in a working paper prepared by Dr. Zaidan for the International Bank for Reconstruction and Development.[29]

[29] G. Zaidan, "The Foregone Benefits and Costs of a Prevented Birth: Conceptual Problems and An Application to the U.A.R." Economics Department Working Paper No. 11, IBRD, January 23, 1968.

He introduces his paper as follows:

> Taking (Enke's) approach as our starting point the object of this paper is (a) to refine and extend this analysis both by working out the upper and lower limits of the above benefits, as well as trying to include additional effects that are capable of being quantified and (b) to explicitly analyze the assumptions and hence limitations of such a procedure.[30]

[30] Ibid., p. 2

Zaidan identifies four paths by which preventing a birth may affect per capita income. The most important is the one which he calls the initial effect (or the "Enke effect,") that is the difference between the consumption stream and the productivity stream of an unborn child.

To the extent that this primary effect raises per capita income of the remaining population there must be an increase in consumption per worker or savings per worker or both if fertility is reduced. These increases are then the bases for several additional rounds of increases in per capita income.

The second effect identified by Zaidan is the "wage productivity effect." (This might be called the "Liebenstein effect.") It is the increased productivity of labor due to improved diet.[31] Zaidan notes that "the existence

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[31] H. Liebenstein, Economic Backwardness and Economic Growth, New York: John Wiley & Son, 1957, ch. 6, pp. 62-69.

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of such an effect implies that (i) the per capita consumption is below the minimum caloric requirements and (ii) that the marginal product of effort is not zero."

Zaidan's third effect is the "savings effect." It is the increase in total (hence per worker) savings and investment as a result of higher per capita income. This savings effect can be divided into two sub-effects. The first of these is the effect on private savings of an increase in per capita income. (This could be called the "Demeny effect" since this was central to Demeny's analysis.) The second of these is the effect on government savings. By reducing births less need be spent for public education and similar public services. (This could be called the "Coale and Hoover effect" since they first noted this possibility.)

After setting forth his Enke type model with the addition of the Liebenstein, Demeny and Coale-and-Hoover effects, Zaidan proceeded to discuss the assumptions underlying this benefit criterion.

They are as follows:

(1) Children are treated "exclusively as investment goods."

(2) Returns are treated "exclusively from the point of view of the country rather than the family."

(3) Births are permanently prevented rather than merely delayed.

Zaidan found one aspect of this technique most disturbing. "This is that there is a built in bias in our criterion that ensures that benefits will always exceed costs."[32]

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[32] Ibid., p. 13.

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That this would be true for the underdeveloped nations of today is not surprising but it is also true for "the developed countries of today and those same countries, in their early period of industrialization in the nineteenth century."

Three reasons are found for the fact that "initial effect is always large and positive." In the first place consumption is set equal to average product but production is measured by marginal product where the latter is assumed to be much less than the former. The second explanation for the "large positive bias" is the fact that the consumption and productivity streams are discounted. "Since consumption starts immediately after birth whereas production is delayed for at least ten to fifteen years, even moderate discounting greatly exaggerates the difference between the present values of both streams."[33]

[33] *Ibid.*, p. 15.

This discount rate is used to reflect social time preference. Bohm-Bawerk explained this in terms of a lack of imagination, "Schatzungfehler," lack of willpower, "Willensfehler," and the shortness of life. Presumably the first two explanations should not apply to public decision makers. The applicability of the third explanation, shortness of life, depends on what is meant by society.

> If we take this to mean the individuals that compose it, then (this) reason is a valid basis for time preference. On the other hand if we view society as an abstract entity that never dies - although the individuals that compose it do - then even (this) basis of time preference is invalid. From the point of view of the persons living in the nineteenth century in countries that subsequently experienced rapid economic growth, it may have been valid to advocate a policy of population limitation. Viewing the matter from the present, however, and looking at a certain country as an abstract entity, it is doubtful that we could endorse such a policy.[34]

[34] *Ibid.*, p. 16. We return to the discounting problem later in this report.

Zaidan concluded that the practice of discounting "implies that we are considering the benefits for people who are alive today and the length of the time horizon implicitly determines which age group we have in mind."

A second explanation for the large positive bias of the Enke criterion is the fact that consumption is considered merely as a cost. It could be a necessary stimulus for growth in nations with insufficient aggregate demand. This could take three forms:

(a) exploitation of economies of scale

(b) the acceleration effect

(c) it aids in labor mobility.

Zaidan concluded that "in both the case of the developed countries today and these same countries in the early phase of industrialization, consumption had a different role than in most of the underdeveloped countries today. Consumption had stimulating as well as braking effects and it is impossible to disentangle the two. In such cases it is illegitimate to treat foregone consumption exclusively as a cost."[35]

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[35] Ibid., p. 20.

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The final portion of Dr. Zaidan's paper dealt with an application of his benefit criterion to the U.A.R. In doing so he illuminates a number of issues which may substantially effect the numerical value of the benefit.

In calculating the initial effect a more refined definition of consumption should be used than merely "GNP minus capital formation." He would deduct investments in human capital, those government expenditures which are really intermediate goods (e.g., fire protection) and those government expenditures which are independent of population (e.g., national defense).

In calculating the private savings effect, Zaidan pointed out that its magnitude will equal the marginal propensity to save times the initial effect. However, he expressed doubt that a reduction in fertility will stimulate savings. "It may be that the desire for smaller families is the result of a desire for more consumption (this is often the basis of the propaganda of many family planning programs) in which case no larger savings can be expected."[36]

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[36] Ibid., p. 33.

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Zaidan's findings for the U.A.R. may be summarized as follows:

(1) The initial (Enke) effect of permanently preventing one birth is equal to something between 2.5 and 4.5 of present per capita income when a 10% rate of discount was used.

(2) The wage productivity (Liebenstein) effect varies between 4.5% and 18% of the initial effect.

(3) The private saving (Demeny) effect is assumed to be zero.

(4) The private saving (Coale and Hoover) effect varies between 18.5% and 37% of the initial effect.

## SECTION III

### Approach II: Projected Income Differentials

#### A. Coale and Hoover

The heart of the Coale and Hoover study was the construction of an econometric model of Indian economic growth in which the size of population and its rate of growth were introduced as explicit variables.[37] Their purpose

[37] A. J. Coale and E. M. Hoover, Population Growth and Economic Development in Low-Income Countries, Princeton: Princeton University Press, 1958, ch. 17.

was to measure quantitatively "the economic significance of a reduction in fertility." A secondary purpose of their study was to test the sensitivity of their model to various alternative assumptions about the non-demographic variables.

Their model made a number of assumptions. First of all it was assumed that the size and quality of the labor force was constant regardless of fertility. This is a reasonable assumption since no additional births would add to the labor force in the first fifteen years and even in succeeding years the contribution would be relatively small. In fact the labor force may be smaller in the high fertility economy because more women must remain at home to care for the young.

In like manner the model did not allow for the fact that higher per capita consumption may allow the labor force to be more vigorous and productive and it ignores the "incentive" effect of higher standards of living.

The model considered only monetized investment, since the data on non-monetary investment was sparse.

The heart of the model is a linear difference equation.

$$Y_{t+2.5} = Y_t + 2.5\left(\frac{G}{R}\right)$$

Where Y refers to real national income, G refers to "equivalent growth outlays" which is a measure of total investment adjusted for the varying degrees of productivity and gestation periods of its components and R is the capital output ratio. In this form we have a simple Harrod-Domar growth model.

If we interpret G as equivalent to I or $\Delta K$ and R as $\frac{\Delta K}{\Delta Y}$ then

$$\frac{G}{R} = (\Delta K) \div \frac{\Delta K}{\Delta Y} = \Delta Y$$

and our first equation reduces to a statement that income in t + 2.5 years is equal to income in t plus 2.5 times the annual growth rate which depends on the level of investment and the capital output ratio.

Coale and Hoover did not treat R as a constant but rather assumed that it grows over time.

$$R = m + nt$$

Initially m was assigned the value (3.0) and n was assigned the value (.02).

The construction of G, or "equivalent growth outlays" was extremely complex. It can be expressed by the equation

$$G = I_c + (e_c I_{wc} + e_i I_{wi})L + (e_c W_c + e_i W_i)_{t-15} \quad (1 - L)_{t-15}$$

The first term represents investment in capital goods and is assumed to be given exogenously. In India this would be determined by the Five Year Plan.

The terms $I_{wc}$ and $I_{wi}$ refer to investments in human resources or welfare type outlays. $I_{wc}$ refers to welfare outlays attributed to the needs of the current population and $I_{wi}$ refers to welfare outlays attributed to the needs of the current addition to population. The e's represent a set of linear weights, fractions, representing their productivity relative to the productivity of equivalent expenditures for physical capital.

The symbol, L refers to the labor force participation rate. Note that current investment in human resources are weighted by the fraction of population actually in the labor force since part of these expenditures would go to non-producers. The remainder of welfare type investment is assumed to effect the production of the economy fifteen years hence therefore, the third term of the equation is the product of weighted welfare investment fifteen years ago multiplied by the portion of the population not in the labor force fifteen years ago.

The values of L are not determined within the model, but rather are determined by demographic projections of the proportion of the population between 15 and 65 and assuming that the participation rate of this portion of the population is constant.

The function of the model then is to produce estimates of $I_{wc}$ and $I_{wi}$. This is done in a sub-system of five simultaneous equations.

Coale and Hoover assume that a constant proportion of income will be spent on welfare investments to meet the needs of the existing population

$$I_{wc} = (I_{wco} / Y_o)Y = hY$$

where h is a fixed proportion. Graphically this can be represented as

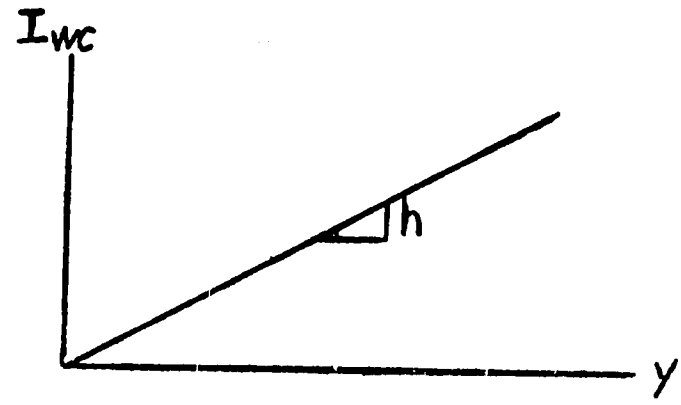


Figure 1

Coale and Hoover then assume that it takes 10 times as much to meet the initial needs of a new addition to the population than to maintain that person thereafter. If $W_c$ is the welfare cost of maintaining a current individual, then

$$I_{wc} = W_c P$$

where P refers to the population measured in units of equivalent adult consumers. Correspondingly

$$I_{wi} = 10 W_c \Delta P$$

If we now take the ratio of these two equations, we have

$$\frac{I_{wi}}{I_{wc}} = \frac{10 W_c \Delta P}{W_c P} = \frac{10 \Delta P}{P} = 10p$$

where p is the rate of population growth. Hence

$$I_{wi} = 10p I_{wc}.$$

This can be graphed as in Figure 2.

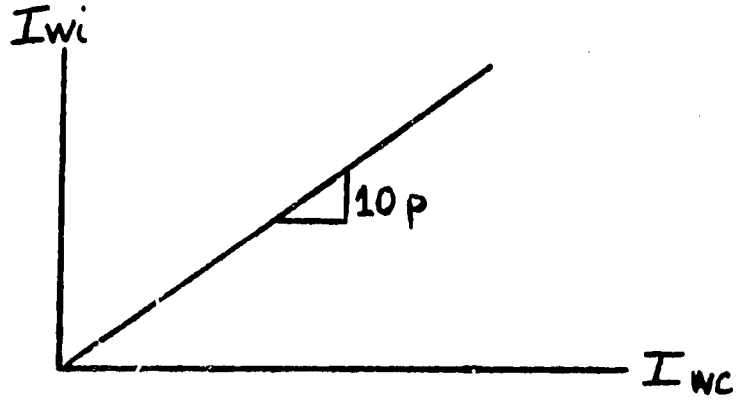


Figure 2

The next equation of the system is a definitional identity:

$I_w = I_{wc} + I_{wi}$

When combined with the previous equation this equation makes the level of total welfare investment a function of the level of current type welfare investment and the rate of population growth.

$I_w = I_{wc} + 10p\ I_{wc} = I_{wc}(1 + 10p)$

This is shown in Figure 3.

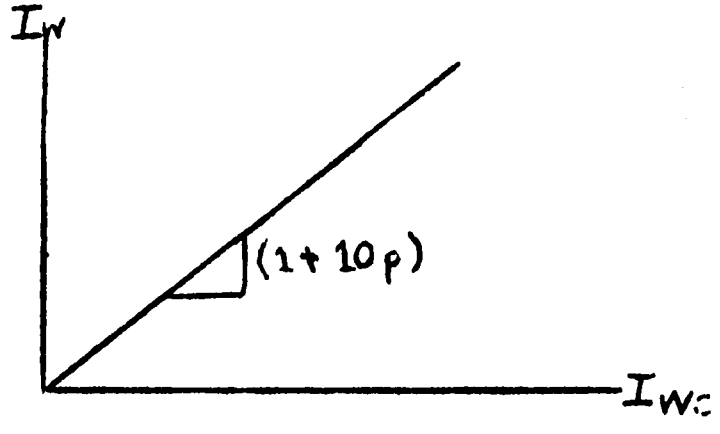


Figure 3

Total investment outlay is then defined as the sum of capital goods outlay and welfare outlays.

$$I = I_c + I_w$$

This is illustrated in Figure 4.

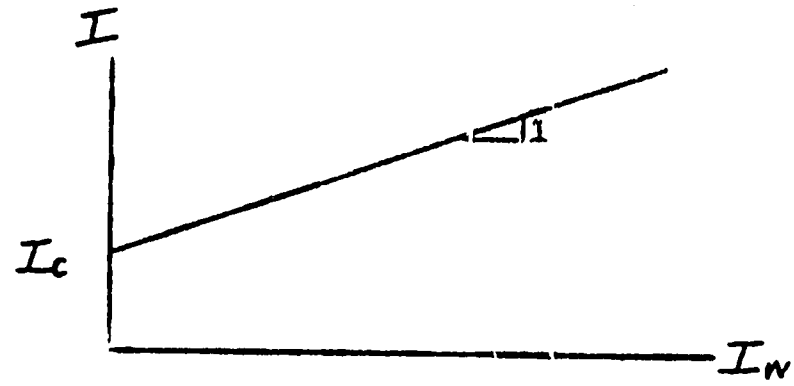


Figure 4

Thus the level of investment outlay is a function of welfare investment outlay which in turn is a function of current type welfare outlay which in turn is a function of current income. We may combine Figures 1, 3, and 4 to see how investment outlay is related to income in Figure 5.

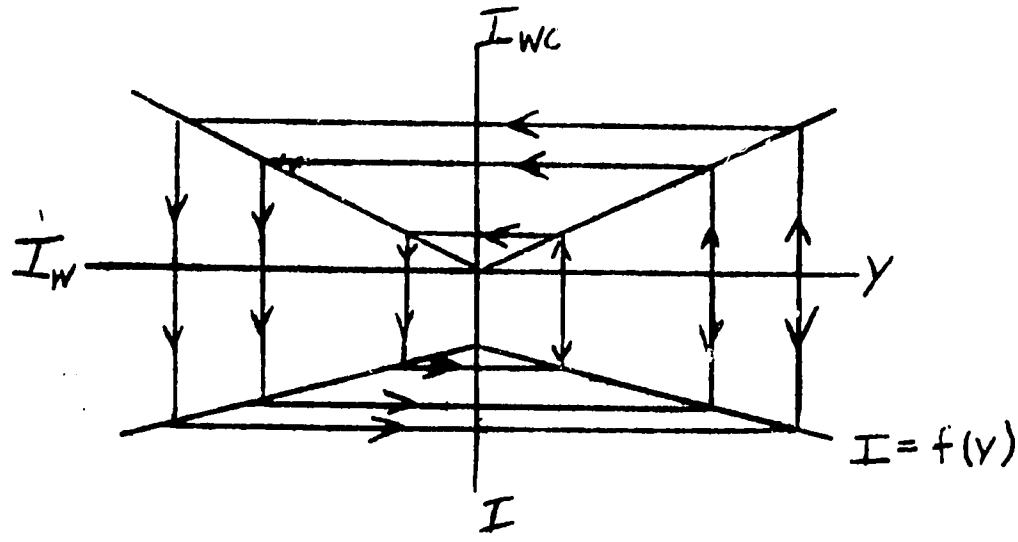


Figure 5

The equation describing this relationship is

$$I = I_c + (1 + 10p)\ hY$$

In order to determine the equilibrium level of income and investment, Coale and Hoover implicitly equate saving equal to investment and introduce the following savings function.

$$I = S = P\ [\frac{I_o}{P_o} + a\ (\frac{Y}{P} - \frac{Y_o}{P_p})]$$

Clearly savings is equal to population multiplied by per capita savings. Per capita savings is assumed to be equal to per capita savings (or investment) in the base period plus a change in per capita saving induced by a change in per capita income. Coale and Hoover assumed that the change in per capita savings is a constant proportion, a, of the change in per capita income from the base period.

By algebraic manipulation the terms of this equation may be rearranged so that it becomes

$$I = aY - (\frac{a\ Yo - Io}{Po})_P = \alpha Y - \beta P$$

In this form it is clear that investment is a linear function of income assuming population size, P, to be demographically determined.

Thus the system is reduced to one of two equations in two unknowns and can be illustrated graphically in Figure 6.

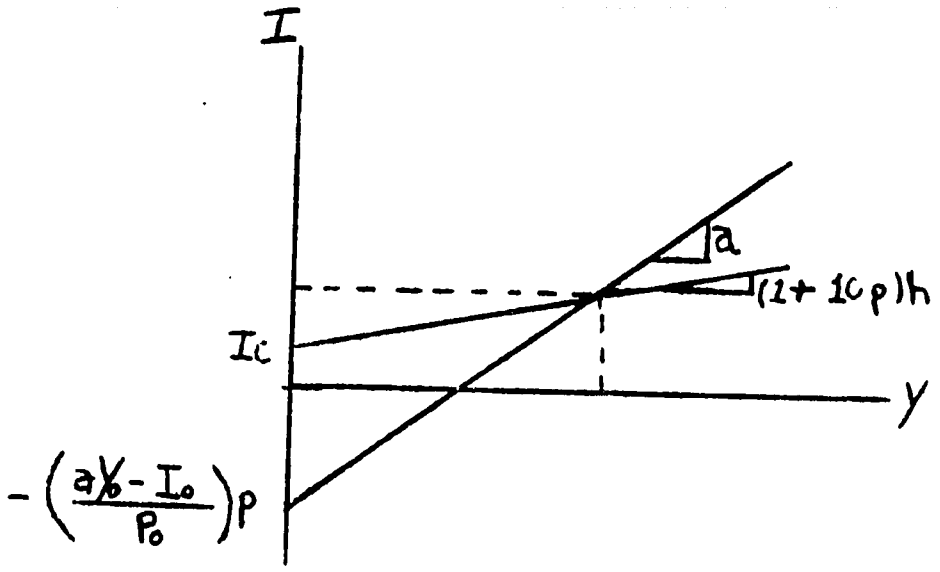


Figure 6

Once the levels of income and investment are determined, then the levels of welfare type investment are determined. This in turn determines the level of equivalent growth outlays, G, which in turn determines the addition to total income and hence total income in the succeeding period.

This model contrasted the outcomes of alternative projections of population growth for five-year periods between 1956 and 1986. For the high rate of population growth income per capita grew by 38%. For the low rate of population growth income per capita grew by 95%. Furthermore the rate of growth of income per capita decelerates under the assumption of a high rate of population growth and accelerates under the assumption of a low rate of population growth.

Perhaps most interesting was the fact that total income grew faster under the low fertility assumption. The reasons for this are not hard to find. Because of higher per capita income in the low fertility case, the proportion of income assigned to investment was larger than in the high fertility case. And of these investment expenditures a greater proportion

was of the high productivity capital goods type as opposed to the welfare type and yet even though welfare type investment was less in the low fertility case, welfare investment per capita was higher.

Lastly Coale and Hoover sought to meet the objection that their findings were merely the happy results of the numerical coefficients of their model. They did this by testing alternative values of these constants which bracketed the selected values to see if they modified the results substantially.

For the original value of "a" (.3) they substituted (.25) and (.35). For the original values of the e's ($e_c$ = .5, $e_i$ = 0) they substituted ($e_c$ = .5, $e_i$ = .5) and ($e_c$ = .0, $e_i$ = .0) and for the original value of R, (3 + .02t) they substituted (3) and (3 + .04t).

Their results could be summarized as follows:

> It shows that through this whole gamut of projections despite the wide variations in rates of progress that they imply the differential associated with reduced fertility is remarkably constant.[38]

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[38] A. J. Coale and E. M. Hoover, Ibid., p. 281.

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B. Myrdal's Criticism of Coale and Hoover

In a recent work Gunnar Myrdal finds fault with the Coale and Hoover study on a number of grounds.[39]

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[39] G. Myrdal, Asian Drama, New York: Random House, 1968, Appendix 7, pp. 2068-2075.

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He is most disturbed about their finding that the "percentage difference in income associated with fertility is said to be persistent and stable ranging between 38 and 48 percent."

He feels this result is not significant for the following reasons. First Coale and Hoover omitted a number of important variables. Secondly a wider range of results would have been achieved by varying the assumed parameters in combinations rather than one at a time. Thirdly the assumptions of constancy in the capital output ratio and certain institutional arrangements were crucial. If abandoned the range of results might have been quite large. Fourthly the size of the labor force is greatly circumscribed by past population in a period as short as thirty years. Fifthly the differentials between the projections widen at an accelerating rate as time passes.

Myrdal also objects to the Savings Function adopted by Coale and Hoover ($S = \alpha Y - \beta P$) which implies $\frac{S}{P} = \alpha\frac{Y}{P} - \beta$. In the first place Coale and Hoover excluded non-monetary savings in India which are of great importance. In the second place "the personal sector accounts for less than three sevenths of total monetized savings, government for most of the rest, and corporations for a small but growing share."[40]

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[40] G. Myrdal, Ibid., p. 2073.

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They assume the average propensity to save will double or triple between 1956 and 1986. This assumption of a growing savings ratio for individuals conflicts with evidence of constancy in other countries. The assumption that government savings or corporate savings will vary directly with per capita income is equally suspect.

In general Myrdal concludes that to be useful "models would have to contain many more parameters and account for many more interrelationships. They would have to be very much more complex in order to be logically consistent and correspond with reality. With the present dearth of empirical data, indulging in this type of preparatory macroanalysis data does not seem to be a rewarding endeavor."[41] This is, thus, not only a criticism of the

[41] G. Myrdal, Ibid., p. 2075.

Coale-Hoover model but of the use of any relatively abstract, theoretical model as a useful guide to policy.[42]

[42] Kuznets has criticized the Coale-Hoover model on substantially similar grounds. See: "Population and Economic Growth," Proceedings of the American Philosophical Society, Vol. 111, No. 3, June 22, 1967, pp. 170-193.

C. Hoover and Perlman

Direct application of the basic Coale-Hoover model was undertaken in 1965 by Professor Hoover and Mark Perlman,[43] both of the University of

[43] Edgar M. Hoover and Mark Perlman, "Measuring the Effects of Population Control on Economic Development: Pakistan as a Case Study," Pakistan Development Review, Vol. 6, No. 4, Winter 1966, pp. 545-566.

Pittsburgh. They chose Pakistan as a country for which the required data on population and economic prospects were available and "focused on evaluating the population impact in terms of selected characteristics of the national economy including aggregate and per capita income, savings and consumption. . . ."[44]

[44] *Ibid.*, p. 1.

Taking four alternative population projections prepared by Brackett and Akers of the U.S. Census Bureau (involving assumptions of constant fertility and declining mortality; both fertility and mortality constant; both fertility and mortality declining; declining fertility and constant mortality) for the period 1965 to 1985, the authors converted these into "equivalent adult consumers" by weighting children under 10 at 0.5, and women over 10 at 0.9 of a male adult. Next 96 alternative projections of GNP and its major components were generated using certain specified assumptions concerning key economic parameters such as the savings ratio, the availability of foreign assistance, the strength of the "autonomous" ("residual") growth factor and the share of current annual investment going to relatively non-productive, "no-growth" social welfare investment purposes. The incremental output-capital ratio (R) was derived from the investment and GNP series in the Third Five Year Plan of Pakistan.

In describing the Hoover-Perlman model, the notation used in the earlier Coale-Hoover model will be employed to make comparison easy.

The heart of this model is a linear difference equation

$$Y_{t+1} = Y_t + R_t \, [I_t - B(I_{w_t})]$$

Where Y is the level of total income, R is the incremental capital input ratio, I is total investment and Iw is welfare investment and B is a weighting factor for the no-growth part of investment, $I_w$ (welfare investment), which Hoover and Perlman dub the investment drain.

Welfare Investment is calculated more simply than in the Coale and Hoover model. It is given by the equation

$$I_{w_t} = \frac{Y_t}{P_t}(P_{t+1} - P_t)$$

Where P is population measured in terms of equivalent adult consumers.

Investment is assumed to be equal to the sum of domestic savings (S) and external resources (E).

$$I = S + E$$

The savings function explicitly introduces the population variable.

$$S = P(\alpha\frac{Y}{P} - \beta) = \alpha Y - \beta P$$

Which reduces to an assertion that per capita savings is a linear function of per capita income.

$$\frac{S}{P} = \alpha\frac{Y}{P} - \beta$$

It is obvious that an increase in population tends to reduce the growth of total income in two ways. In the first place it reduces the level of total savings, hence total investment. Secondly it adds to the welfare (no growth) component of investment by increasing the size of the $(P_{t+1} - P_t)$ term.

The various models which are then worked out and presented give the greatest weight to changes in the assumed incremental output/capital ratio, the presence or absence of "autonomous" growth, and the size of the "investment drain." The authors summarize the interactions among these factors by noting: ". . . the reduction of the marginal savings ratio weakens the impact of population-growth differences, as does the introduction of an autonomous element of growth. Giving more weight to the 'investment drain,' by contrast, accentuates the impact of population-growth differences. . . ."[45]

[45] Ibid., p. 551.

Combining these economic factors with the four population projections, one finds that the impact of mortality reduction is to lower per capita income in 1985 by about 5%. If fertility declines and mortality remains constant, then per capita income will be about 16% higher in 1985 than it would otherwise have been. Other possibilities fall between these limits. The most favorable possible economic situation which declining fertility and constant mortality result in a 20% increase in per capita income by 1985.

The authors suggest that generally their results should apply only to other countries with the same type of economic situation and parameters as Pakistan. They do not derive an estimate of the benefit per birth prevented but state that their model clearly makes this possible.

D. Paul Demeny

Coale and Hoover demonstrated that in the absence of costs, a program of fertility reduction would benefit a developing country. But such programs do have costs and so Paul Demeny undertook to investigate the question: Assuming that the cost and effectiveness of a birth control program was known, what price would be worth paying for it and how would that price depend on the structural parameters of the economy?[46]

[46] P. Demeny, "Investment Allocation and Population Growth," Demography, Volume 2, 1965, p. 203-233.

He also employs a variant of the basic Harrod Domar model to explore this question. It differs from the simplest formulation in several ways.

He has included an exogenous growth factor (g) to take into account such factors as organizational changes, improvements in skill and motivation of the labor force, etc.

Thus the first order linear difference equation which underlies his system is

$$Y_{t+1} = g\,Y_t + \left(\frac{s}{R}\right)Y_t$$

Where s is the average propensity to save of the population and R is the capital output ratio so defined as to take into account exogenous growth.[47]

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[47] This equation is substituted for the form Demeny presented in his article

$$R = \frac{I_t}{Y_{t+1}/g - Y_t}$$

---

Thus

$$R = \frac{I_t}{Y_{t+1} - g\,Y_t}$$

Demeny then takes into account the fact that the propensity to save is not independent of population growth and thus introduces the Coale-Hoover savings function.

$$S_t = sY_t = P_t\left[\frac{sY_o}{P_o} + a\left(\frac{Y_t}{P_t} - \frac{Y_o}{P_o}\right)\right] = \alpha Y_t - \beta P_t$$

By substituting this into the growth equation, Demeny gets

$$Y_{t+1} = g\,Y_t + \left(\frac{\alpha Y_t - \beta P_t}{R}\right)$$

It should be noted that this is a much simpler model than that of Coale and Hoover. It assumes that g, R, and a are all constant. The values of P are determined outside the economic system.

Demeny assumed a base population of one million. He assigned to it the following initial parameters: Gross Reproduction Rate = 3, the life expectancy at birth is 35.0 and the masculinity ratio at birth is 1.06. From this he generated a stable age and sex distribution for the base population. He then introduced an exogenous increase in life expectancy at the rate of 2.5 years every five years.

He then defined two population projections based on alternative assumptions about the gross reproduction rate. In the first projection the GRR remains constant for the first twenty five years and then falls linearly to 1.5. In the second projection the GRR rate will fall linearly from 3.0 to 1.5 and then remain constant thereafter. This is shown in Figure 7.

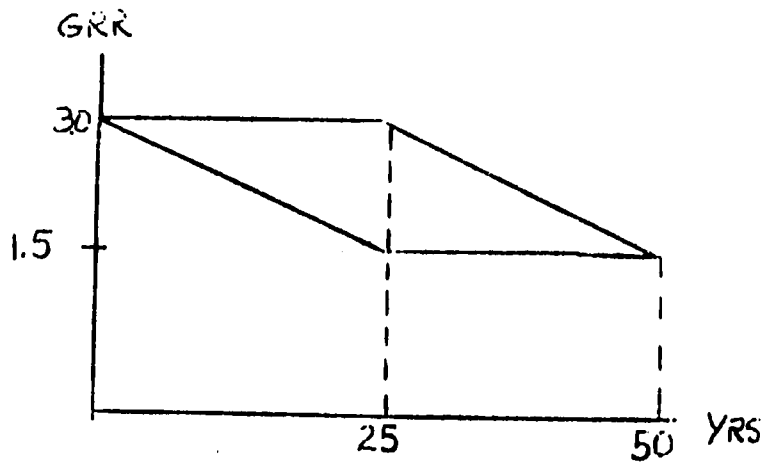


Figure 7

It should be noted that though fertility rates are the same for both projections after fifty years, the absolute growth of population will be greater in projection I because the population is larger.

Population will grow by 81% in 25 years under projection I and by 49% in 25 years under projection II. Yet, under projection I the work force will only be 4% larger than in projection II since almost all of the population loss under projection II is in the 0 to 15 year old group. The dependency ratio would be 2.65 in the high fertility case and 2.12 in the declining fertility case. This gap is narrowed when population is converted into units of equivalent adult consumers.

In the Coale and Hoover study this decline in population was accompanied by an increase in total income in the first 25 years because the labor force did not decline appreciably and it had more capital goods to work with.

If a reduction in fertility rate was itself costly in resources, then the results might not have been so unequivocally favorable. If demographic investments were to replace investments in capital goods, then total output might decline along with population.

To the question, "What are the maximum levels of (demographic) investments from year to year which are economically permissable provided that they cause fertility to decline in the fashion specified in Projection II?" Demeny answers "any pattern of demographic investments which during the first twenty-five years would keep income per equivalent adult consumer at the same level as it would be in the absence of such investments."[48]

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[48] P. Demeny, Ibid., p. 220.

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It is clear that the difference between this maximum and the actual level of demographic investment required is a measure of the efficiency of such investment.

By placing an asterisk on those values which are the result of demographic investment, the maximum allowable demographic investment can be expressed as

$$\max D = S_t^* - R\left[\frac{P_{t+1}^*}{P_{t+1}}\left\{gY_t + P_t\left[\frac{\frac{s_o Y_o}{P_o} + a\left(\frac{Y_t}{P_t} - \frac{Y_o}{P_o}\right)}{R}\right]\right\} - gY_t^*\right]$$

The first term is merely a savings function of the Coale and Hoover variety indicating the savings that will be forthcoming under projection II. The second term measures the amount of non demographic investment that would be required to maintain $\frac{Y_t^*}{P_t^*} = \frac{Y_t}{P_t}$. This can be written more simply as

$$\max D = S_t^* - R\left[\frac{P_{t+1}^*}{P_{t+1}} Y_{t+1} - gY_t^*\right]$$

Demeny then calculated a series of five indicators based on alternative assumed values for the parameters $S_o$, a, R, and g. The indicators were: (1) Y/P assuming $Y_o/P_o$ = \$100, (2) the maximum value for D assuming $P_o$ = 1 million, (3) the maximum permissible value per birth prevented D/B, (4) the maximum permissible portion of total investment that can be demographic, D/I*, and (5) the maximum portion of total income that can be assigned to demographic investment, D/Y*.

He attained the following results. The maximum permissible demographic investment per prevented birth is never less than \$120. The results were roughly the same for all plausible levels of $S_o$ and g. A higher value of R will result in a higher value of D/B. The maximum permissible value of D varies proportionately with the effectiveness of demographic investment in preventing births. The maximum permissible values of D will vary directly with per capita income. The maximum permissible value of D will vary

directly with the capital output ratio for this is equivalent to a decline in the opportunity cost of demographic investment.

Using the same model Demeny investigated the outcome of three alternative demographic investment policies assuming each would result in a 50% linear reduction in fertility over twenty five years. The alternative policies were:

(1) $D_t = VI^*$ where V is a constant.

(2) $D_t/B_t = j(Y_o/P_o)$ where j is a constant.

(3) $D_t = kY_o$ where k is a constant.

Demeny takes pains to discuss the effects of the simplifying assumptions that he used. Coale and Hoover explicitly introduced the effect of population growth on the capital output ratio through shifts in the composition of investment from capital goods to welfare investment. Demeny has ignored this in his model hence his procedure understates the advantages of fertility reduction in this respect.

Demeny like Coale and Hoover ignored effects of changing the size of the labor force on the capital output ratio. To the extent that additional workers would have been added, R would have been reduced but this effect is very slight since only a small portion of the additional births would be old enough to work and this effect would in all likelihood be outweighed by the fact that more women would be free to work.

Demeny assumed a fixed capital output ratio so that reductions in the capital stock occasioned by demographic investment result in proportionate reductions in output. If substitution were possible, there would be a less than proportionate decline in output when capital was reduced.

By assuming that the capital output ratio was the same with and without demographic investment, Demeny abstracted from the possibility of

declining average productivity of capital. If those investments foregone had a lower productivity (higher capital output ratio) than those attempted, then the loss in potential output is less than the model implies. Thus the maximum permissible demographic investment is understated. This particular conclusion could be reversed if there are significant economies of scale or demographic investments can only be substituted for investments of higher than average productivity.

The model abstracts from the concept of optimum population size. It disregards national economies or diseconomies of scale. In all probability most underdeveloped countries are above the optimum and so the model probably again understates the gain from fertility reduction.

It may be argued that an increase in per capita income would not increase savings since the gains would be so small as to be imperceptible. To this Demeny answers that the gains will be large to those families directly affected. However, this raises still another objection. Since benefits are clustered, the use of the economy wide propensity to save out of changes in per capita income, a, may be invalid. The importance of this objection depends on the distribution of the gains from fertility reduction. However, it must be pointed out that a major beneficiary will be government which will bear less social overhead costs and its propensity to save can be assumed to be unitary.

It may be objected that if children are a source of satisfaction which is not measured by per capita income, then the latter is not a trustworthy index of the welfare gains of this program. To this Demeny replies that the fact that individuals voluntarily participate in a program of birth control proves that the participants do realize gains.

Still another criticism of the Demeny model is that it ignores the effect of increasing population on the inventive to invest. Demeny points out that if investment requires stimulation, this can be accomplished by monetary and fiscal policies.

To the Hirschman type argument that an economy will strive harder and accomplish more in the face of threatened reductions in its standard of living, Demeny replies that the demonstration of gains from population reduction will serve as a spur to increased efforts.

The objection to which Demeny devotes the greatest attention is the critique that his model involves a one-way direction of causation. That is income is determined by demographic factors but "Population trends are assumed to be independent from economic factors except for demographic factors."[49]

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[49] P. Demeny, Ibid., p. 207.

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If demographic investment raises per capita income, and per capita income in turn induces population growth which may offset partially or wholly the previous decline, then his model may overstate dramatically the benefits of demographic investment.

He disposes of this argument in the following way. First of all he limits his analysis to the case of low income countries where the neo-Malthusian inverse relationship between per capita income and fertility does not apply. In fact Demeny assumes that there is a significant lag in fertility reaction to changes in per capita income. He assumes that fertility will be constant for a period of twenty five years in the absence of demographic investment.

He rejects the Malthusian doctrine of changes in population based on changes in death rates due to variations in per capita incomes. He argues

that mortality in the underdeveloped countries is no longer linked to per capita incomes. Public health control, insecticides and antibiotics have dramatically reduced deaths in the less developed countries and income is not an important factor in their availability.

## SECTION IV

### Approach II (A): Neo-Classical Benefit Models

The models of Coale and Hoover, Hoover and Perlman and Demeny were all based on Harrod-Domar economic models. The capital output ratio was assumed to be invariant with respect to all variables save technological progress. The force of this assumption is to make output solely a function of the capital stock. This in turn had two critical effects on these three models. First of all it made the marginal productivity of labor zero since it denied entrepreneurs the option of adopting more labor intensive methods thus reducing the capital output ratio. In terms of the Enke framework benefits were assured since additional increments to population could add only to consumption not production. The second result of this assumption is to make the choice of a savings function crucial. Since savings was assumed to be identical with capital accumulation and capital is by assumption the only productive factor, the major contribution which population can make to total output is through its influence on the savings function.

As a short run proposition for the analysis of business cycle phenomena in the context of growth, the assumption of a constant capital output ratio may prove a useful simplification. However, the emphasis of the models reviewed in this section was on long-term growth over two or more decades. In such a context the assumption of a Leontief type fixed-coefficient aggregate production function cannot be justified. For this reason attention has shifted away from such models to those based on the neo-classical framework.[50]

[50]An excellent discussion of the relative merits of Harrod-Domar versus neo-classical models and their relationships to one another can be found in F. H. Hahn and R.C.O. Mathews, "The Theory of Growth: A Survey," The Economic Journal, Vol. 74, December 1964, pp. 787-793.

Since the neo-classical growth model assumes a continuous and well-behaved[51] aggregate production function demographic variables may effect out-

[51]"Well-behaved" in the technical sense that the function displays diminishing returns to any one factor, proportionate returns to scale for changes in all factors, and certain other properties.

put directly through the labor input, it is not as important that they influence the capital stock through special assumptions about the form of the savings function. Three such studies are those of Stephen Enke, Peter Lloyd and T. K. Ruprecht. All three are based on the Cobb-Douglas production function and hence are non-linear; all three employ a system of lagged relationships hence are dynamic in character. None have been estimated empirically, although computer-simulation runs have been made to test the effects of alternative fertility hypotheses.

A. Stephen Enke

Enke has recently published the results of a simulation study using a dynamic model constructed along fundamentally neo-classical lines.[52]

[52]S. Enke, Raising Per Capita Income Through Fewer Births, Santa Barbara: TEMPO, General Electric Company, March 1967.

At the heart of the model is a Cobb-Douglas type production function

$$Q_t = \phi L_t^{\alpha} K_t^{\beta} T_t^{\nu}$$

Where $Q_t$ refers to current output, $\phi$ refers to a numerical conversion factor, $L_t$ refers to the current labor force, $K_t$ refers to the current size of the capital stock, $T_t$ refers to the current time period. The exponents of labor and capital ($\alpha$ and $\beta$) are the elasticities of productivity of labor and capital respectively. The percentage time rate of technical progress is given by $\nu$. It should be noted that in this function technological progress is neutral and the sum of $\alpha + \beta$ indicates the nature of the scale effects.

The second major component of Enke's study is a demographic sub model. From it is generated the values of L and K.

He postulates a hypothetical population for a "typical LDC." For each five-year age group he postulates the percent of the population, the annual death rate, the annual birth rate per 1,000 women and the initial per capita consumption in each age category.

Thus the labor force would be defined as

$$L_t = 3/4 \sum_{i = 15 - 19}^{i = 50 - 54} A_{it}$$

Where $A_{it}$ represents the number of living persons in age category i in period t. The labor force is 3/4 of this amount on the assumption that "all the male and half the females between 15 through 54 years of age are assumed to be equivalent members of the labor force." Clearly the size of $A_{it}$ depends on the number of births i years before and the annual death rates during the intervening periods. In this way a significant and complex lag structure is built into the model. It should be noted that Enke does not vary the labor force participation rate for women in accordance with birth rates.

The capital stock can be defined as

$$K_t = K_{t-1} + I_t$$

Investment in productive equipment (as opposed to unwanted inventory accumulation) is assumed equal to savings. This too is traditional in neo-classical models.

$$I_t = S_t$$

Total savings is definitionally the sum of savings in each age category

$$S_t = \sum_i S_{it}$$

In each age category the propensity to save is a function of per capita income. "Specifically, the fraction of GNP saved in any year is .05 times the ratio of current to initial age specific incomes per head.

$$\frac{S_t}{Y_t}_i = .05 \left(\frac{Y_t/A_t}{Y_o \; A_o}_i\right)$$

This represents a major improvement over Enke's previous work in that the reduction in required consumption is now related to age. In this model "Each prevented birth does not release the all-ages average (annual consumption) for others to consume but considerably less" at first since the consumption of the very young is considerably below average.

A major by product of this model is an <u>Index of Benefit</u>, Z. This is a measure of how much more a person of a specific age could consume due to a change in fertility. It is based on the assumption that the relative distribution of income within a family remains the same as family income increases. Mathematically the Index of Benefit is defined as

$$Z = \frac{A_{it} \cdot C_{it}}{A_{io} \cdot C_{it}}$$

where $C_{it}$ refers to per capita consumption of members of the ith age group (cohort) assuming no saving.

We may now trace out the chain of events triggered by a reduction in fertility. Initially the labor force would be unaffected but consumption and savings would be increased due to increased per capita incomes. Due to increased savings the capital stock would be larger and hence labor productivity would be greater in later periods. After fifteen years the labor force would be smaller than in the absence of fertility control but this loss of input would be partially offset by a greater than otherwise capital stock. In any case per capita income would have risen so long as the percentage decline in population exceeded the percentage declines in output.

Enke examines three degrees of birth control. They are no birth control, full birth control and increasing birth control. By full birth control is meant that the birth rate per 1,000 women is cut in half in all age categories. The notion of increasing birth control is more complex.

It is assumed that in the first 5-year period none of those women between 15 and 19 practice birth control; 10% of those between 20 and 24 do so, 20% of those between 25 and 29 do so, 30% of those between 30 and 34 do so, 40% of those between 35 and 39 do so, and 50% of all above that age practice birth control with complete effectiveness. In each succeeding 5-year period the proportion of women in each age category who practice birth control will increase by 10% up to a maximum of 50%. At the end of thirty years this would result in full birth control.

Enke assumes that the cost per birth control acceptor is $2. The cost per birth prevented will depend on the annual birth rate of the acceptor age group.

Under each of the three degrees of birth control Enke calculated for a hypothetical population at five-year intervals GNP, population, crude birth rate, labor force, participation rates, marginal productivity of labor and capital, births prevented, cost per birth prevented, percent increase in per capita income from the base period and an Index of Benefit.

By dividing the difference in income with and without birth control by the differences in births, Enke calculates the dollar value per birth prevented. By dividing the difference in income by the cost of the birth control program he calculates an undiscounted rate of return.

Enke then examines the questions "By how much would the rate of technological progress have to be increased in order to yield the same per capita income after 30 years as would be attained under increased birth control?", and "By how much would the rate of saving have to be increased to do likewise?" He found that either the rate of technological change would have to be doubled in the next 15 to 20 years and tripled in the next 25 to 30 years.

Previous theoretical models of the benefits of fertility control have indicated that benefits are a montonically increasing function of per capita income. Enke's model has the virtue of yielding a positive optimal rate of births. Employing the discounted present value of the production stream net of the consumption stream as a basis for determining the value of a birth, Enke points out that though this may now be negative in most LDC's, as per capita income and hence saving and capital formation are increased, the marginal productivity of labor might rise to the point where the present discounted value of an infant is positive.

He also recognizes explicitly that "Infants must be considered as sources of enjoyment for their parents and others and not solely as a particular kind of investment asset."

Since Enke's model is fundamentally of the neo-classical variety, a number of obvious variations suggest themselves. In the first place the aggregate production function might be disaggregated into a two sector model, (e.g. agricultural and non-agricultural). A function other than the Cobb-Douglas might have been employed. Technological progress need not have been assumed to be neutral but rather it might have been labor saving or capital saving. Technological progress might be embodied in labor or capital using a "vintage" model.

Under competitive assumptions the elasticities of productivity of the productive factors determine the functional distribution of income. Changing weights in a two sector model could change the distribution of income and the savings function could be made sensitive to changes in the distribution of income. This is but one of many variants on the savings function that might have been employed.

Lastly the choice of a discounting factor should not be set arbitrarily (e.g. 15%). Under neo-classical assumptions the rate of interest should be related to the productivity of capital which is an endogenous variable in Enke's system.

## B. Peter Lloyd

Peter J. Lloyd has developed an alternative model which corrects some of the deficiencies of Enke's model but at the cost of a number of important simplifying assumptions.[53]

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[53] Peter J. Lloyd, "A Growth Model with Population and Technological Change as Endogenous Variables," unpublished paper, 1968.

Like Enke's TEMPO model, Lloyd's is essentially neo-classical in character. Output is determined by a single aggregate production function.

$$Y_t = B_t(K_t, L_t, N_t)$$

where $Y_t$ is current output. $B_t$ is a multiplicative factor of the production function which in turn depends upon an index of technology, A. $K_t$ is the current capital stock, $L_t$ is the current labor force measured in efficiency units and $N_t$ is the stock of arable land.

The multiplicative factor is no simple function of times as in Enke's model rather it is dependent on the whole history of government technology development expenditures $E_3$

$$B_t = (A_o + \varepsilon \sum_{j=1}^{t=T_3} E_{3j})^{\delta}$$

$$o < \delta < 1$$

As in Enke's model savings and investment are assumed equal hence the capital stock is equal to

$$K_t = K_o + \sum_{j=1}^{t=1} S_j$$

Lloyd's saving function is much more complex than that of Enke. It is the sum of a personal savings function and a government savings function. The former is

$$S_{pt} = -c\, P_t + s\, Y_{dt}$$

where $P_t$ is population in period t and $Y_{dt}$ is disposable income in period t. This is the same type of function used by Coale and Hoover, except that saving has been made to depend on disposable income rather than total income.

$$Y_{dt} = (1-u)\ Y_t + E_{5t}$$

where u represents the average tax rate and $E_{5t}$ represents government transfer payments to participants in the bonus birth control program.

Government savings is the excess of tax receipts over expenditures

$$S_{gt} = u\ Y_t - \sum_{i=1}^{5} E_{it}$$

where u, $E_3$ and $E_5$ have been defined. $E_1$ refers to current government expenditures, $E_2$ refers to expenditures for birth control and $E_4$ refers to expenditures for land development.

Putting the private and public savings functions together we have

$$S_t = -c\ P_t + s(1-u)\ Y_t + u\ Y_t + s\ E_{5t} - \sum_{i=1}^{5} E_{it}$$

$$c > 0$$

The treatment Lloyd gives to the labor input is quite different from that of Enke. Labor input is measured in homogeneous labor units which depend on the number of laborers employed $M_t$ and "a factor, m, which measures the ability to work at different levels of consumption."

Rather than derive a labor force from a demographic sub model as did Enke, Lloyd simply assumes that it will grow exponentially at the rate $q_1$

$$F_t = F_o\ (1 + q_1)^t$$

The number of laborers actually employed, M, is assumed to be a constant fraction, f, of the labor force

$$M_t = f\ F_o\ (1 + q_1)^t$$

The efficiency of labor, m, is dependent on caloric intake in a non-linear way. Using per capita consumption, Z, as a proxy for caloric intake, Lloyd postulates the equation

$$m = 1 - \frac{Z^*}{Z_{t-1}} \qquad Z^* > o$$

which will approach 1 as a limit as per capita consumption grows indefinitely.

The final input of the aggregate production function is arable land which can be increased by land development expenditure

$$N_t = N_o + h \sum_{j=1}^{t=T} E_{4j}$$

The population equation of his model assumes that the death rate is constant and that the birth rate depends solely on the expenditure for birth control

$$P_t = P_o (1 - q2)^t - \phi_{2t} - \phi_{3t}$$

where q2 is the rate of population growth in the absence of birth control programs and $\phi_{2t}$ and $\phi_{3t}$ are the number of births prevented by subsidizing the means of birth control and paying bonuses respectively.

The results of expenditures to subsidize the means of birth control can be expressed as

$$\phi_{2t} = a\, E_{2,t-T_2} \qquad E_2 \leq E_2 max,\ a>o$$

The value of $\phi_{3t}$ is dependent in a complex way on $E_5$. Lloyd postulates supply and demand functions for a sub market in prevented births.

It should be obvious to the reader that the labor force is assumed to grow exponentially while the level of population is dependent on birth control expenditures. Such a dichotomous model is valid for short periods (15 years or less).

If the initial values of the variables are given, the model will trace out a time path from period to period. Lloyd uses it to examine the effects of alternative government expenditure policies on the annual rate of growth of per capita income.

In a simulation study Lloyd examined "five budget sets, representing five different allocations of the government budget among the five types of government expenditures in period o, and the growth rate in period 1 which results from each budget. He found that for plausible sets of parameters" the growth rate was maximized if the moneys are expended first on birth control to the maximum coverage possible, and the rest on technology. A unit of expenditure subsidizing the cost of birth control means turns out to be 80 times more effective in raising the rate of growth than a unit of expenditure on capital formation.

Lloyd himself points out that his model suffers from the fact that he has not divided it into agricultural and non agricultural sectors and he has not considered the effect of birth rates on the labor force participation rates of women.

It is obvious that the Lloyd model could be adopted to estimating the value of preventing a birth and the rate of return on demographic investment as was done in the case of Enke's model.

C. T. K. Ruprecht

The demand for a multisector neo-classical type model has been met by T. K. Ruprecht.[54] Unlike the models of Lloyd and Enke, it is not general

[54] T. K. Ruprecht, "The Two Sector Demometric Model," unpublished paper, 1968.

in nature, applicable to any LDC. It was designed to describe the economy of the Philippines from the present to the year 2000.

In his study he creates a complex model which stresses the role of demographic variables. Then through a series of simulation experiments he examines the effects of alternative population projections under a variety of assumed conditions. His objectives were to explore the effects of alternative population trends on Philippine development, on the level and structure of savings and on the growth and pattern of employment.

Ruprecht divides the economy into agricultural and non agricultural sectors. In each, output is determined by a Cobb-Douglas production function. He built into his model "as many interactions of population on economic development as possible." Then alternative population projections were fed into the model in order to examine the resulting differences in the time path of economic variables.

The model is fully recursive; that is, the endogenous variables do not interact, the line of causation is unidirectional.

Since the production functions are at the center of neo-classical growth models let us begin with the agricultural production function.

$$Y_{A_{t+1}} = R_{A_t} \; L_{A_t}^{\varepsilon A} \; K_{A_t}^{\rho A} \; N_t^{\lambda}$$

Where $Y_{A_{t+1}}$ refers to agricultural output in period t+1, $R_{A_t}$ is a multiplicative factor indicating technological change, $L_{A_t}$ is equal to the agricultural labor force in period t, $K_{A_t}$ is the agricultural capital stock in period t and $N_t$ is the stock of arable land in period t.

In logrithmic form this formulation is linear.

$$\ln Y_{A_{t+1}} = \ln R_{A_t} + \varepsilon_A \ln L_{A_t} + \rho_A \ln K_{A_t} + \lambda \ln N_t$$

Since a rate of growth is equal to the derivative of the natural log with respect to time

$$\frac{d \ln Y_{A_{t+1}}}{dt} = \frac{d \ln R_{A_t}}{dt} + \varepsilon a \frac{d \ln L_{A_t}}{dt} + \rho_A \frac{d \ln K_{A_t}}{dt} + \lambda \frac{d \ln N_t}{dt}$$

By employing an asterisk to indicate a rate of growth the equation can be rewritten

$$Y_{At+1}^{*} = R_{A_t}^{*} + \varepsilon_A L_{A_t}^{*} + \rho_A K_{A_t}^{*} + \lambda N_t^{*}$$

Ruprecht assumed that the exponents of the production function summed to unity or constant returns to scale in agriculture.

The purpose of this equation is not to determine what the rate of growth of agricultural output shall be given inputs as is traditional in such models. Rather it is inverted to determine what inputs will be required to meet the "predetermined rate of increase in agricultural output." $Y_{A*}$ depends upon the growth in the demand for agricultural output in two sub sectors, domestic final consumption $A_c$ and intermediate inputs to the non agricultural sector (including export) $A_I$.

The growth rate of consumption demand is equal to the growth rate of equivalent adult consumption units which depends on exogenous population projections. The growth rate of agricultural output, $Y_{a*_{t+1}}$, is a linear combination on the growth rate of its two sub sectors.

$$Y_{A*_{t+1}} = W_o A_{co}^{*} + (1-W_o) A_{Io}^{*}$$

where the weights depend in a complex way on population growth $M_t^*$ and the growth of non agricultural output $Y_{NA}^*$.

Whereas agricultural output is determined by the forces of demand, non agricultural output is determined by the forces of supply. Given available inputs output is determined by the following function.

$$Y_{NA_{t+1}} + R_{NA_t} \; L_{NA_t}^{\varepsilon NA} \; K_{NA_t}^{\rho NA}$$

The variables are defined as in the case of the agricultural function. In terms of rates of growth the function becomes

$$Y_{NA_{t+}}^* = R_{NA_t}^* + \varepsilon NA \; L_{NA_t}^* + \rho NA \; K_{NA_t}^*$$

National Income is then defined as the sum of agricultural and non agricultural outputs.

By means of "typical growth pattern" coefficients estimates are made of the growth of four sub sectors, mining, industry, transportation and communication and other services.

The growth of the capital stock (productive investment) is assumed to be constrained by the supply of savings. Savings in turn are estimated by summing three separate savings functions. To the private savings function and the public savings function of Lloyd, Ruprecht adds a business savings function. Business saving is assumed to be a linear function of profits which are assumed to be a linear function of GNP.

Household saving is defined as disposable income less consumption. Consumption is disaggregated into two types, a widening component to meet the needs of increased consumption units.

$$C_{W_{t+1}} = \frac{C_{T_t}}{J_t} J_{t+1}$$

Where $C_{W_{t+1}}$ refers to consumption for widening $C_{T_t}$ refers to total consumption in period t and $J_t$ refers to the number of male equivalent consumer units in period t.

Consumption deepening is more complex, it is a linear function of the rate of growth of net disposable income. That is disposable income net of income devoted to consumption widening. This can be expressed as follows

$$Y_{DN_{t+1}} = Y_{D_{t+1}} - (C_{W_{t-1}} - C_{T_t})$$

where $Y_{DN_{t+1}}$ is net disposable income in period t+1 and $Y_{D_{t+1}}$ is simply disposable income in the same period. Hence consumption deepening is expressed as

$$C_{D_{t+1}} = e + g\ (Y_{DN_{t+1}})$$

where $C_{D_{t+1}}$ refers to consumption deepening.

Government Saving as in Lloyd's model is simply government revenue less certain government expenditures

$$S_{G_{t+1}} = RV_{t+1} - E_{H_{t+1}} - Ed_{t+1} - E_{o_{t+1}}$$

where $S_{G_{t+1}}$ refers to government savings in period t+1, $RV_{t+1}$ refers to government revenues in period t+1, $E_{H_{t+1}}$ refers to expenditures on health, $Ed_{t+1}$ refers to expenditures on education an $E_{o_{t+1}}$ refers to other government expenditures.

Revenues and other government expenditures are assumed to be a linear function of GNP. Expenditures on health and education are assumed to depend

on population. These are factors stressed in the Coale and Hoover model.

The capital concept is unusual in that it excludes inventory accumulation and investment in housing. In the latter respect this model also follows Coale and Hoover.

Thus Ruprecht's equation defining the growth in the capital stock is

$$K_{t+1} = K_{T_{t+1}} - (P_{t+1} + I_{n_{t+1}} + K_{H_{t+1}})$$

where $K_{t+1}$ is net productive investment $K_{T_{t+1}}$ is total investment (equal to total savings), $P_{t+1}$ is equal to depreciation, $I_{n_{t+1}}$ refers to inventory change and $K_{H_{t+1}}$ refers to investment in housing.

Once the total increment to the capital stock is determined it must be allocated between the agricultural and non-agricultural sectors.

Let us now return to the agricultural sector. The required output has already been determined. The input of land is determined by an exogenous projection. On the assumption of a labor to land ratio which varies according to a linear time trend, the number of units of labor required is also determined.

The determination of the rate of technological change on the other hand is extremely complex. It depends on such diverse factors as the pressure of population on available land (on the assumption that the extensive margin has "spoiled" Philippine agriculture), the agricultural capital stock per acre and government and private savings and consumption deepening all of which represent improvements in labor quality.( Lloyd would have included this in the labor input.)

Once the rate of technological progress is determined the amount of agricultural capital required to meet the predetermined level of agricultural

output can be calculated. $\Delta K_{NA}$, the remainder of the capital, is available to the non-agricultural labor force.

$$\Delta K_{NA_t} = \Delta K_t - \Delta K_{A_t}$$

Assuming no change in relative factor prices, the growth in employment in the non-agricultural sector will be proportional to the growth in the capital stock. However, this ratio is assumed to change over time in accordance with a linear time trend.

The rate of technological change is determined by a complex function of the non-agricultural capital stock, the rate of growth of labor quality and the rate of growth of the economy. This last element is based on the notion that "the faster the economy is growing the more learning by doing is taking place."

Ruprecht has used his model to make 35 simulation runs based on 14 categories of assumptions about the nature of the economy. Among those parameters that he varied was fertility. He considered two cases, that of constant and of falling fertility. This model could be adopted to perform the kind of calculations Enke made in his simulation study.

Peter Newman and R. H. Allen prepared a neo-classical simulation model which stands as a bridge between the work of Coale and Hoover and the other more recent neo-classical benefit models.[54a]

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[54a] P. Newman and R. H. Allen, Population Growth Rates and Economic Development in Nicaragua (Prepared for the Government of Nicaragua and USAID Nicaragua), Robert R. Nathan Associates, Inc., Washington, D.C., November 1967.

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Like the Coale Hoover study it is not intended as a general model for less developed countries but is directed to the economic situation of a

specific country, Nicaragua. And like that study its purpose is to compare the long-term path of per capita income and consumption under three alternative fertility assumptions.

The Newman-Allen high fertility projection adopted the assumption that age-specific fertility rates would remain unchanged during the succeeding 50 years. The medium fertility projection assumed that in 1968 birth rates for women 35 years and over would decline at the rate of 7% per five years. In 1973 birth rates for women 30 to 34 would decline at that rate. In 1978 birth rates for women under 20 and between ages 25 and 30 would similarly decline. Lastly in 1978 the birth rates for women between 20 and 25 would begin to decline at the rate of 7% per five years.

The low fertility projection would have fertility rates in the age groups 15 to 19 and 35 and over fall at 12% per five years from 1963 onward while birth rates for those 20 to 34 fall by 7% starting in 1963.

The purpose behind the staggered starts and differential rates of decline is to produce a structure of birth rates at the end of 50 years which approximates that of a developed country.

They then employ their demographic sub model to generate estimates of population in terms of equivalent adult consumers as did Coale and Hoover. However, Newman and Allen employed a more plausible set of weights with five categories instead of Coale and Hoover's three.

Lastly the sub model was used to project the labor force in each period. They assumed that the entire population between the ages of 15 and 64 were members of the labor force. However those aged 15 to 19 were given a weight of .85 due to the fact that they would be less efficient while learning and a certain percentage would be continuing their schooling.

It should be noted that their sub model did not allow for a feedback whereby changing economic conditions would effect fertility and mortality.

The core of the Newman-Allen model is a Cobb Douglas production function

$$Y_t = JK_t^u L_t^v$$

Where J is a constant term, $K_t$ is the capital stock in year t and $L_t$ is the labor force in year t. This model abstracts from technological change. However the sum of u and v which is the degree of homogeneity and measures returns to scale need not sum to one (constant returns).

The labor input is provided by the demographic sub model. Hence the remainder of the model is devoted to determining the capital input. The capital stock in period t is defined as equal to the capital stock of the previous period plus investment in the previous period

$$K_t = K_{t-1} + I_{t-1}$$

Investment is defined as equal to the sum of domestic and foreign savings

$$I_t = S_t + E_t$$

Domestic savings is the sum of private and government savings

$$S_t = S_{P_t} + S_{G_t}$$

Newman and Allen employ the Coale Hoover savings function for the private sector

$$S_{P_t} = aW_t + bN_t$$

Where $W_t$ is national income and $N_t$ is population measured in equivalent adult consumers. The negative of b may be thought of as autonomous

consumption expenditure per person. Government is introduced into the total savings function by introducing the constant $b^a$, the negative of which refers to the amount of public goods which the government will provide to each new equivalent adult consumer. The domestic saving function can thus be written

$$S_t = aW_t - b_t^G N_t - bN_t$$

The value of $b_t^G$ is proportional to average public consumption over the previous five years.

$$b_t^G = \phi \, \overline{C}_t^P / \overline{N}_t$$

Net foreign saving (the trade deficit) is assumed to be proportional to the arithmetic mean of the previous five years net domestic product $\overline{Y}$

$$E_t = e \, \overline{Y} \, .$$

The model is completed with a Balance of Payments Identity and a National Product-Expenditure Identity.

By varying the coefficients assigned to the production function and the savings function the model was used to generate several hundred simulated 50-year time paths of economic variables under the three fertility assumptions. The major conclusions developed from these simulations under reasonable assumptions a higher level of fertility will eventually result in higher total output however a lower level of fertility will <u>always</u> give a higher rate of growth in private consumption per equivalent adult consumer.

It is important to note the time pattern of benefits. The difference in the growth of the capital stock under the low fertility assumption is

small at first but becomes substantial by the end of the projection period. "The benefits must inevitably be a long time in coming, both because with a low savings rate the absolute differences in capital accumulation cannot initially be very large and because it takes time for children to become members of the labor force, and so for the size of the dependency ratio to fall."

D. Summary of Neo-Classical Models

Enke's study had the virtue of containing a detailed demographic sub model which allowed him to work with the age composition of the population. It was, however, a one sector model which ignored both the influence of the factor of production land and the role of government. It did make direct calculations on the benefits of a prevented birth.

Lloyd's model was also of the single sector variety but he did introduce investment in land development and technological progress as alternatives to investment in fertility control in addition to investment in capital goods. By utilizing efficiency units he brought into his model the beneficial effects of increased nutrition. However, his time horizon was admittedly short extending for only about ten years. This is because the size of the labor force was assumed to be independent of population.

Ruprecht's use of the neo-classical structure was highly unorthodox. However, his model did have the virtue of disaggregating the economy into two sectors. His treatment was deficient from the point of view of this study in that he neglected to treat government expenditures for fertility control and its effect as endogenous elements of his model.

The Newman-Allen model, while neo-classical in form, is definitely in the Coale-Hoover tradition. It is unique in that it explicitly introduces a foreign trade sector and also a quite detailed demographic sub model.

## SECTION V

### Reconciliation of Approaches I and II

#### A. Julian Simon

In a recent article Julian Simon returns to the Krueger and Sjaastad critique of the Enke thesis, namely, that "because the child's consumption is provided by the parents one can think of the child as a durable good that the parents prefer to other consumption outlets.[55] The decision to

[55] J. L. Simon, "The Value of Avoided Births to Underdeveloped Countries," unpublished paper, 1967.

have the child can then be simply a matter of consumer sovereignty without the public interest being involved." He rejects Enke's reply that the children of the prolific will compete for jobs and "disadvantage more careful parents." If this loss is discounted at 15% back to the present from the time it occurs (15 or more years hence), it will have an insignificant present discounted value.

Of course at lower rates of discount this cost may be significant but this would place Enke on the other horn of the dilemma, for at low rates of discount marginal babies may have a positive net value.

Thus Simon would totally abandon this approach and adopt one akin to that used by Demeny. He estimated the increase in family savings due to fewer children. Then he estimated the resulting increase in the capital labor ratio and finally the increase in per capita income. To do this he employed the data developed by Coale and Hoover.

First he calculated the annual differences in income under the high and low fertility assumptions. He then calculated the present value of

these differences using a 15% rate of discount. He then discounted the differences in the number of births under the two fertility assumptions by 15% "because if a given bonus is paid to all future non-births at the time of non-birth, the bonus would be discounted; hence a discounted number of births prevented multiplied by the money bonus is the relevant quantity."[56]

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[56] J. L. Simon, Ibid., p. 9.

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Lastly Simon divided the present value of the income differential by the number of discounted births to find the benefit to the economy of preventing a single birth. This he estimated to be $108.

This is the amount a taxpayer would find it worth paying to reduce one birth, assuming his rate of discount is 15%. If the rate of discount were lower, e.g., 5% then the societal benefit per reduced birth would be $248.

This figure would indicate the maximum incentive bonus that can be paid and still leave everyone better of.

The Coale and Hoover model did not consider the fact that an expenditure to reduce births might utilize resources which would otherwise go into development projects. Hence the Simon model cannot be used to answer the question of how large a quantity of real resources can a society devote to birth control and still be as well off. It is restricted to examining the maximum transfer payment allowable.

Demeny's model is designed to answer the former question but Simon would argue that Demeny's question is of almost no importance since the real resources involved are inconsequential and "one can safely disregard the effect of real resource expenditures for birth reduction on investment when calculating the value of avoided births."[57]

[57] Simon, Ibid., p. 13.

B. Leonard Bower

Leonard G. Bower in a paper presented at the 1967 Population Association of America meetings offered a variant on the Enke theme.[58]

[58] Leonard G. Bower, "The Return from Investment in Population Control in Less-Developed Countries: An Analytical Model and Its Applications," paper presented at the Population Association of America's Annual Meetings, Cincinnati, Ohio, April 1967.

Like Enke he assumes that the goal of policy should be to maximize the present discounted value of per capita income. Like Demeny he recognizes that the opportunity cost of demographic investment (D) is the increase in output which would have resulted from non-demographic investment (I).

In order to make Bower's argument easily comparable with that of Demeny, we will use the latter's notation.

For the year (t) real per capita income would be $\frac{Y_t}{P_t}$ if no demographic investment is made while it would be $\frac{Y_t^*}{P_t^*}$ with D demographic investment over the internal from period o to period t. "The real return per person in the year (t) from demographic investment is simply

$$\left(\frac{Y_t^*}{P_t^*} - \frac{Y_t^*}{P_t}\right).$$

The total return to the country is given by

$$\left(\frac{Y_t^*}{P_t^*} - \frac{Y_t^*}{P_t}\right) P_t^*."$$

It may be of interest to note that the total return as Bower calculates it is mathematically equivalent to total income multiplied by the percentage reduction in population or per capita income multiplied by the reduction in population.

$$\left(\frac{Y_t^*}{P_t^*} - \frac{Y_t^*}{P_t}\right) P_t^* = \left(\frac{P_t Y_t^* - P_t^* Y_t^*}{P_t^* P_t}\right) P_t^* =$$

$$Y_t^* \left(\frac{P_t - P_t^*}{P_t}\right) = \frac{Y_t^*}{P_t} \Delta P_t$$

In this form it is obvious that the size of the total benefit is proportional to the size of per capita national income $Y_t^*$ and the relative effectiveness of the scheme of population control. It follows logically from this model that if $P_t^*$ were zero, the total benefit would be maximized. This nonsense conclusion is the direct result of the fact that Bower has assumed $Y_t = Y_t^*$ or $Y_t$ is a constant for all values of $P_t^*$. In other words the marginal product of labor is zero for all values of $P_t^*$. Here, of course, Bower parts company with Enke who made no such powerful assumption.

Bower then converts this total benefit to a rate of return (d) by dividing through by total demographic investment D.

$$d = \frac{Y_t^*}{D} \left(\frac{P_t - P_t^*}{P_t}\right) = \frac{Y_t^*}{D} \left(\frac{\Delta P_t}{P_t}\right)$$

It follows that (d D) is equal to the total benefit from demographic investment. "If r is marginal rate of return to capital in the LDC, the opportunity cost in making the demographic investment was the chance to raise GNP by an amount r D in the year t."

Thus $r = \frac{\Delta Y_t}{D}$. If we divide d by r, we have the reciprocal of Enke's superiority ratio.

$$\frac{d}{r} = \left(\frac{Y_t}{D}\frac{\Delta P_t}{P_t}\right) / \frac{\Delta Y_t}{D} = \frac{Y_t}{\Delta Y_t}\frac{P_t}{P_t} = \frac{\% \Delta P}{\% \Delta Y}$$

Demographic investment is superior if $\frac{d}{r} > 1$. This implies that demographic investment is superior to non demographic investment if the transfer of a unit from the former to the latter will increase population by a greater percentage than it will increase product.

Bower presented an alternative way of viewing the superiority of demographic investment. Per capita income with demographic investment would be $\frac{Y_t^*}{P_t^*}$. Per capita income with equal non-demographic investment is

$$\frac{Y_t^* + r\,D}{P_t}.$$

The net benefit of demographic investment per capita can thus be expressed as

$$\left(\frac{Y_t^*}{P_y^*} - \frac{Y_t^*}{P_t} - \frac{rD}{P_t}\right).$$

If this is multiplied by $P_t^*$ we have the total net benefit.

It can be shown that the total net benefit is:

$$\left(\frac{Y_t^*}{P_t} - \frac{Y_t^*}{P_t} - \frac{rD}{P_t}\right) = \frac{P_t^*}{P_t}\left[Y_t^*\left(\frac{P_t}{P_t^*} - 1\right) - rD\right]^{59}$$

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[59] Bower incorrectly presented this term as merely:

$$Y_t^*\left(\frac{P_t}{P_t^*} - 1\right) - rD$$

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If demographic investment is superior this term will have a positive sign.

Bower then presents an imposing algebraic expression which purports to give the value in one year of preventing one birth. It is

$$\frac{\left(\frac{Y_t^*}{P_t^*} - \frac{Y_t^*}{P_t}\right) P_t^*}{P_t - P_t^*}$$

It has already been shown that the numerator reduces to $(Y^* / P_t) \Delta P_t$ and the denominator is $\Delta P_t$ hence the entire expression is nothing more than per capita income in the absence of demographic investment.

$$\frac{Y_t^*}{P_t} = \frac{\left(\frac{Y_t^*}{P_t^*} - \frac{Y_t^*}{P_t}\right) P_t^*}{P_t - P_t^*}$$

The value in one year of preventing one birth in Bower's model is merely the income that would have gone to an unborn person had he shared equally in the income of period t. This follows from Bower's assumption that population has a zero marginal product.

Like Enke, Bower calculates the benefit of a prevented birth as the discounted present value of a series of annuities of size $\frac{Y_t^*}{P_t}$ over a period of e years where e is the average life expectancy. He uses r as his rate of discount and explicitly assumes that $\frac{Y_t^*}{P_t}$ is the same during all years of an individuals life. If $\frac{Y}{P}$ was less than $\frac{Y_t^*}{P_t}$ prior to period t and greater than $\frac{Y_t^*}{P_t}$ after period t, the gain would be overstated in the earlier period and understated in the later period since the gain is proportional to $\frac{Y}{P}$.

The annuity formula is

$$B = \frac{Y_t^*}{P_t} \left( \frac{1 - (1 + r) - e}{r} \right)$$

Where B refers to the total benefit from preventing one birth.

This is exactly the same as Enke's calculation except Enke assumed that at some point in their lives additional persons added to output as well as consumption and thus he would deduct the present discounted value of that output from Bower's B. Bower's very high rates of return to demographic investments---4,500% in the most favorable case--is a direct result of this omission.

# SECTION VI

## Summary and Conclusions on Approaches Reviewed

Thus far this report has reviewed the literature on the benefits of population control. As noted, two major approaches emerge which are, however, more complimentary than competitive.

Let us review them briefly. Stephen Enke began by observing that of two alternative investment policies the one which would have population reduction as a side effect would result in greater long-run growth. In a series of articles he then began arguing for programs aimed directly at birth prevention, through the payment of bonuses to individuals for not having children. The basis of his argument was that children should be considered like other social investments, with expected lifetime production and consumption streams from a birth discounted back to the present in order to judge present costs and benefits of a birth.

Several issues were raised with respect to this approach. Should the marginal or average product of labor be used as a measure of a newborn baby's potential contribution? Should the marginal product at the time of birth be used as an estimate of the marginal product during the individual's working years? Or should it be assumed that marginal productivity would be different due to capital accumulation and technological advance as well as changes in the size of the labor force? Or should marginal productivity be assumed to be zero on the assumption of fixed technical input coefficients? When does a child enter the labor force?

In addition to questions regarding the measurement of the potential production stream, a number of questions arise with regard to the consumption

stream. What percentage of an adult's consumption is the consumption of children at various ages? Do additional children in any given age category receive as much as the average child in that age group or does the "marginal" child receive less?

Perhaps most crucial is the selection of an appropriate rate of discount since a high rate of discount tends to increase the size of the consumption stream relative to the production stream because the former occurs earlier.[60]

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[60] These issues are developed in: G. Heslop, "A Critical Review of Cost Benefit Analysis with Particular Reference to Discounting," Washington, D.C.: PS/OWH, USAID, mimeographed, 1968.

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Demeny criticized Enke's assumption that a bonus program imposes no real costs since they are merely transfers. Demeny argued that once mobilized these public funds could have been channeled into investment and that such capital projects represent the opportunity cost of the Enke scheme. Furthermore he points out that whether supported by taxing or borrowing such schemes will have real effects on the economy through the redistribution of income.

Lastly Kreuger and Sjaastad questioned whether anything was to be gained from the social point of view by inducing families not to bear children if they are willing to bear the costs of having such children. Enke replied that all of society had an interest in keeping their total numbers small since the children of all would compete with one another in the job market. Julian Simon points out that if high rates of discount are used, this point becomes irrelevant and if low rates of discount are used (as suggested by Goran Ohlin), then the benefits become smaller.

About the same time that Enke wrote, Richard L. Meier developed a very similar analysis. He followed a cohort through its life cycle to determine

its pattern of consumption, production and mortality and then simply reversed the process by which one would calculate the loss to society of a public health measure to discover the gain to society of a birth control scheme. His findings were much the same as Enke's. However, the benefit was less due to the fact that Meier assumed production to begin ten years earlier than did Enke and he used the average rather than the marginal product as his measure of the cohort's contribution.

By far the most sophisticated variant of the investment model is that developed by George Zaidan. He referred to the "Enke effect" as the primary effect of birth reduction on per capita income. As a result of the social gains due to this primary effect a harvest of secondary benefits would also be reaped by a nation which limited population growth. In the first place, productivity per worker would rise due to increased per capita caloric intake. This might be called the "Leibenstein effect." Secondly there would be an effect on savings hence capital formation. To the extent that private savings are a function of per capita income the primary effect would lead to increased household savings. This might be called the "Demeny effect." Zaidan questions the empirical support for such a hypothesis, however.[61]

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[61] A Study recently completed by one of the present authors of the nature of the savings function in India finds no evidence that changes in population size are an important casual factor in changes in the savings ratio. David H. Horlocher, "The Influence of Demographic Factors on the Long-Run Consumption and Savings Functions in Developing Countries," unpublished paper, 1968.

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He also notes that the government can reduce its expenditures on such welfare investments (or investments in human capital) as public education. This could be called the "Coale-Hoover effect."

The investment models described above are exercises in partial equilibrium analysis. The question they asked was: "What would be the impact of preventing a single birth assuming all other things remain constant"? Though such a question may be appropriate from the point of view of the household, it is of questionable value from the point of view of the nation. For if a nation embarks on a substantial program of birth control it cannot assume ceteris parabis. To evaluate the effects of an economy-wide birth prevention program one must employ a dynamic macroeconomic model which will introduce demographic variables explicitly and trace out the time path of economic magnitudes as they change in response to alternative demographic policies.

Broadly speaking two types of models have been chosen for this task. The first type is the Harrod-Domar model which assumes a capital output ratio which is fixed at any point in time though it is subject to change over time as a result of technological progress. Such models assume that the only way to increase output per capita is to increase the capital stock per capita. The marginal productivity of labor is assumed to be zero.

Coale and Hoover in their study constructed such a model of the Indian economy. Investment was assumed to be a weighted average of investment in capital goods and in new human beings. The weights were in proportion to their productivity. It was assumed that the contribution of a rupee of investment in human capital was far less than the contribution of a rupee of investment in capital goods By reducing population growth, a smaller fraction of total investment need be of the less productive type. The total amount of investment was equal to total savings. Total savings was assumed to vary directly with income but inversely with population. Population reduction would thus increase total investment and increase the share of investment going to capital goods.

Coale and Hoover contrasted the outcomes of alternative population growth projections for five-year intervals between 1956 and 1986. Not only did per capita income rise more rapidly in the low fertility case but total income grew more rapidly as well. Since the marginal productivity of labor was assumed to be zero, the loss of population meant no loss of output.

Gunnar Myrdal in his Asian Drama criticized the Coale Hoover findings on a number of grounds. Among them were the assumptions of a constant capital output ratio and of a savings ratio which increased as a result of increases in per capita income. Kuznets has made the same criticisms. Zaidan also pointed out that it is questionable whether households will prevent births to accumulate savings. It is more likely that this will be done in order to increase per capita consumption.

These criticisms would also apply to the Hoover-Perlman study which is a simpler version of the Coale-Hoover model applied to Pakistan.

Paul Demeny criticized the Coale-Hoover study for failing to include within their model the costs of a program of fertility reduction. Assuming these costs to be known he sought to determine what price would be worth paying per birth prevented and how this price would depend on the structural parameters of the economy.

To answer this question he employs an even simpler variant of the Harrod-Domar model. He does not assume that population growth affects the composition of investment as did the models of Coale-Hoover and Hoover-Perlman. The sole effect of population change was on per capita savings and thus per capita investment. For this he employed the Coale-Hoover savings function. In the Demeny study demographic investment had two effects. Initially it reduced the amount of resources available for investment in

capital goods. But its secondary impact was to reduce population hence increasing per capita income and raising per capita savings.

Demeny calculated the maximum amount that could be transferred to demographic investment without reducing per capita income. When this sum is divided by the number of births, it measures the maximum permissible value per birth prevented.

Demeny himself pointed out the restrictive nature of his assumptions. Not only did he discuss the implications of assuming a constant capital output ratio, he also pointed out that his model abstracts from possible scale effects. He recognized that children may be regarded as a non economic source of satisfaction. He also noted that increasing population may serve as a stimulus for investment.

Finally he disposed of the criticism that increased per capita income might stimulate offsetting increases in birth rates by assuming that there is a significant lag in the fertility reaction to changes in per capita income and that death rates are no longer linked to per capita incomes.

The Harrod-Domar growth models were designed to extend the Keynesian analysis of business fluctuations to periods where the capital stock is growing (or declining). In such a context the assumption of fixed point input coefficients is reasonable. However, when the purpose is to forecast the effect of changes in demographic variables over a period of decades, then the neo-classical assumption of continuous well behaved production functions is more appropriate. The marginal productivity of labor need not be zero and the saving function is not crucial as a lever by which population affects growth. Three recent studies have employed neo-classical frameworks.

The first of these was prepared by Stephen Enke. The heart of his model is a Cobb-Douglas production function where output is dependent upon the input of labor, capital and time (a proxy for technological progress which is assumed to be neutral). Estimates of the labor input are generated from a demographic submodel. The capital input is dependent upon the saving function. The demographic submodel is employed to generate the saving by age group. For each age group the saving ratio is assumed to vary directly with the increase in per capita income.

In the Harrod-Domar based models a reduction in population could only increase output. In Enke's model it depends upon whether the increase in capital offsets the effect of reduced labor input.

He defined three degrees of birth control, full, increasing and none and claculated for a hypothetical population the values at five-year intervals of population, crude birth rate, labor force, participation rates, marginal productivity of labor and capital, births prevented, cost per birth prevented and percent increase in per capita income. The dollar value per birth prevented was calculated by dividing the differences in income between degrees of birth control by the differences in births.

Peter Lloyd also used the Cobb Douglas production function as the basis for his model. However, he did not assume as did Enke that technical change is a simple function of time but rather is dependent upon the history of government expenditures for technology development.

As in Enke's model the growth in the capital stock is dependent upon savings. However, his savings function is more complex than that of Enke in that it takes account of both household saving and government saving. The household saving function is not made dependent upon demographic variables but the government saving function is dependent upon them in several ways.

Expenditures for the means of birth control and transfer payments to induce people to participate in such programs reduce government savings.

The total number of workers is assumed to be independent of population size. However in efficiency units labor input is assumed to vary directly with per capita caloric consumption, the "Leibenstein effect." The effect of birth control expenditures is to reduce government savings and thus the capital stock but this is offset by increases in labor efficiency due to increased per capita income as a result of reduced births.

A weakness of both Enke's and Lloyd's neo-classical models as vehicles for estimating the benefits of population control in LDC's is the fact that they fail to recognize the duality of such economies. T. K. Ruprecht developed a demographically oriented model which utilized separate Cobb-Douglas productions for the agricultural and non-agricultural sectors. His model also represents an advance of that over Lloyd in that his government savings function includes expenditures for health and education which vary directly with population size, the so-called "Coale-Hoover effect."

The Newman-Allen model is in the tradition of Coale and Hoover in that it abstracts from technical change and depends heavily for its results on the adverse effects on investment of increased population. However it is in the neo-classical tradition by assigning a positive marginal productivity to increased labor. It is unique among all the models discussed in this paper in that it explicitly introduces the foreign sector. The fertility assumptions employed are also unique in that they were specifically designed to change the structure of the population from that of a less developed country to that of a developed country.

There have been two recent attempts to reconcile the investment approach with the projected income macro-model approach. Julian Simon using a Coale-Hoover type model calculated the annual differences in income under the high

and low fertility assumptions and then discounted them to the present. He also discounted the number of births prevented multiplied by the money bonus. The ratio of these two terms yields his estimate of the value of preventing a single birth. This is the maximum bonus that can be paid for preventing a birth without reducing anyone's welfare. This calculation differs from that of Demeny in two important respects. In the first place it depends upon the chosen rate of discount. In the second place it fixes the maximum transfer payment rather than the maximum transfer of real resources. It is Simon's view that the real resources needed for a campaign of birth reduction are so meager as to be safely disregarded.

In a recent paper Leonard Bower sided with Demeny and thus took issue with Simon by arguing that one must take into account the opportunity cost of demographic investment which is the increase in output which would have resulted from investment in capital goods.

He calculated the benefit of a given amount of demographic investment which is proportional to the size of per capita national income and the effectiveness of the birth control program and converted it into a rate of return. This was compared with the rate of return on capital goods. The ratio of the former to the latter is formally equivalent to the reciprocal of superiority ratio which is the percentage change in income divided by the percentage change in population. Though it seeks to answer the question posed by Demeny, Bower's model is mathematically equivalent to Enke's investment model except that Bower like Demeny assumes the marginal product of labor is zero. It is for this reason that Bower finds the value in one year of preventing one birth is merely the income that would have gone to that unborn person had he shared equally in the income of that year.

from an economic standpoint. . . ." "It should now be added that while the preoccupation of policy makers with the immediate future is understandable, economists abdicate of their responsibilities if they declare a limited time horizon as a proper basis for formulating population policy. Few worry about the long run or care to represent the interest of the next generation."[67]

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[67] Ibid., p. 7.

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In answer to Demeny the Congressional Report argues quite cogently:[68]

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[68] U.S. Congress, op. cit. Baumol, op. cit. makes the same argument. "In particular in our economy if past trends and current developments are any guide, a redistribution to provide more for the future may be described as a Robin Hood activity stood on its head--it takes from the poor to give to the rich. Overage real per capita income a century hence is likely to be a sizeable multiple of its present value. Why should I give up part of my income to help support someone else with an income several times my own.

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> The wisdom of imposing additional sacrifices on the current population (with a per capita income of $4,250) to increase the wealth of future citizens whose per capita income will be $10,000 in the year 2000 even without additional transfers is highly questionable.

Demeny's reply to this position is that it is the duty of the economist to represent the interest of future generations. This is especially true of the population problem which "is a long-run problem par excellence." He therefore holds that "under certain circumstances action now is necessary even though its major effects might be felt only after several decades."

The weakness of comparing discounted consumption and income streams is that in the process of discounting "long-run considerations are eliminated effectively and almost automatically from the picture. With realistic discount rate it matters little what happens after 15 or 20 years."

The prime weakness of Demeny's position is that it gives us no decision rule for deciding which are the appropriate "circumstances when action now is necessary even though its major effects might be felt only after several decades."[69] Thus, the prime beneficiaries of programs of

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[69] Baumol, op. cit., may provide one such case. "In a country which is stagnating and where only a major restriction of current consumption can put life into its development program, one may well wish to make the sacrifice for tomorrow, for in such a case, without it the future generation will be as impoverished as the present." p. 801.

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population control must be future generations and therefore holds that the preferred method of relating the costs to the benefits of a program of birth control is to employ a dynamic macroeconomic model which will generate the time path of the benefits and costs of alternative demographic policies. The decision maker can then discount these streams at a rate and to a year of his own choosing.

Thus far, this paper has outlined a number of such models which have been employed for this purpose. The flaws of each have been set forth. However it should be possible to construct a model which is both complex enough to be reasonably descriptive of actual economic processes in underdeveloped countries and captures the major effects of demographic change yet simple enough to be capable of estimation in the face of the limited sources of data in underdeveloped countries. The present report attempts this in the next section.

## SECTION VIII

### A Proposed Benefit-Evaluation Model

There is no single theoretical structure for weighing the costs against the benefits of a program of population which is superior to the others in all respects. It is the purpose of this section to present a new model, which in our judgment, combines the best features of the models cited thus far. Even this model contains large elements of judgment.

The macromodel approach has been chosen because the objective is to gauge long-run effects of population control. The basic framework is neo-classical rather than of the Harrod-Domar variety since the former allows changes in population to influence the level of output directly. Lastly the model is a development model rather than a growth model. Dale W. Jorgenson described this distinction in the following terms. "In the theory of development emphasis is laid on the balance between capital accumulation and the growth of population, each adjusting to the other. In the theory of growth the balance between investment and saving is all important and the growth of population is treated as a constant or shunted aside as a qualification to the main argument. . . ." "In particular limitation of the analysis to situations in which there is effectively one producing sector rules out much of what is interesting about growth and development."[70]

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[70] Dale W. Jorgensen, "The Development of a Dual Economy," The Economic Journal, Volume 61, V, June 1961, pp. 309-334.

The model introduced here is much like one developed by Jorgenson. It disaggregates the economy into an agricultural and non agricultural sector using a Cobb-Douglas production function to describe each. It differs from Jorgenson's model in two very important respects. Where Jorgenson used simple linear aggregate birth rate and death rate functions this model will employ a detailed demographic sub model broken down by age classes. In this respect it is like the work of Coale and Hoover and Enke's neo-classical model. The introduction of such a sub model is almost mandatory if one's purpose is to measure the costs and benefits of demographic changes since the various age classes differ significantly with respect to birth and death rates, consumption and labor force participation rates.

The second respect in which this model differs from that of Jorgenson (as well as Enke's neo-classical model) is that this model introduces a government sector. Since the purpose of such models is generally to assist in the decision making process of government planners, government must play an explicit role. Even if the purpose was a purely descriptive one it would seem that a reasonable correspondence with the facts demands that a government sector be included. Lawrence Klein lends support to this position in the case of a major LDC, India.[71] He maintains that "An aggregative model

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[71] Lawrence Klein, "What Kind of Macroeconometric Model for Developing Economies"? The Econometric Annual of the Indian Economic Journal, Vol. XIII, Number 3, 1966, p. 324.

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of the Indian economy must at a minimum be divided into three production sectors--agriculture, private non agricultural output, and the public sector."

Since the purpose of the model is to measure the costs and benefits of demographic change, it must contain a demographic sub model indicating the determinants of population size, the proportion of the population in the labor force ages, labor force participation rates, birth rates and death rates and the impact of governmental expenditures on births and deaths. Since the point of view is the long run, the neo-classical growth model is most appropriate since it allows for changes in the capital/labor, capital/output, and labor/output ratios. Thus the structures used by Coale and Hoover, Hoover and Perlman and Demeny are rejected since they are based on the assumption of a fixed capital output ratio.

The heart of a neo-classical model is an aggregate production function. Because it is linear in the logarithms and can be made to yield positive but diminishing returns to additional units of productive factors the Cobb-Douglas function is preferred. Furthermore under competitive conditions the parameters of this function determine the functional distribution of income.

A major fault of most earlier models is their failure to disaggregate the production function. However, it is well known that the agricultural and non-agricultural sectors differ in three important respects.

In the first place land enters into the agricultural production function where it does not in the case of the non-agricultural production function. The importance of this factor was brought out in a recent paper by Demeny. "It is obvious that the traditional sectors of underdeveloped countries exhibit a wide range of variations . . . that can be shown to be quite unrelated to differences in the rate of growth of the labor force but that are powerfully influenced by the fundamental endowments in traditional agriculture as inherited from the past. In other words, something uncomfortably akin to such old fashioned and slippery notions as "population/resources ratio," "population density" or even "overpopulation" or "population pressure"

seems to reenter the scene and a more detailed analysis of the effects of alternative demographic processes on economic development is attempted."[72]

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[72]Paul Demeny, "Notes on Economic Considerations Influencing Population Policies in Underdeveloped Countries," unpublished paper, 1968.

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In another recent paper George Zaidan also revives interest in the issue of population density saying "It has been argued that density has a secondary importance, in relation to how far it affects the future rate of growth of per capita income. Nevertheless it has considerable implications for many other questions such as the level of wages, the distribution of income, the choice of techniques and the extent of unemployment."[73]

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[73]G. Zaidan and E. K. Hawkins, "The Treatment of Population in Bank Economic Work," IBRD, Economics Department Working Paper, No. 16, p. 13.

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The supply of land need not be considered fixed but rather augmentable at a cost through public and private investment.

In arguing for the use of a two sector model in his recent paper Demeny points out still another justification and that is that wage rates and hence standards of living may be different in the two sectors and that intersectoral shifts of the labor force may raise per capita incomes even though wage rates may remain constant in each sector.

The third reason for this disaggregation is that the demographic characteristics of the agricultural or traditional sector may be significantly different from that of the modern or non-agricultural sector.

A general model for underdeveloped countries should make sectoral outputs a function of supply forces. That is, output should be regarded as the dependent variable in the production function, where factor inputs (L, K, J), and technical change (F) are the casual variables.

$$(1) \qquad Q_{A_t} = \phi_A F_{A_t} L_{A_t}^{\alpha A} K_{A_t}^{\beta A} J_{A_t}^{\lambda A}$$

$$(2) \qquad Q_{N_t} = \phi_N F_{N_t} L_{N_t}^{\alpha N} K_{N_t}^{\beta N}$$

The rate of technological change will be assumed to be a function of the rate of growth of output in each sector and time, as in the "learning by doing" approach.

$$(3) \qquad F_{A_t} = f\left(\frac{\Delta Q_{A_{t-1}}}{Q_{A_{t-1}}}, t\right)$$

$$(4) \qquad F_{N_t} = f\left(\frac{\Delta Q_{N_{t-1}}}{Q_{N_{t-1}}}, t\right)$$

The assumption of neutral technological change may be unduly restrictive however it will simplify the model as a first approximation.

The input of labor into each sector will depend on the following factors: Z, the number of persons over a certain age (as generated by a demographic sub model); the level of nutrition as measured by per equivalent adult consumer agricultural output in the previous period; and the labor force participation rate in each sector (R) which may in turn depend on the proportion of women who must remain at home to rear children:

$$(5) \qquad L_{A_t} = L_A\left(Z_{A_t}, \frac{Q_{A_{t-1}}}{P_{T_{t-1}}}, R_{A_t}\right)$$

$$(6) \qquad L_{N_t} = L_N\left(Z_{N_t}, \frac{Q_{A_{t-1}}}{P_{T_{t-1}}}, R_{N_t}\right)$$

The inputs to this equation are drawn from the demographic sub model which consists of two tabulations of population structure by age class, one for each sector. Corresponding to each age class will be an initial annual mortality rate (d'i) and an initial annual birth rate per 1000 individuals (b'i).

The age specific birth rates in period t are assumed to be a function of the initial rates, government birth control expenditures ($G_{4A_{it}}$, $G_{4N_{it}}$) and transfer payments to encourage birth prevention ($TR_{A_{it}}$, $TR_{N_{it}}$). Such equations could be derived from a detailed analysis of cost effectiveness of such expenditures and transfer payments by sector and age class:

(7) $$b_{A_{it}} = b_{A_i}(b'_{A_i}, G_{4A_{it}}, TR_{A_{it}})$$

(8) $$b_{N_{it}} = b_{N_i}(b'_{N_i}, G_{4N_{it}}, TR_{N_{it}})$$

In each sector the number of births will equal the sum of births in each age category which in turn is the produce of the birth rate and the number of people ($H_i$) in each age category.

(9) $$B_{A_t} = \sum_i (b_{A_{it}} H_{A_{it}})$$

(10) $$B_{N_t} = \sum_i (b_{N_{it}} H_{N_{it}})$$

The number of individuals age i in period t can be expressed as

(11) $$H_{A_{it}} = B_{A_{t-i}} - \sum_{x=t-i}^{t} D_{A_{ix}}$$

$$(i = 0\text{-}75)$$

(12) $$H_{N_{it}} = B_{N_{t-i}} - \sum_{X=t-i}^{t} D_{N_{ix}}$$

$$(i = 0\text{-}75)$$

where $D_{ix}$ refers to the number of deaths in year x occurring to those born in year t-i. The number of such deaths is the product of the age specific death rate and the number of persons in the age class.

$$(13) \quad D_{A_{it}} = d_{A_{it}} H_{A_{it}}$$

$$(14) \quad D_{N_{it}} = d_{N_{it}} H_{N_{it}}$$

The age specific death rates are assumed to be falling over time. They are thus assumed to be a function of per capita agricultural production, per capita government welfare expenditures ($\pi$), a time trend and the initial death rates.

$$(15) \quad d_{A_{it}} = d_{A_i}\left(d_{A_i}\frac{Q_{A_t}}{P_{T_t}}, \pi, t\right) \qquad (i = 0...75)$$

$$(16) \quad d_{N_{it}} = d_{N_i}\left(d_{N_i}\frac{Q_{A_t}}{P_{T_t}}, \pi, t\right) \qquad (i = 0...75)$$

We may thus define Z, the labor force eligible group as

$$(17) \quad Z_{A_t} = \sum_{i=15}^{75}$$

$$(18) \quad Z_{N_t} = \sum_{i=15}^{75} H_{N_{it}}$$

Letting $\omega$ equal age specific consumption as a percent of adult consumption, then total population in terms of equivalent adult consumers may be found as a weighted sum of the number of people in each age class.

(19) $P_t = \sum_i \omega_i H_{A_{it}} + \sum_i \omega_i H_{N_{it}}$

The labor force participation rate is assumed to depend upon the ratio of small children to adult workers

(20) $R_{A_t} = R_{A_t} ( \sum_{i=0}^{5} H_{A_{it}} / Z_{A_{it}} )$

(21) $R_{N_t} = R_{N_t} ( \sum_{i=0}^{5} H_{N_{it}} / Z_{A_{it}} )$

The capital input in each sector is equal to the capital stock in the previous period plus net capital formation or investment

(22) $K_{A_t} = K_{A_{t-1}} + I_{A_t}$

(23) $K_{N_t} = K_{N_{t-1}} + I_{N_t}$

It is also assumed that total planned investment is equal to total realized saving as a long-run proposition recognizing that there may be cyclical departures from this norm. Hence total saving will equal the sum of investment in each sector.

$S_{T_t} = I_{A_t} + I_{N_t}$

(This equation is not included in the model structure since it can be derived as a linear combination of equations 24 through 26 below.)

Total saving may be defined as the sum of savings in the agricultural, non-agricultural and farm sectors.

(24) $S_{T_t} \equiv S_{A_t} + S_{N_t} + S_{G_t}$

Investment in agriculture is assumed to be a constant fraction of agricultural and government savings.

$$(25) \quad I_{A_t} = (1-\lambda)S_{A_t} + (1-\theta)S_{G_t}$$

Investment in the non-agricultural sector is assumed to equal saving in that sector plus the remaining portions of agricultural and government saving.

$$(26) \quad I_{N_t} = \lambda S_{A_t} + \theta S_{G_t} + S_{N_t}$$

Many of the previous models (including the Coale-Hoover and Newman-Allen models)[74] employed the assumption that per capita savings was a non

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[74] A. J. Coale and E. M. Hoover, Population Growth and Economic Development in Low-Income Countries, Princeton: Princeton University Press, 1958, chapter 17; Peter Newman and R. H. Allen, Population Growth Rates and Economic Development in Nicaragua, Washington, D.C.: Robert R. Nathan Associates, 1967.

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homogeneous linear function of per capita income. This implied mathematically that aggregate savings was a direct linear function of income and an inverse linear function of population. Zaidan and Myrdal have questioned the empirical support for this assumption and there is additional support for such skepticism. We will allow for a possible relationship between population and saving in our model but not specify the exact form that the relationship may take. This term $s[P_t]$ will be added to simple Keynesian savings functions which make aggregate savings equal to an average propensity to save times sectoral disposable income which is defined as output less taxes (T) plus government transfer payments (TR).

(27) $S_{A_t} = \sigma_A(Q_{A_t} - T_{A_t} - TR_{A_t}) + s_A(P_{A_t})$

(28) $S_{N_t} = \sigma_N(Q_{N_t} - T_{N_t} - TR_{N_t}) + s_N(P_{N_t})$

The sectoral populations in units of equivalent adult consumers ($P_{A_t}$ and $P_{N_t}$) can be derived from our demographic sub model.

(29) $P_{A_t} = \sum_i \omega_i H_{A_{it}}$

(30) $P_{N_t} = \sum_i \omega_i H_{N_{it}}$

Government savings would simply be equal to total tax receipts less expenditures and transfer payments.

(31) $S_{G_t} \equiv T_{A_t} + T_{N_t} - G_{1_t} - G_{2_t} - G_{3_t} - G_{4A_t} - G_{4N_t} - TR_{A_t} - TR_{N_t}$

It will be assumed that $G_1$ is a policy variable involving government expenditures which are exogenous to our model (e.g., national defense). $G_2$ refers to government expenditures for land reclamation and improvement which will also be considered a policy variable. $G_3$ refers to government expenditures for education, hospitals and other demographically determined services. $G_{4A}$ and $G_{4N}$ refer to government expenditures for population control in the two sectors while $TR_A$ and $TR_N$ refer to transfer payments made in the two sectors as part of a birth control inventive scheme. Like $G_1$ and $G_2$ these variables will be considered as "policy variables" hence exogenously determined.

Total taxes collected in each sector will be assumed to be a fraction of output in those sectors. This parameter can be considered an exogenously determined policy variable.

(32) $T_{A_t} = \rho_{A_t} Q_{A_t}$

(33) $T_{N_t} = \rho_{N_t} Q_{N_t}$

The stock of land shall be defined as equal to the stock in the previous year plus the annual growth $\Delta J$.

(34) $J_t = J_{t-1} + \Delta J$

where $\Delta J$ is a function of government expenditures on land improvement

(35) $\Delta J = g(G_2)$

Welfare expenditures made by government are assumed to be a constant amount ($\pi$) per equivalent adult consumer. Hence

(36) $G_3 = \pi_t P_{T_t}$.

Like tax rates the parameter $\pi$ may be considered as a policy variable from the point of view of the governmental decision maker. We assume it is constant, however, for purposes of this model.

The model can now be summarized as follows:

<u>Sector Subscripts</u>

A = Agricultural Sector

N = Non-Agricultural Sector

G = Government Sector

T = Total Economy

## Current Endogenous Variables

| Variable | Sectors | Definition |
|---|---|---|
| Q | (A,N) | Production in value units |
| F | (A,N) | Index of Technical Change |
| L | (A,N) | Labor input in efficiency units |
| K | (A,N) | Capital input in value units |
| J | (A) | Land input in spatial units |
| Z | (A,N) | Population over 14 years of age |
| P | (T,A,N) | Population in Equivalent Adult Consumers |
| R | (A,N) | Labor Force Participation Rate |
| $b_i$ | (A,N) | Age Specific birth rate for the ith age group |
| B | (A,N) | Births |
| $H_i$ | (A,N) | Persons in ith age class |
| $D_i$ | (A,N) | Deaths in the ith age class |
| $d_i$ | (A,N) | Age specific death rates for the ith age group |
| I | (A,N) | Investment net of depreciation |
| S | (T,A,N,G) | Annual saving from current production |
| T | (A,N) | Taxes |
| $G_3$ | | Government expenditures on demographically determined services |
| $\Delta J$ | | Annual addition to the stock of land |

## Exogenous Variables

| Variable | Definition |
|---|---|
| t | time |
| $G_1$ | exogenous government spending |
| $G_2$ | government expenditures for land reclamation |
| $G_4(A,N)$ | government expenditures for birth control programs |
| TR(A,N) | government transfer payments for family planning |

## Parameters

| Variable | Sectors | Definition |
|---|---|---|
| $\phi$ | (A,N) | constant used to convert to value units |
| $\alpha$ | (A,N) | elasticity of productivity of labor |
| $\beta$ | (A,N) | elasticity of productivity of capital |
| $\lambda$ | (A) | elasticity of productivity of land |
| b'i | (A,N) | initial age specific of birth rates |
| d'i | (A,N) | initial age specific death rates |
| $\omega i$ | | age specific consumption as a percent of adult consumption |
| $\sigma$ | (A,N) | average propensity to save out of disposable income |
| $\gamma$ | | share of agricultural saving invested in the non-agricultural sector |
| $\theta$ | | share of government saving invested in the non-agricultural sector |
| $\pi$ | | average government demographic expenditure per equivalent adult consumer |
| $\rho$ | (A,N) | average tax rates |

The structural relationships are thus:

$$(1) \quad \phi Q_{A_t} = {}_A F_{A_t} L_{A_t}^{\alpha A} K_{A_t}^{\beta A} J_{A_t}^{\lambda A}$$

$$(2) \quad \phi Q_{N_t} = {}_N F_{N_t} L_{N_t}^{\alpha N} K_{N_t}^{\beta N}$$

$$(3) \quad \phi_{A_t} = f_A\left(\frac{\Delta Q_{A_{t-1}}}{Q_{A_{t-1}}}, t\right)$$

$$(4) \quad \phi_{N_t} = f_N\left(\frac{\Delta Q_{N_{t-1}}}{Q_{N_{t-1}}}, t\right)$$

(5) $$L_{A_t} = L_A(Z_{A_t}, \frac{Q_{A_{t-1}}}{P_{T_{t-1}}}, R_{A_t})$$

(6) $$L_{N_t} = L_N(Z_{N_t}, \frac{Q_{A_{t-1}}}{P_{T_{t-1}}}, R_{A_t})$$

(7) $$b_{A_{it}} = b_{A_i}(b'_{A_{it}} G_{4A_{it}}, TR_{A_{it}})$$
$$(i = 0 \ldots n)$$

(8) $$b_{N_{it}} = b_{N_i}(b'_{N_{it}} G_{4N_{it}}, TR_{N_{it}})$$
$$(i = 0 \ldots n)$$

(9) $$B_{A_t} = \sum_i b_{A_{it}} H_{A_{it}}$$

(10) $$B_{N_t} = \sum_i b_{N_{it}} H_{N_{it}}$$

(11) $$H_{A_{it}} = B_{A_{t-i}} - \sum_{x=t-i}^{t} D_{A_{ix}}$$

(12) $$H_{N_{it}} = B_{N_{t-i}} - \sum_{x=t-i}^{t} D_{N_{ix}}$$

(13) $$D_{A_{it}} = d_{A_{it}} H_{A_{it}}$$

(14) $$D_{N_{it}} = d_{N_{it}} H_{N_{it}}$$

(15) $$d_{A_{it}} = d_{A_i}(d'_{A_i}, \frac{Q_{A_t}}{P_{T_t}}, \pi, t)$$

(16) $$d_{N_{it}} = d_{N_i}(d'_{N_i}, \frac{Q_{A_t}}{P_{T_t}}, \pi, t)$$

(17) $$Z_{A_t} = \sum_{i=15}^{75} H_{A_{it}}$$

(18) $$Z_{N_t} = \sum_{i=15}^{75} H_{N_{it}}$$

(19) $$P_t = \sum_i \omega_i H_{A_{it}} + \sum_i \omega_i H_{N_{it}}$$

(20) $$R_{A_t} = R_A\left(\sum_{i=0}^{5} H_{A_{it}} / Z_{A_{it}}\right)$$

(21) $$R_{N_t} = R_N\left(\sum_{i=0}^{5} H_{N_{it}} / Z_{N_{it}}\right)$$

(22) $$K_{A_t} = K_{A_{t-1}} + I_{A_t}$$

(23) $$K_{N_t} = K_{N_{t-1}} + I_{N_t}$$

(24) $$S_{T_t} \equiv S_{A_t} + S_{N_t} + S_{G_t}$$

(25) $$I_{A_t} = (1-\lambda)\, S_{A_t} + (1-\theta)\, S_{G_t}$$

(26) $$I_{N_t} = \lambda\, S_{A_t} + \theta\, S_{G_t}$$

(27) $$S_{A_t} = \sigma_A\, (Q_{A_t} - T_{A_t} + TR_{A_t}) + s_A(P_{A_t})$$

(28) $$S_{N_t} = \sigma_N\, (Q_{N_t} - T_{N_t} + TR_{N_t}) + s_N(P_{N_t})$$

(29) $$P_{A_t} = \Sigma\omega_i\, H_{A_{it}}$$

(30) $$P_{N_t} = \Sigma\omega_i\, H_{N_{it}}$$

(31) $S_{G_t} \equiv T_{A_t} + T_{N_t} - G_{1_t} - G_{2_t} - G_{3_t} - G_{4_t} - G_{4N_t} - TR_{A_t} - TR_{N_t}$

(32) $T_{A_t} = \rho_A Q_{A_t}$

(33) $T_{N_t} = \rho_N Q_{N_t}$

(34) $J_t = J_{t-1} + \Delta J$

(35) $\Delta J = j(G_2)$

(36) $G_{3_t} = \pi_t P_{T_t}$

In terms of this model now let us examine the train of events that would occur as a result of a combined program of expenditures on birth control means and transfer payments to induce acceptance. The birth prevented function, which is the inverse of a cost function of birth control as applied to the demographic sub model, would indicate the number of births which would be prevented in the agricultural and non-agricultural sectors in the next period (Equations 7 and 8). This would have two effects in this period. First the number of consumers would be less than otherwise would be the case (Equation 19) and therefore average caloric intake would be greater (Equations 5 and 6) thus increasing labor input (Equations 1 and 2). The labor participation rates (R in Equations 5 and 6) would also be higher since fewer women would be at home tending infants (Equations 19 and 20). Simultaneously there would be a decline in some other form of government spending or investment or both (Equation 31). It is within the province of the decision maker to decide from which sector the resources applied to birth prevention will be drawn. For the sake of illustration let us assume that proportionate

reductions are made in $G_1$ and $G_2$ (Equation 31). The effect of this is to reduce the inputs of capital and land into the aggregate production function (Equations 1 and 2). The net effect on the rate of economic growth will depend on the comparative strength of the two opposing effects (increasing the labor input and reducing the other inputs). The effect on growth rates will in turn affect the rate of technological change in the following period (Equations 3 and 4). The reduction in births will reduce $G_3$ (Equation 36) to the extent that the government would provide medical care. In succeeding years $G_3$ will be smaller to the degree that educational costs are foregone. This increased saving in the public sector should add to the capital or labor inputs (Equationsl and 2). (Ultimately the labor force will also be smaller to the extent that increased education of individuals will lower participation rates, and this again affect R in Equations 5 and 6.)

This model escapes the short-run partial equilibrium emphasis of the investment type models. It also escapes the restrictiveness of a fixed capital output ratio that would assign labor a zero marginal productivity and its excessive reliance on the form of the saving function for the demonstration of benefits.

This model incorporates the primary ("Enke") effect of raising per capita income as soon as births fall. It also incorporates the secondary effects of rising nutritional levels on labor productivity (the Leibenstein effect) and the savings to government arising from decreases in social overhead needs (the Coale-Hoover effect). (This model explicitly introduces investment in land development as an alternative to demographic investment.) It recognizes the possible effect of rising per capita income on the saving ratio (the Demeny effect) , however, it is not an essential feature of the model.

This model also recognizes the dual nature of the economies of underdeveloped countries and works in a two sector format. Operationally this requires more data to estimate actual coefficients of relationship but the increased meaningfulness of results may make this worth while. It is also unique in that it introduces a cost-effectiveness equation for birth prevention expenditures (Equations 7 and 8).

Thus, in summary this model explains per capita income in period t for the agricultural and non-agricultural sectors as follows:

$$\frac{Q_{A_t}}{P_{A_t}} = \frac{\phi_A F_{A_t} L_{A_t}^{\alpha A} K_{A_t}^{\beta A} J_{A_t}^{\lambda A}}{\sum_i \omega_i H_{A_{it}}}$$

$$= \frac{\phi_A \, f\left(\frac{\Delta Q_{A_{t-1}}}{Q_{A_{t-1}}}, t\right) L_A\left(Z_{A_t}, \frac{Q_{A_{t-1}}}{P_{T_{t-1}}}, R_{A_t}\right)^{\alpha A} [K_{A_{t-1}} + (1-\lambda)S_{A_t} + (1-\theta)S_{A_t}]^{\beta A} [J_{A_{t-1}} - g(G_2)]^{\lambda A}}{\sum \omega_i [\sum b_{A_{it}} + H_{A_{it}} - \sum d_{A_{it}} H_{A_{it}}]}$$

$$\frac{Q_{N_t}}{P_{A_t}} = \frac{\phi_N F_{N_t} L_{N_t}^{\alpha N} K_{N_t}^{\beta N}}{\sum_i \omega_i H_{A_{it}}}$$

$$= \frac{\phi_N \, f\left(\frac{\Delta Q_{N_{t-1}}}{Q_{N_{t-1}}}\right) L_N\left(Z_{N_t}, \frac{Q_{N_{t-1}}}{P_{T_{t-1}}}, R_{N_t}\right)^{\alpha N} [K_{N_{t-1}} + \lambda S_{A_t} + \theta S_{G_t} + S_{N_t}]^{\beta N}}{\sum \omega_i [\sum b_{N_{it}} H_{N_{it}} - \sum d_{N_{it}} H_{N_{it}}}$$

This model includes now the most important and most relevant impacts and interactions between spending on family planning and the economic-demographic time-path of the economy. It is flexible in form and is capable of being applied to any time period as operational situation for which the required data are available.

Paul Demeny has remarked that "additional investments in aggregate general models; illustrating the economic implications of alternative demographic trends will tend to yield rapidly diminishing returns. Further research should be increasingly directed towards the analysis of empirical relationships between demographic characteristics and economic behavior.[75]

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[75] Paul Demeny, op. cit., p. 13

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Of all the relationships sketched out in the above model the one about which we know the least is the impact (in cost-effectiveness terms) of government programs on birth rates and death rates. This, then, is the next important empirical research step which will, in turn, make our model more accurate and useful.