Human Resource Development and Economic Growth in Developing Countries: A Simultaneous Model

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A Background Study for World Development Report, 1980

This paper is a cross-country statistical analysis of the relationships among economic growth, human resource development (improvements in education, health and nutrition), and population growth in developing countries. It applies simultaneous equation techniques to a large set of data recently assembled by the World Bank in ways that reduce some of the difficulties and ambiguities that beset earlier work in this field.

As well as confirming that economic growth promotes human resource development, the analysis indicates that human resource development contributes substantially to growth -- by increasing labor productivity and physical investment, and by reducing fertility. Education appears to be particularly important. Family planning programs are also shown to have an independent effect on fertility, although their strength is affected by other social and economic variables.

The estimated model is used to simulate the effects of alternative policies over long periods of time. This permits, among other things, an examination of the tradeoffs between increased physical investment and increased spending on human resource development.

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FOREWORD

This report has been subdivided in a manner which may seem peculiar at first glance. Chapters I, II, and III devote most of their attention to a general discussion of research hypotheses and the results of the study. Technical detail has been relegated to the numerous appendices wherever possible. Readers who are accustomed to having their methodology served up as the first course in a research presentation may find this approach quite troublesome. I sincerely hope that they are not inconvenienced.

This rather broad-ranging study may be read by people who have general or highly specialized interests in several development-related fields. The mode of organization which I have chosen represents my own attempt to strike a balance among these rather diverse interests. Hopefully, non-specialists can absorb the main themes of the study by reading only the first three chapters. At the same time, I have provided signposts throughout which direct specialists to the relevant technical appendices.

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I. INTRODUCTION AND SUMMARY OF RESULTS

During the past two decades, many poor countries have experienced improvements in per capita income and human resource variables such as education, health, and nutrition. Empirical analyses of the development process have generally assigned a purely causal role to income expansion, although a few have identified the human resource variables as possible "sources of growth." This study attempts to incorporate both views by examining the growth process as a set of dynamic relations linking output, population, and human resources. Extensive use has therefore been made of insights provided by both economists and demographers. Prior work by economists has been helpful in the definition of an output growth model which is explicitly simultaneous in output and human resource changes. The associated model of population growth owes much to prior work by demographers.

The full dynamic model developed in this report contains both recursive and simultaneous elements. Within growth periods, income, population, and human resource variables change in response to prevailing rates of birth, death, capital accumulation, and labor force growth. These rates are in turn influenced by the full set of induced changes. Because the four crucial stock-adjustment rates are regarded as fixed in the short run, it is convenient to refer to them collectively as "accumulation parameters." By the same logic, the human resource measures will join income and population as "response variables" when a composite reference is required.

In the determination of output growth, the role of human resource variables has been considered in the context of both accumulation and response. In the direct determination of output, the argument that human resource variables have an important role is so plausible as to be beyond

argument, at least in a general sense. The Western empirical literature on growth has discerned an important role for education in the growth process, whether its contribution is taken to be labor-augmenting, capital-augmenting, or factor-neutral (1). Few would doubt that the process of education can have a positive impact on workers' earnings, although there is disagreement about the degree to which the pure role of "learning" can be divorced from the behavioral effects of "schooling" and the impact of credentialism (2).

The case could also be made that health and nutrition are potentially-important contributors to productivity in LDC's. Both of these

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(1) Econometric work on factor-augmentation in industrial societies has generally used time series to measure the contribution of education (see Intriligator (1965), Denison (1967), and Barger (1969)). Econometric work on the sources of growth in LDC's has tended to compensate for data scarcity by adopting a cross-sectional approach (Robinson (1971)). Fallon and Layard (1975) have estimated the degree of complementarity between skills and physical capital in productivity determination across countries. Other recent papers (Correa (1970), Hicks (1979), Wheeler (1980)) have attempted to extend the study of sources of growth in LDC's to include health and nutrition, as well as education.

(2) The debate concerning social returns to education has been long and heated. Fields (1980) notes that most work suffers from a failure to take simultaneity into account in analyzing the intertemporal association between change in income and change in education. Among those who have done empirical work on the relationship between education and productivity change, conclusions are very mixed. A study of agricultural productivity by Hayami and Ruttan (1970) suggests an important role for technical and general education in explaining the differential between rich and poor countries. This conclusion is supported by the extensive comparative work of Psacharopoulos (1973), who has calculated a substantial average social rate of return across countries. Among the skeptics, contrary evidence is cited by Nadiri (1972), who concludes from a survey of the literature that eduation has generally been unimportant as a determinant of differentials across countries, although within-country contributions often appear significant. Blaug (1973,1978) and others have explained this seeming paradox with a "credentialist" interpretation of within-country differentials.

Micro-level studies seem to have been no more successful in resolving this controversy than their macro-level counterparts. In an excellent study of labor absorption in the Japanese cotton-spinning industry, Saxonhouse (1977) finds very strong evidence to support the hypothesis of complementarity between capital and educated labor. On the other hand, some direct studies of the relationship between education and the industrial performance of workers have failed to discern any such association (see, for example, Fuller (1975)).

factors are undoubtedly characterized by thresholds beyond which their effects on output are negligible. In countries whose populations must endure widespread epidemic illness and nutritional deficiency, however, it is plausible to suppose that productivity is below its potential level with existing stocks of capital and effective labor. The evidence, although relatively scanty, certainly does not suggest a rejection of the hypothesis that these factors can make a difference (3).

If it is possible to entertain the hypothesis that education, health, and nutrition have an impact on productivity in poor countries, it is of course certain that the opposite is true. Wealthier societies enjoy substantially higher levels of all three variables. In part, this is because higher levels of public investment in health and education are possible in societies which can mobilize more revenue. In addition, increased disposable income allows families to purchase more welfare-enhancing goods and services.

Obviously, it is impossible to evaluate hypotheses concerning the impact of human resource improvements on growth without taking simultaneity explicitly into account. We can therefore characterize a plausible model of the "response" system as a multi-equation model in which levels of output, education, nutrition, and health are simultaneously determined. In such a system of equations, the stocks of capital and labor would be joined by existing institutional capacity for education and health promotion and other policy variables as exogenous elements in any particular (short) growth period.

While a "response" role for human resource variables may be important, they may also have a significant effect on investment behavior.

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(3) A few micro-level studies of the relationship between nutrition and productivity have been attempted. See Basta and Churchill (1974).

In this study, both literacy and life expectancy have been hypothesized to join per capita income as determinants of the investment rate. The role of life expectancy was taken to be potentially significant because of life-cycle effects on consumption and savings behavior. In the case of literacy, a potentially important role can be traced to studies which attribute significant shifts in economic behavior to the effect of education on attitude formation and economic calculation (4). For LDC's, it also seems plausible to expect a positive relationship between per capita income and the rate of capital formation, ceteris paribus. This hypothesized relationship would follow from the observable decline in marginal propensity to consume as societies shift away from the subsistence margin toward a condition in which some discretionary income is available.

In the preceding brief discussion, attention has been focused on hypothesized relations which tie human resource variables to the process of accumulation and response in output determination. Another plausible set of hypotheses links these variables to demographic changes. The death rate in any society is linked to the existing institutional and technical capacity for preventive and curative medicine, as well as the prevailing levels of education and income. Several persuasive arguments also tie human resource variables to the birth rate, although an appropriate model of causation is somewhat more complex than in the case of death rate determination. The birth rate itself is determined by the population proportion of childbearing women and their total fertility. Since the number of women is exogenous during any growth period, it is really differences in total fertility rates which must be explained.

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(4) Support for this hypothesis has been found by Koh (1977) in the case of entrepreneurial behavior in Japan.

Within the relevant age cohort, the fertility rate can plausibly be related to a set of human resource and other variables. The perceived opportunity cost of children seems to rise with income, so that fertile-age women bear fewer children, ceteris paribus. At the same time, the relationship between child-bearing and marriage would seem to dictate some relationship between age at marriage and total fertility. It is plausible to suppose that age at marriage is, in turn, a function of education, income, and life expectancy. In addition, appropriate education should have an effect on fertility once women accept the notion that fewer children are desirable, as would the cost and availability of contraceptives (5). Finally, since it is arguably the expected number of surviving children which should be the ultimate object of fertility decisions, the infant mortality rate should have some effect.

Certainly, the arguments which have been posed in the preceding paragraphs would be acceptable to many students of particular aspects of the development process. As previously mentioned, micro-level studies have examined at least some of them in considerable detail. Until fairly recently, however, the data available for cross-country examination of the major hypotheses have simply been insufficient for econometric work. An additional problem has been posed by the degree to which macro-level cross-section results are believable. Cross-country comparisons of value-based data such as GDP statistics are suspect in many ways, and problems of data scarcity have prevented the application of some compensatory techniques in the past. In cross-section work, there is also the problem of masked correlations, so that even results which seem to

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(5) Existing cross-sectional evidence concerning the relationship between education and fertility has been summarized in Cochrane (1979). Dyson, et. al. (1978) have recently published work on the long-run dynamic links joining fertility, mortality, and income.

corroborate maintained hypotheses about causal relations can frequently be explained with reference to other, unobserved variables. Finally, the evident presence of simultaneity in the determination of socio-economic outcomes has always presented a major stumbling block to the pursuit of consistent and believable research efforts in this domain.

In the project whose results are being reported in this paper, all of these problems were evident from the beginning. A major part of the research effort has therefore been devoted to overcoming them, insofar as this has been perceived to be possible. In all cases, an attempt has been made to move toward believability in results by estimating regression equations with cross-country changes rather than levels. This use of change relations has yielded one additional advantage: Among plausible models of output determination, several have an intertemporal specification in percent change form. In a cross-section of time series, the calculation of percent changes within countries avoids the index number problems which plague many cross-country studies.

Even when a cross section of time series is employed, of course, it is not possible to give an unambiguous interpretation to econometric results in most cases. Masked correlations may still be present, and it would be rare to find a case in which at least one alternative explanation for observed results could not be imagined. In addition, the use of relatively scanty data and the necessity for some experimentation in the evaluation of alternative functional forms and the testing of variables which seem plausible a priori increase the risk that any single set of regression results is simply a sampling accident.

For this reason, considerable time and effort have been expended in the attempt to cross-check the data in a variety of ways. Identical models of behavior for the 1960's and the 1970's have been estimated separately for the output response equations, since this part of the model

is most subject to the difficulties associated with the simultaneity problem and the possible effect of intervening variables. This same set of equations has been re-estimated with whole world regions excluded, to test for the possibility that apparently "general" phenomena are in fact traceable to the characteristics of a particular region. Finally, a substantial set of plausible intervening variable effects has been hypothesized, and the fundamental equations have been re-run to see whether the originally specified relations seemed to remain once other factors were accounted for.

With all this as prelude, it is undoubtedly fitting to conclude the introduction with a summary of the principal findings of the research project. In the response component of the output equations, simultaneous equation estimating techniques have been employed throughout. The results have suggested the confirmation of some prior hypotheses and the rejection of others. As anticipated, changes in per capita income across countries seem to have a significant, positive impact on changes in literacy and life expectancy. In addition, a positive impact is suggested for calorie consumption, which can be interpreted as the best single available measure of general nutritional status. None of the direct links from per capita income to social indicator variables is particularly surprising, although the results have the advantage of being based on changes rather than levels.

Of more potential interest in the simultaneous estimates is the evaluation of hypotheses concerning the impact of the social indicator variables on output growth. In each case, as previously mentioned, there is a plausible argument for some contribution to productivity.

After an exhaustive series of tests over different time periods, with various regional exclusions, and with the use of many plausible intervening variables to test for continued significance, a relatively

clear set of conclusions has emerged. The impact of literacy change on output change is apparent in all the tests which have been run. When life expectancy change is used as a proxy for health improvement, however, no consistent results are obtained. In simultaneous estimates for the 1960's, changes in life expectancy appear to contribute significantly to changes in output. In the 1970's, however, the effect is reversed: This variable loses significance and in fact exhibits a negative relationship with output change in the simultaneous estimates. It seems appropriate to conclude that the results for the 1960's may have been a sampling accident, and that life expectancy as a proxy for health cannot be identified as a significant contributor to productivity growth (6).

Although education and health are really at the focus of attention here, it is certainly of interest to examine the hypothesized impact of nutrition on productivity. The results of all the econometric exercises certainly lend support to this hypothesis, if the available index of nutrition is acceptable as a proxy. After simultaneity has been explicitly accounted for, changes in calorie consumption appear to have a significant impact on output changes across countries. It must be noted, however, that the calorie variable may be serving as a proxy for relative changes in agricultural productivity. Some development economists have maintained that agricultural growth has a differential impact on output growth, and the observed result may be in part an indirect confirmation of this hypothesis. At the present time, there does not seem to be any good way of separating the two effects.

As previously noted, plausible hypotheses link human resource

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(6). This is not to say, of course, that health has no effect on productivity in poor countries. The results simply suggest that the available measure is not very helpful in gauging the marginal effect of health improvements at the macro level.

variables with accumulation parameters as well as response variables in the growth system. In the case of output growth, an association can be hypothesized between levels of education and life expectancy and the investment rate in LDC's. Such a link, if established, would suggest an indirect role for the available health measure in the generation of productivity change, as well as an additional role for education.

Again, econometric work on the relationship between the investment rate and various causal variables has yielded mixed conclusions. Time series work in this particular context has not been plentiful in the past, and in this project it was hypothesized that the effects which were being tested might show up over relatively long periods if at all, given the substantial measurement problems which exist. In the case of the investment rate, regression equations were fitted to data on changes in the investment rate across LDC's during the period 1960-1977. The results suggest relatively strong roles for per capita income and literacy in the determination of this rate. The result for life expectancy is extremely weak when it is used along with literacy in the investment rate equation, although the coefficient of the life expectancy term satisfies the usual statistical criteria when literacy is excluded. At best, any hypothesized role for life expectancy in the determination of relative investment rates is certainly cast into doubt by these results.

In the demographic component of the modeling exercise, the results are similarly mixed. As previously mentioned, part of the variation in birth rates across countries can be attributed to differing proportions of young women in their populations. There is obviously a component of the death rate which is sensitive to age structure differentials as well. Once this deterministic component is accounted for, both rates can plausibly be related to several human resource and policy variables. Technical and institutional capacity should have an effect on the death rate, as should

changes in the level of health-promoting consumption at higher income levels. Other variables such as nutrition and education might be supposed to have some effect, as well. In the case of fertility rates, income, infant mortality rates, and appropriate family planning efforts could certainly be suggested as causal variables. A potential complication is raised by the possibility that family planning activity will occur differentially in countries which have already exhibited some decline in fertility rates, because of encouragement effects.

In econometric work on birth and death rate determination, regression equations were fitted to seventeen-year changes to allow for periods of time sufficient to overcome the effects of measurement error. In both cases, the data allowed for explicit testing of the hypothesis that the causal variables had differential effects in different age cohorts. In the case of fertility rates, estimation was further complicated by the necessity of allowing for explicitly simultaneous determination of fertility rates and family planning activity, as well.

Among the variables which might plausibly have been related to changes in death and fertility rates, those mentioned above all appear to play a significant role. In the case of death rate changes, only the availability of medical personnel as indexed by doctors per capita appear to account for effects beyond those attributable to changes in per capita income and a strong autonomous technical change component.

In the simultaneous equation estimates, an important role in fertility rate determination is suggested for per capita income, the death rate (which is a proxy for unavailable infant mortality rate data), the literacy rate of the population, and the level of family planning activity. The latter, in turn, seems well explained by contemporaneous declines in the fertility rate and the institutional capacity of the society in question (as proxied by the secondary school enrollment ratio).

The results certainly do not refute the hypothesis that fertility decline contributes significantly to the initiation of family planning activity across countries, for whatever reason. In addition, the fertility results suggest that the marginal effects of causal variables across age cohorts cannot be differentiated from one another at a high level of statistical confidence, although cohort-specific constant terms appear to differ significantly.

Although the impact of singulate age at marriage on fertility rates could not be measured in the time-change equation because data were insufficient, this variable was tested in a set of separate equations fitted to the combined pool of data for the years 1960 and 1977 in order to maximize degrees of freedom. These results suggest that age at marriage is well accounted for by literacy and life expectancy. When all three variables are included in a cross-section regression, the residual component of age at marriage seems to account for no additional variance in the fertility rate.

In the aftermath of a relatively complex set of econometric estimation exercises, it is always of interest to examine the dynamic behavior implied by the full set of equations. As previously mentioned, the equation system whose parameters have been estimated is too complex for the calculation of fixed multipliers. Simulation is thus the relevant tool for analysis and prediction. In a later section of this report, the econometric results are translated into a simulation model which is used to examine growth dynamics under alternative policy assumptions for a set of "representative" LDC's. Full hypothetical data sets to be used as initial conditions for these simulations have been assembled for Sub-Saharan Africa, South Asia, and South America. In addition, data for the full set of LDC's has been employed in constructing a "representative" LDC case.

II. MODELING OUTPUT GROWTH

In this chapter, particular attention will be paid to the portion of the modeling exercise which links human resource development to output growth. The first section will be devoted to a discussion of results for a basic growth model which treats the national economy as if it were closed. In the second part, an open-economy model will be used to test the first results for the effects of certain important intervening variables.

Briefly, the model of responses which is the basis for the econometric exercise in this section is designed to overcome several serious methodological problems. First, it is explicitly simultaneous in the relevant variables. Improved nutrition, health, and education can make a contribution to productivity in poor countries, but it is also evident that growth in national income can produce positive increments in these same variables. The structural equations used for the growth model contain sufficient numbers of exogenous variables to allow the disentangling of joint causal effects (that is, they are just- or over-identified in the parlance of econometrics).

In the specification of the growth response equations, it has been necessary to address another problem which is complementary with the first. Much of the criticism of cross-section work in the past has centered on the use of relative variable levels across countries. Many socio-economic variables are highly correlated with one another, and in running cross-section regressions the researcher always faces the intervening variable problem in interpreting results. It would be better to incorporate time series on individual national experiences into such work if possible, and fortunately the available data are now sufficient to allow for this. Thus, all of the econometric work reported here has been done on cross-sections of changes rather than levels across countries.

This creates a much more stringent test of hypotheses concerning the behavior of individual variables than would otherwise be possible.

Combined with the need for explicit simultaneity and the desirability of time changes in this sort of model, there is an additional requirement of theoretical credibility. In econometric work, any specification of relationships beteen variables will automatically impose behavioral hypotheses on the data. For models which relate output to factors of production, this point is of particular significance. Unless we believe that factors of production are always perfect substitutes for one another (so that diminishing returns do not apply), then we should not be interested in a simple linear regression model of the production process. Similarly, if we believe that factors of production cannot be substituted for one another at all, we should have no interest in putting all of them together in a regression equation. We could simply calculate their relations to final output one at a time. For all intermediate cases (and almost all believable cases are intermediate, especially at the aggregate level), it is obviously desirable to have an appropriate specification.

The simplest intermediate specification in common use in economics is the Cobb-Douglas, which is linear in the logarithms of inputs rather than in their original levels. It is easy to show that this specification implies diminishing returns while still allowing for a substantial degree of substitutability among inputs (In fact, it imposes the assumption that the elasticity of substitution is unitary, which might well be overly liberal in many cases). A slightly more supple specification is provided by the CES ("constant elasticity of substitution") form, which can be approximated by a regression equation which is linear in the logarithms and the squares of differences in logarithms of inputs. The CES specification does the Cobb-Douglas specification one better by continuing the assumption of diminishing returns and constant elasticity of

substitution while allowing the latter to take on other-than-unitary values if these are suggested by the available data.

Finally, to summarize a complex subject with heroic brevity, it should be noted that even more general specifications are currently available. These forms allow, among other things, for the measurement of variable elasticities of substitution among inputs. Several have been extensively studied and applied, but the specification which seems to be most convenient has been christened the "translog" (after transcendental logarithmic) function. This function is linear in the first powers, squares, and cross-products of the logarithms of inputs. Clearly, its flexibility is balanced by a rather disagreeable proliferation of right-hand side terms, many of which may be subject to the familiar curse of multicollinearity. Where data are relatively scarce, the associated loss of degrees of freedom is likely to present statistical problems, as well.

Hopefully, this brief discussion has provided some evidence in favor of the argument that it is never sufficient to throw variables into a linear regression unless there is good reason to believe that "infinite substitutability" is as good an assumption as any other a priori. Since this is not likely to be the case in an output equation, we are forced to shop among the other candidates. In this study, the shopping has been confined to a comparison of the Cobb-Douglas and CES specifications. The need for simulaneous equations estimation, the use of variables in time-change form, and the requirement of a plausible specification of the relationship of inputs to outputs simply precluded the use of the translog specification. As it turned out, these same conditions produced circumstances under which the necessary linear approximation of the CES specification also performed very badly. Thus, the output equation work which is reported in this study has been heavily dependent on

specifications which are derived from the basic Cobb-Douglas form.

Having briefly surveyed the theoretical terrain, we can pass to the equation set which has actually been estimated. As noted, the output equation is basically derived from the Cobb-Douglas function. This log-linear specification, when translated to time-change form, is linear in percent changes in model variables. Thus, a specification of the input-output relationship suggested by our basic hypotheses concerning the contribution of human resources to growth at the macro-level would look like the following (7):

$$\langle dq \rangle = a0 + a1*\langle dk \rangle + a2*\langle dl \rangle + a3*\langle dh \rangle + a4*\langle dn \rangle + a5*\langle de \rangle + u$$

where

<dq> = Change in output
<dk> = Change in capital
<dl> = Change in the labor force
<dh> = Change in health status
<dn> = Change in nutrition status
<de> = Change in education
u = A random error term

In the output equations which have actually been estimated for this study, data problems have necessitated some departures from the pure Cobb-Douglas form. Capital stock data across countries are simply unavailable, and the variable actually employed in the equations is the intraperiod change in capital (investment), divided by the initial level of output. The consequences of this assumption are discussed in Appendix

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(7) Apologies are offered for the expression of relatively complex symbolic equations on single lines in this report. The writing, editing, and final production of the paper have been greatly facilitated by the use of word-processing software which, unfortunately, makes no provision for mathematical symbols. Hopefully, this form of "technical progress" will not prove too inconvenient for the reader.

A. For the moment, it should suffice to say that they may not be overly damaging in work at this level of aggregation.

The second major departure from the form implied by the Cobb-Douglas specification is the substitution of the intraperiod change in literacy for the intraperiod percent change as the measure of basic educational improvement. This substitution is intended to solve a significant measurement problem. During a period in which many countries have moved from extremely low literacy to somewhat higher levels, modest absolute gains translate to huge percent changes. The result for econometrics is that a relatively small number of countries which began at very low literacy levels in 1960 can dominate the entire sample numerically. It has therefore been deemed desirable to use absolute differences for literacy change. In theoretical terms, this translates to a model which is very similar to the Cobb-Doublas except that the effect of education enters as a multiplicative exponential rather than a multiplicative power of education itself.

The other equations of the output model have been specified in a way which dovetails with the specification of the output equation. For the available measures of nutrition and health, percent changes have been employed. In addition, the nutrition change equation incorporates a term which captures some delay in the adjustment of current consumption to per capita income, while the life expectancy change equation incorporates terms to capture the effects of nutrition, education, and the availability of medical personnel.

Because the contribution of literacy to output change has been modeled using absolute changes, the literacy change equation has been specified in compatible form. Its exact mathematical derivation is presented in Appendix A. This equation measures the marginal effect of per capita income growth on the growth of literacy as well as the actual

effect of schooling on the age cohort which passes to adulthood in each period. In the regression equation, the coefficient of the appropriately-modified schooling variable can be interpreted as the measured probability that a student who attended primary school during the period in question actually became literate in the process. In the life expectancy equation, an index of medical personnel availability is used to capture the effect of public health efforts on life expectancy change. Both of the availability indices mentioned above represent service intensity levels which make contributions to changes in endogenous variables. At first glance this may seem inappropriate, since an adequate causal model must in the final analysis relate changes to changes. This remains true for the current exercise, but service levels are crucial intermediaries. In the literacy equation, for example, the change in adult literacy is mainly due to the result of a "throughput" process. Children have passed through primary education facilities (whose capacity is represented by the primary enrollment ratio), and some have emerged literate. Thus, an automous flow (children) through service institutions whose capacity is defined results in a changed condition of literacy for the adult population.

This same "throughput" notion applies to all equations in the response model except the output equation. In the life expectancy equation, the flow in question is health technology. For a poor country, the degree to which a constantly-improving technology can be applied depends upon the availability of appropriate channels. One channel is clearly the set of potential services defined by available medical personnel and facilities. Another is associated with the means for effectively transferring public health information. Undoubtedly, primary schooling is important in this process, as are various printed media. Thus, both the primary school enrollment ratio and the adult literacy rate

are defensible indices of information-transfer capacity.

A look at the global evidence for the past two decades also suggests that there has been a sizable and near-universal up-shift in life expectancy which has been due to the widespread employment of mass vaccinations and other internationally-subsidized technologies. For any country, then, there should be a substantial component of life expectancy change which is simply "autonomous." Since countries may well differ with respect to their ability to implement such universally-available health measures, it makes sense to suppose that life expectancy change in the 1970's should exhibit some lagged relationship with the change in the 1960's for a particular country. A lagged adjustment term has therefore been included in the life expectancy equation.

In the interest of completeness, three sets of basic regression results are presented here. As a fairly stringent test of the underlying hypothesis concerning the direct contribution of human resource variables to growth, the same model was run on data for the 1960's, data for the 1970's, and a set which pooled data for both periods. The initial results made it clear that life expectancy as a measure of health has no consistent impact on output growth, although the reverse phemenon is apparent. Because the exclusion of life expectancy change from the output equation and the consequent decoupling of the life expectancy change equation from the simultaneous system allowed for a significant saving in degrees of freedom in estimation, the basic model presented here is in three-equation simultaneous form (8).

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(8) In the growth model as specified, all of the equations are over-identified. A series of dummy variables for major sub-regions were introduced in the second stage to aid in absorbing unexplained variance, since it was clear that local culture and natural conditions could have have an important influence on the processes being observed. The sub-regions defined for this work were the Caribbean, Central America, the Andean countries, the rest of South America, North Africa, the Sahel, West

Figure 1

OUTPUT EQUATION RESULTS -- CLOSED ECONOMY MODEL (*)

1960 - 1970

	N	R**2
<dq> = .052 + .142*<dk> + .301*<dl> + .869*<dn> (.124) (.034) (.319) (.440)	39	.39
+ .016*[E{t}-E{t-1}] (.005)		
<dn> = -.057 + [4.215-.868*lnN]*[<dq>-<dp>] (.022) (1.031) (.222)	39	.38
+ .038*ln[(Q/P)/N] (.020)		
E{t}-E{t-1}*[1/(1+<da>)] = -2.423 + .988*S*[<da>/(1+<da>)] (2.259) (.137	39	.56
+ 8.313*[<dq>-<dp>] (3.697)		

1970-1977

<dq> = -.109 + .182*<dk> + .592*<dl> + .557*<dn> (.079) (.036) (.337) (.390)	43	.51
+ .0080*[E{T}-E{t-1}] (.0037)		
<dn> = -.033 + [4.450-.948lnN]*[<dq>-<dp>] (.016) (1.370) (.292)	43	.31
+ .051*ln[(Q/P)/N] (.014)		
E{t} - E{t-1}*[1/(1+<da>)] = 2.985 + .639*S*[<da>/(1+<da>)] (2.045) (.174)	43	.43
+ 14.485*[<dq>-<dp>] (5.248)		

Africa, Central Africa, East Africa, West Asia, South Asia, Southeast Asia, East Asia.
(*) Standard errors in parentheses beneath coefficients.

Pooled Data

	N	R**2
<dq> = [.012 - .087*D70] + .146*<dk> + .565*<dl> + 1.011*<dn> (.088) (.048) (.025) (.239) (.417)	82	.50
+ .0096*[E{t}-E{t-1}] (.0037)		
<dn> = [-.040 + .009*D70] + [3.259-.674lnN]*[<dq>-<dp>] (.017) (.016) (.894) (.191)	82	.35
+ .042*ln[(Q/P)/N] (.012)		
E{t} - E{t-1}*[1/(1+<da>)] = [-.996 + 3.986*D70] (2.265) (1.810)	82	.31
+ .755*S*[<da>/(1+<da>)] + 12.291*[<dq-<dp>] (.138) (4.188)		

Life Expectancy Change, 1970-1977

<dh> = -.124 + 6.948*(1/H) + [.573-.144lnH]*[<dq>-<dp>] (.038) (1.570) (.290) (.072)	52	.63
+ .142*<dh{t-1}> + .077*<dn{t-1}> + .027*[E/H] (.082) (.027) (.012)		
- 1.10E-5*[M/H] + .010*[S/H] (.70E-5) (.006)		

Variable Definitions

<dq>,<dl>,<dh>,<dn>,<dp>,<da> = Percent changes in real GDP, labor, life expectancy, nutrition, population, and adult population, respectively.
<dk> = [Change in capital]/initial GDP (See Appendix A)
E{t-1},E{t} = Literacy rate in initial and final years of estimation period, respectively.
ln N = Logarithm of initial nutrition level
Q/P = Initial level of per capita income
S = Previous primary school enrollment ratio relevant for the newest adult age cohort.
D70 = Dummy variable with values [0=1960-1970, 1=1970-1977]
H = Initial life expectancy level
M = Initial availability of medical personnel
E (In life expectancy equation) = Initial literacy rate

The three sets of estimates presented above seem to tell a consistent story (9). Capital, labor, literacy, and the measure of nutritional adequacy all show up in the output equation in both periods with the expected sign, reasonable magnitudes, and a general pattern of adequacy by an appropriate one-tailed criterion. An exception is posed by the labor coefficient in the period (1960-70). Since it does not seem plausible to suppose that labor has no effect on output in any case, attention should be focused on the magnitude of the estimated coefficient itself.

In interpreting the results for the output equation, it is important to note that the capital stock change variable is really the total change in capital during the estimation period divided by the initial output level. For reasons which are explained in detail in Appendix A, interpretation of the resulting coefficient depends upon an independent estimate of the capital-output ratio. Generally, the estimation results seem consistent with a capital-output ratio of about 3 and constant returns to scale. The implied capital and labor shares are not radically different from those found in econometric estimates for the industrial societies (10).

As mentioned in the introduction, some ambiguity attaches to the "nutrition" coefficient which accompanies the percent change in calorie consumption. In part, this result may represent the beneficial impact of rapid agricultural growth, which has been pointed to by numerous development economists as a potential source of differential productivity

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(9) Clearly, the intersection samples used for estimation of the change equations are much smaller than the full set of countries. In limited samples, the risk of systematic bias is always present, but the country observations represented in the preceding estimates look remarkably like a random draw. See Appendix H for a complete list.
(10) See for example Barger (1969).

in LDC's. It might well be overly optimistic to attribute all of the measured impact to nutrition, although it is certainly plausible to suppose that some of the effect is due to this variable (11).

In summary, the simultaneously-estimated response equations do not refute two of the basic hypotheses which were of interest to this study -- that basic nutrition and education make a contribution to the explanation of output growth patterns when changes in the basic factors of production (capital and labor) and simultaneity are taken into account. The same pattern appears in the 1960's, the 1970's, and in the pooled sample, with observable differences in estimated coefficients no greater than might be expected from normal sampling variation. As always in statistical inquiry, these results do not "prove" anything. They simply show that an appropriately-specified model yields rather robust results which are consistent with the hypothesis that human resource improvements are productivity-augmenting at the aggregate level (12).

In the other two equations, the measured impact of per capita income growth shows up as expected. A log-interaction term has been included in the nutrition equation to control for a declining calorie demand elasticity as the general nutrition level rises (13). Note that the endogenous variable in these equations is output growth itself, while population growth enters exogenously. In the system being modeled,

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(11) For the reader who leans toward the agricultural interpretation of this result, the nutrition component has been excluded and the resulting two-equation output model estimated by 3SLS in a subsidiary exercise. The results are reported in Appendix B. Except for a reduction in explained variance as a result of the exclusion, they are very similar to the full output equation results.
(12) The oil-producing states have been excluded from all regressions in this study except for the open economy variant of the output response model. In this version, the inclusion of import growth on the right-hand side allowed for the introduction of oil producers without horrendous outlier effects.
(13) A complete discussion of this issue can be found in Reutlinger and Selowsky (1975).

percent change in population is the difference between birth and death rates, both defined as "accumulation parameters." For the short periods used in estimation, these parameters are assumed to be fixed (determined by the initial levels of several variables, including some of the human resource variables), although it is clear that they can change between periods in a way which makes the model fundamentally recursive.

In the nutrition change equation, the importance of the coefficient of the initial income/nutrition ratio suggests that delayed adjustment is not negligible in explaining current changes in nutrition in LDC's. No major differences in the nutrition equation results for the two decades seem evident. In the literacy equations, however, one important difference is obvious. If the estimates for the 1960's and 1970's are to be believed, they suggest that attempts to move rapidly to mass primary education with limited material and human resources has resulted in a substantial decline in the marginal efficiency of the schooling process in many LDC's. For the 1960's, the estimated probability that any student who actually attended primary school would become literate is quite close to one. For the 1970's, however, the probability is apparently lower (14). This is not to say that rapid expansion has not had a beneficial impact, since seventy percent of a large number is clearly preferable to ninety-eight percent of a much smaller number (15).

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(14) Some studies of educational performance in LDC's support the implication of this finding. Inkeles (1974) has found a significant performance gap between students from LDC's and industrial economies on equivalent examinations in recent years.
(15) Although the distribution of literacy growth data in the 1960's is relatively smooth, some unfortunate tendencies in national self-reporting seem to have cropped up in the 1970's. Reported literacy gains for Tanzania and Somalia are gross outliers in the distribution, and it seems probable that measurement and enthusiasm for adult literacy campaigns have become intertwined in the reporting for these two countries. They have been excluded from the response model because of a strong feeling on the part of the author that the kind of literacy growth which is meaningful for productivity cannot be divorced from the process of schooling. If the

There are, of course, numerous possible explanations for this downshift in probability. Its existence seems entirely plausible, however, given the circumstances under which rapid expansion has taken place. In passing, it should be noted that attention was given to the possibility that the literacy probability parameter would itself vary across countries as a function of relative capacity indices such as initial literacy and per capita income. In several trials, no apparent sensitivity emerged, and the assumption of constancy across countries cannot be refuted using the kinds of data which were available for this study.

In summary, it seems fair to conclude that hypothesized impacts for basic education and nutrition on productivity change are consistent with the available data. The growth model performs about equally well for the 1960's and the 1970's. It should be emphasized here that the result for the 1960's lacks one note of ambiguity which is unavoidably present in the second set. The available World Bank estimates for nutritional adequacy and literacy are "mid-seventies" observations, which can realistically be regarded as random draws from the period 1974-1976. Under the assumption that the change registered during the observation period could be extrapolated directly through 1977, these data can be used in an output equation along with measured labor, capital, and output changes for the entire 7-year period. Nevertheless, it is comforting to note the strength of the results for the 1960's.

The results for the life expectancy regression are satisfactory, although this particular equation was subjected to more experimentation than any other in the study (16). Both lagged life expectancy change and

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two countries are included in the sample, the output equation results are unaffected but the proportion of variance accounted for by the literacy equation drops by about .10.

lagged nutrition change have an apparent impact, along with contemporaneous per capita income change. All of the throughput variables previously mentioned appear to make a contribution, as well (17).

Although the reported econometric estimates are the best which could be produced under the circumstances, the reader may feel justified in retaining a certain skepticism concerning the degree to which they actually reflect the hypothesized interactions. At least two bases for such skepticism can readily be imagined. Although regression coefficients always purportedly measure "representative" impacts across data sets which can be characterized by smooth frequency distributions, they may in fact be quite sensitive to the impact of a few outliers in the data. If the term "outlier" is used rather loosely, it can also represent cases in which purportedly general results are actually reflections of experience in one or two relatively homogenous subsets of the data. In the current context, for example, it might be imagined that measured human resource impacts were in fact due to particular circumstances in single regions. East Asia has recently been celebrated as an exemplar of both educational and economic progress, and the informed skeptic might well wonder whether the measured impact of literacy on output were not in fact a reflection of a peculiar set of dominating circumstances in East Asia alone.

It is impossible to control for all sources of such skepticism in exercises like the current one. It does seem reasonable, however, to attempt some obvious further tests of the numbers. A simple device is an examination of the scatter diagrams which are associated with the measured

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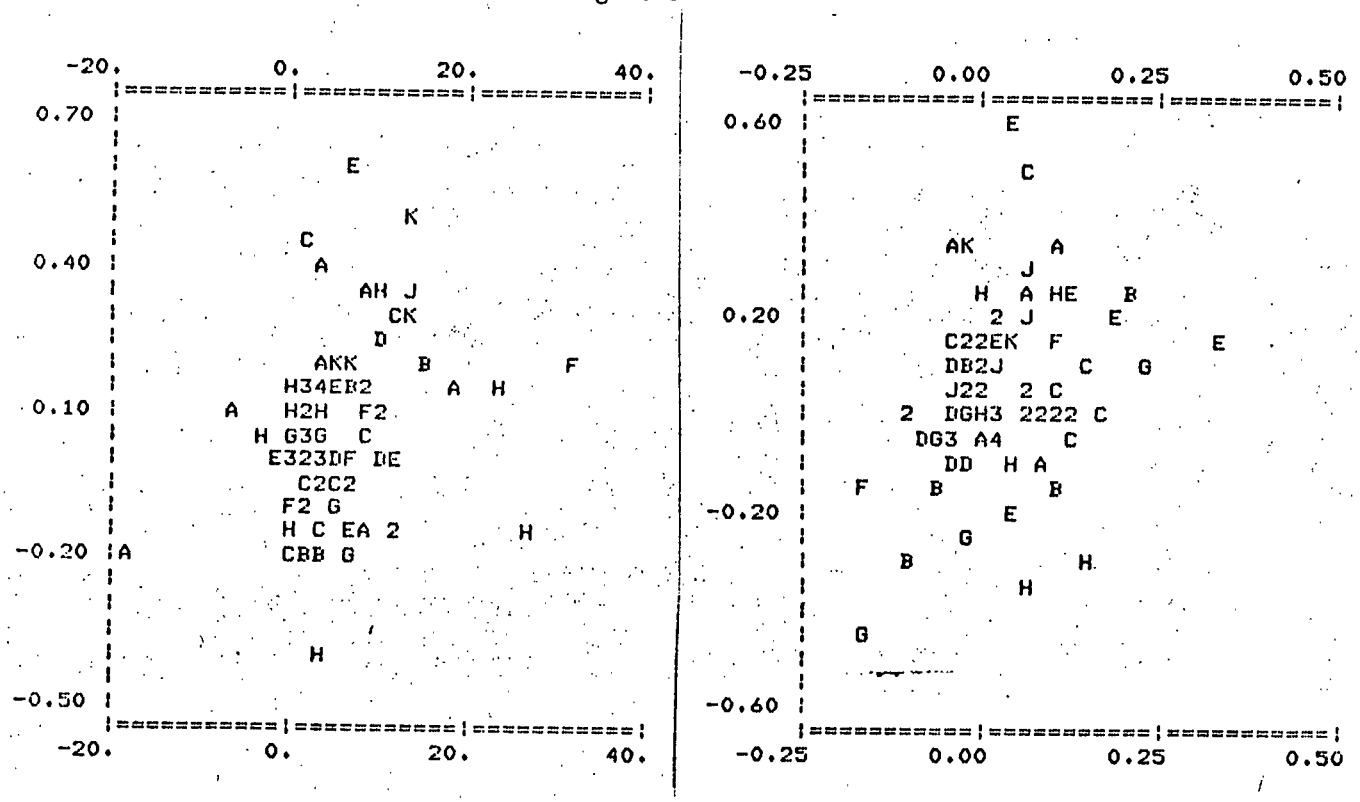
(16) Most plausible variables simply made no contribution to explained variance in the change equation. See Appendix G for amplification.
(17) It should be borne in mind that the index for medical personnel has been entered as population/doctor, so that the expected value of the associated coefficient is negative in the case of life expectancy and positive in the case of the death rate.

partial coefficients in the output equations. In order to produce such scatters, a variable of interest such as literacy change is plotted against "residualized" output change, where the estimated regression coefficients are used as a means of introducing statistical control for the presence of other variables in the equation. In the following figures, the relevant scatter diagrams are reproduced for literacy and nutrition change for the pooled data. They do not suggest that the measured results have been produced by one or two outliers in any case.

Figure 2



Literacy vs. Output, Pooled

Nutrition vs. Output, Pooled

As an additional test for regional dominance in the regression equations, entire regions were excluded from the pooled sample and the system re-estimated in a series of experiments. The results are reported in Figure 3.

Figure 3

CLOSED ECONOMY MODEL WITH REGIONAL EXCLUSIONS

MODEL EQUATIONS

(1) $\langle dq \rangle = [a1 + a2*D70] + a3*\langle dk \rangle + a4*\langle dl \rangle + a5*\langle dn \rangle + a6*[E\{t\}-E\{t-1\}]$

(2) $\langle dn \rangle = b1 + [b2 + b3*\ln N]*[\langle dq \rangle-\langle dp \rangle] + b4*\ln[(Q/P)/N]$

(3) $E\{t\}-E\{t-1\}*[1/(1+\langle da \rangle)] = c1 + c2*S*[\langle da \rangle/(1+\langle da \rangle)] + c3*[\langle dq \rangle-\langle dp \rangle]$

3SLS RESULTS WITH SPECIFIED REGIONS EXCLUDED (*)

	AFRICA	S. AMERICA	E.,S.E. ASIA	S.,S.E. ASIA
a1	.0376	.0149	-.0043	-.0420
	(.0999)	(.1044)	(.0903)	(.0949)
a2	-.0574	-.0554	-.0746	-.0594
	(.0465)	(.0547)	(.0444)	(.0480)
a3	.1393	.1678	.1706	.1737
	(.0271)	(.0285)	(.0258)	(.0267)
a4	.3472	.3957	.4078	.4446
	(.2994)	(.2922)	(.2334)	(.2557)
a5	.5474	.5838	.4800	.5934
	(.4775)	(.3971)	(.3429)	(.3671)
a6	.0207	.0105	.0099	.0135
	(.0056)	(.0045)	(.0038)	(.0041)
b1	-.0514	-.0395	-.0373	-.0427
	(.0201)	(.0131)	(.0144)	(.0163)
b2	3.1732	5.6945	3.7803	4.1827
	(.8997)	(.9562)	(1.000)	(.9799)
b3	-.6529	-1.2072	-.7965	-.8744
	(.1919)	(.2064)	(.2146)	(.2104)
b4	.0419	.0685	.0568	.0481
	(.0137)	(.0169)	(.0131)	(.0147)

(continued on next page)

(*) Standard errors in parentheses beneath coefficients

	AFRICA	S. AMERICA	E.,S.E. ASIA	S.,S.E. ASIA
c1	.6151	.3658	1.2819	.9534
	(1.7385)	(1.7556)	(1.6770)	(1.7035)
c2	.8481	.8515	.8387	.8552
	(.1009)	(.1544)	(.1267)	(.1317)
c3	9.3233	8.2971	5.7916	7.5153
	(2.9056)	(3.7554)	(3.6345)	(3.4090)
R**2				
(1)	.52	.57	.58	.56
(2)	.35	.56	.37	.38
(3)	.56	.47	.43	.46
N	58	58	71	69

Although the exclusion procedure resulted in a substantial loss of degrees of freedom in the cases of Africa and Southern America, the resulting estimates seem to diverge by no more than would be expected from sampling variability. A possible exception is the greater responsiveness of output change to literacy change when Africa is excluded from the sample. In any case, there is certainly nothing in these results to suggest that the estimates for the full pooled sample have been spuriously generated by a dominating association in one region.

One additional source of doubt must be confronted in evaluating the reliability of the results. It is possible to propose explanations for differential growth performance which go considerably beyond those offered by the basic model. It could plausibly be argued that variables such as literacy and nutrition change are in fact rough proxies for other forces whose impact, if directly measured, would render negligible the coefficients of the human resource variables themselves.

Since several extended views of the growth process were of independent interest to the production of this report, an attempt has been made to expand the basic model to incorporate them. The roles of exports and capital inflows in the process of growth have been given particular attention by many development theorists, and a model which attempted to take these phenomena explicitly into account would certainly be of interest as a complement to the current exercise.

An Open Economy Variant

It has been suggested by many development theorists that "extraverted" LDC's could be expected to grow more quickly than others. Many reasons for this have been offered. Countries which subject themselves to the rigors of international competition are quite likely to

be forced toward relatively efficient resource allocations, with consequent productivity benefits. At the same time, such economies are the most likely to attract foreign investment, so that the easing of the domestic capital constraint might serve a growth-promoting role. Complementary reasons for supposing that extraversion would have a growth-promoting role are easy to imagine. The importing of associated management skills or recent capital vintages could make a measureable difference in aggregate productivity. Similarly, the employment of local labor in efficiently-operated export industries might, under normal conditions of turnover, be supposed to have a training impact which would produce more general benefits through spread effects.

All of these arguments are plausible, and many of them have been reinforced by the performance of several LDC's which have focused on export promotion policies in recent years. East Asian societies such as South Korea, Hong Kong, Taiwan, and Singapore are particularly notable in this regard, of course, although cases in Africa and Latin America can also be cited. In this subsection, a relatively simple extension of the previous modeling exercise will be used to measure the apparent impact of the kinds of factors mentioned above, as well as the degree to which the statistical results for the human resource variables survive the translation to a more complete model.

Again, the specification of the output equation is in growth rates, with the exception of the literacy change variable. In the revised output equation, the relative severity of the foreign exchange constraint will be indexed by the contemporaneous growth rate of imports, while a test for any differential effect of manufacturing export performance on productivity will be attempted using the growth rate of manufacturing exports. The latter variable has been explicitly endogenized in the expanded model.

The manufacturing export equation itself has been specified to reflect some obvious, simple principles of comparative advantage, as well as the simultaneous impact of output growth. Capital is more mobile than labor in the world, and the relative attractiveness of labor as a complement to capital across LDC's must be systematically related to relative quality and price, appropriately measured. In the expanded model, relative wage levels have been proxied by per capita incomes, and the available measures of basic education (the literacy rate) and health (life expectancy) have been used as quality indices (18).

In the open economy model, then, the manufacturing export growth rate in a particular period is specified as a function of the total output growth rate during the period, the initial level of per capita income, and initial levels of literacy and life expectancy. The growth rate of imports is left exogenous. The results for the 1960's and 1970's are reported in the following figures.

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(18) This approach to the role of human resources in comparative advantage owes much to Balassa (1979).

Figure 4

OPEN ECONOMY MODEL - 3SLS RESULTS (*)

Pooled Data

	N	R**2
<dq> = .2298 + .0366*<dk> + .2441*<dl> + .6194*(dn>	71	.65
(.0963) (.0302) (.2120) (.4276)		
+ .0091*[E{t}-E[t-1}] + .7257*dmx + .1.6080*dim		
(.0041) (.3429) (.4538)		
dmx = -.1221 + .0012*E + .0024*H - .00022*(Q/P) + .1955*<dq>	71	.36
(.0951) (.00078) (.0026) (.00007) (.0434)		
1960-1970		
<dq> = .1863 + .0060*<dk> + .2476*<dl> + 1.5196*<dn>	32	.23
(.1492) (.0472) (.3217) (.4286)		
+ .0112*[E{t}-E{t-1}] + .6808*dmx + 2.6754*dim		
(.0045) (.4137) (.9017)		
dmx = .1312 + .0016*E - .0048*H + .00016*(Q/P) + .1951*<dq>	32	.15
(.1493) (.0013) (.0044) (.00014) (.0616)		
1970-1977		
<dq> = .0170 + .0780*<dk> + .4255*<dl> + .1584*<dn>	41	.69
(.0583) (.0343) (.2540) (.3256)		
+ .0089*[E{t}-E[t-1}] + .7661*dmx + 1.000*dim		
(.0031) (.1745) (.3362)		
dmx = -.3011 + .0014*E + .0064*H - .00038*(Q/P) + .1672*<dq>	41	.62
(.0924) (.00074) (.0024) (.00006) (.0523)		

Variables Not Previously Defined

dmx = Growth rate of manufacturing exports
dim = " " imports

(*) Standard errors in parentheses beneath coefficients. The estimates for the nutrition and literacy equations are effectively identical to those obtained for the closed economy model. These results have been excluded from the Figure for the sake of readability.

Several interesting patterns are suggested by these results. Certainly, the apparent role of literacy in the growth process is not called into question. Literacy change retains essentially the same magnitude, the appropriate sign, and a high degree of statistical significance in all three sets of regression results. The role of nutrition, on the other hand, is made more ambiguous by the poor result for the 1970's. The use of the import terms in the output equation substantially reduces the directly-estimated contribution of capital. The fact that much capital has been imported by the sample countries makes this result unsurprising. With the exception of the nutrition result for the 1970's, then, the use of the open economy model appears to add explanatory power without neutralizing human resource effects on output.

Even a cursory examination of the manufacturing equation results reveals that the fit is much better for the 1970's than for the previous decade. As always, two alternative explanations for this result are possible. The first might suggest that one of the two sets of results is simply a sampling accident, and that the export equation is: (a) irrelevant or (b) acceptable, depending upon the predisposition of the observer. A second plausible interpretation of the result might be that the world has changed, and that the international market is now sufficiently articulated that these simple measures of comparative advantage in labor resources capture an important source of differential competitiveness for LDC's.

If the optimistic interpretation of the mixed result is accepted, an interesting implication for human resource policy follows immediately. If it is really true that manufacturing export activity is a source of differential productivity gain, for whatever reason, and if it is also true that part of comparative advantage is attributable to basic human resources such as literacy, then it follows that countries which pay

little attention to these factors will suffer a double penalty. They will lose part of the output differential which is apparent in both sets of results on "closed economy" grounds alone. In addition, they will experience more difficulty in export promotion, with attendant benefits, than their counterparts which have focused on human resources. If the pooled results are regarded as the best summary of the evidence from both decades, the role of education in this domain certainly shows up more convincingly than the role of health (insofar as health is indexed by life expectancy, that is).

Obviously, this sort of argument is only partial, however. Funds for human resource investments and the support of heavy associated recurrent costs may well come from surpluses which could be allocated to physical investments. To say that human resource investments can have benefits is not, therefore, the same thing as claiming that the productivity impact of these investments is necessarily superior to that of physical investment. At this point, an explicit consideration of the trade-off question would be premature. After the entire socio-economic growth model has been specified and fitted to the available data, the resulting equations will be combined into a simulation model which will provide a vehicle for trade-off exercises.

The Investment Rate

Before moving from a consideration of output components in the growth model to the demographic side, some attention must be paid to the investment rate. A recursive specification of its relationship with the rest of the output equations seems justifiable. It is the level of the investment rate which determines the change in the capital stock and subsequent change in the output growth rate. Since the investment rate is

itself hypothesized to be a function of several variables which represent initial conditions in any growth period, the investment equation has been estimated separately by ordinary least squares.

In many ways, the investment relation represents the most limited part of this study. It is obvious that the observable aggregate investment rate in any society results from the interplay of many public and private resource allocation decisions. In addition, both domestic and international factors can play a role. No attempt has been made to handle these complexities in a structural model. Rather, the equation which is fitted to the data is a reduced form with some rather heroic presuppositions built in.

The basic investment equation has three components. These components are all determinants of the supply of investible funds, and an implicit assumption is made that this supply is actually translated into investment activity through the intermediation of public or private institutions. As any analyst of financial affairs in LDC's can affirm, this view is an oversimplification at best. At least, however, one would expect a substantial degree of correlation between the supply of investible funds and investment activity across countries.

The supply-side components which are incorporated into the investment equation for this exercise are three in number. Per capita income is included, since it is to be anticipated that the rate of personal savings will rise as a society moves away from the subsistence margin. In addition, two human resource variables are incorporated in the specification. Life expectancy is employed because of an hypothesized link between expected lifespan and savings behavior on the part of individuals in a particular society. In effect this represents nothing more than an extension of the life cycle approach to savings behavior. The literacy rate is included to test the hypothesis that higher levels of

basic education promote a fundamental change in attitude toward economic calculation and long-range planning. In the view of some, this effect may be particularly pronounced in rural areas.

Again, then, all the incorporated variables are really supply-side factors, and the explicit connection between the associated forces and the ultimate realized investment rate is left obscure in the specification. It should be noted in passing that both basic education and health could be regarded as human capital variables, in the spirit of the manufacturing export equations, and that an alternative interpretation of any perceived effect on the investment rate would pass through the impact of differences in human capital for the international flow of investment. Whether the hypothesized effect is foreign, domestic, or some combination, however, the investment equation remains entirely a supply-side construct.

With all this as precautionary introduction, we now pass to a brief consideration of specification and estimation. In this case, as in the others, the regression equation has been fitted to changes in the investment rate rather than to levels. The right-hand side has been made explicitly nonlinear in an attempt to control for a presumed decrease in the marginal impact of the included supply factors as the investment rate rises. Thus, changes in life expectancy and the literacy rate are divided by the initial investment rate in the complete specification, while shifts in per capita income are specified as percent changes rather than absolute differences.

The estimation results, as produced by least-squares regression, are reproduced below (19). The initial investment rate was also incorporated

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(19) For reasons explained in Chapter II, Somalia and Tanzania have been excluded from the sample used to estimate the investment equation. In addition, Argentina and Mauritania have been excluded. The reported investment increase for Argentina is obviously in error -- it is absurdly large. The reported increase for Mauritania is also so large as to be an

as a means of controlling for any sensitivity of autonomous shift factors to initial conditions. Indeed, as the following scatter diagram of the investment level in 1960 and changes in investment from 1960 to 1977 makes clear, the phenomenon of regression toward the mean seems to have operated quite powerfully in this domain. The scatter shows that (ceteris paribus), countries with unusually high investment rates exhibited a decline over the period, while countries with unusually low rates exhibited an increase.

```
      0.          15.         30.         45.
       |===========|===========|===========|
  25.  |
       | C
       |      J
       |     C K
       |       A
       |       E   G
       |
       |         2 J
  10.  |    D  K   F2E
       |         2 2KA
       |        EF   A
       |    B  HC D2  JF 2
       |        B  BF  A
       |    J      HG   B
       |         2C      G      A
       |        B   D
  -5.  |        E   F   GE  F
       |                      H
       |
       |                      C
       |
       |
       |               C
       |
 -20.  |
       |===========|===========|===========|
      0.          15.         30.         45.
```

Investment Rate (1960) (X) vs Investment Rate Changes (1960-77) (Y)

The regression equation in this case has been fitted to seventeen-year changes in order to reduce the effect of measurement error and sluggish responsiveness on the overall measure of error variance. The results are presented in the following Figure:

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extreme outlier in the distribution, which is otherwise quite regular.

Figure 5

INVESTMENT RATE CHANGES, 1960-1977 (*)

	N	R**2
I{t} - I{t-1} = 11.0502 - .7842*I{t-1} (2.4479) (.1351) + 5.3056*[Q/P{t}-Q/P{t-1}]/[Q/P{t-1}] (1.6174) + 3.1372*[E{t}-E{t-1}]/I{t-1} (1.3612)	39	.63
I{t} - I{t-1} = 8.1247 - .5321*I{t-1} (3.3318) (.1524) + 6.2889*[Q/P{t}-Q/P{t-1}/[Q/P{t-1}] (1.1106) + 3.6924*[H{t}-H{t-1}]/I{t-1} (1.7719)	58	.59
I{t} - I{t-1} = 8.3445 - .6939*I{t-1} (6.9651) (.2568) + 5.3017*[Q/P{t}-Q/P{t-1}]/[Q/P{t-1}] (1.6369) + 2.1829*[H{t}-H{t-1}/I{t-1} + 3.0705*[E{t}-E{t-1}]/I{t-1} (5.2518) (1.3869)	39	.62

Variables Not Previously Defined

I = Investment rate

(*) Standard errors in parentheses beneath coefficients

The results suggest an important role for income change in the generation of investment rate change, and changes in the literacy rate have apparently had an impact as well. Although its effect is not statistically significant when it is incorporated along with literacy change in the equation, life expectancy change emerges impressively when literacy change is excluded. The literacy data are relatively sparse, and it should be noted that twenty degrees of freedom have been gained in the second equation. A fundamental ambiguity therefore remains. It is possible that multicollinearity is the culprit, but it also entirely possible that life expectancy change has no independent explanatory power.

As a conclusion to this section, it is worth noting that the use of seventeen-year changes in estimation throws the recursive assumption into doubt. Over this long a period, an upward-shifting investment rate would undoubtedly promote upward shifts in human resource variables, so that simultaneous causation (in a rather complex, second-order form) would create difficulties for the interpretation of regression coefficients. Although the long-period results will be used in subsequent simulation exercises, the possibility of some simultaneity bias in the coefficients of this particular equation must be borne in mind. Hopefully, future work can cast further light on this entire subject by recasting investment rate determination into explicitly structural form with allowances made for the contributions of public and private decision makers (both domestic and foreign), as well as the supply-side variables which have been utilized in this report.

III. MODELING POPULATION GROWTH

In the demographic part of this modeling exercise, the focus will be on the determination of two accumulation parameters -- the birth rate and the death rate -- whose difference is the population growth rate. Since these parameters join the investment rate as initial conditions in the determination of growth dynamics during a particular period, they are to be incorporated into the full model recursively. Our interest here will be in specifying a set of linear demographic models whose validity across countries will be tested in time difference form. In this case there are persuasive arguments for the use of the full seventeen-year period which is available for the measurement of time changes.

Appropriate models of birth and death rate determination should both allow for the representation of different age cohorts in the population. At the same time, their behavioral underpinnings differ in some important ways. The promotion of death rate decline is primarily a problem of education and institutional capacity, since the idea of a longer life span has undeniable universal appeal. Fertility, on the other hand, is significantly affected by explicit personal decisions. Once women have decided to bear fewer children, it is true that appropriate contraceptive supplies and institutional capacity can help in the translation of intent into result. The fact remains, however, that the decision (in most societies, at least) is essentially a family matter.

Thus, two sets of variables are necessary for a complete approach to the analysis of fertility rate changes. Some can plausibly be related to fertility decisions, while others have more to do with the provision of appropriate supplies and institutional capacity. Admittedly, some variables could be said to have effects which transcend this kind of dichotomy. "Appropriate" education, for example, can certainly aid women

who have decided to have fewer children; it can also be organized to play a persuasive role. In the specification which will be employed in this study, a variable is introduced which attempts to capture both effects.

Modeling Fertility Change

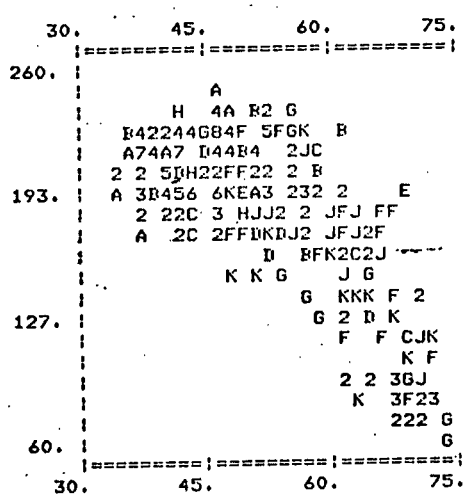
Obviously, the focus here must be on the fertility rate of women in the appropriate age cohorts rather than on the crude birth rate. It is only in the context of fertility rates that estimated behavioral coefficients can be readily interpreted. Fortunately, the available data permit the calculation of rough fertility measures across countries. For the years 1960, 1970, and 1977, age cohort estimates by sex have been taken from the UNESCO data file available to the World Bank. When the Bank's own estimated crude birth rates are divided by the proportions of women aged 15 to 49 in national populations, rough but serviceable national fertility rates are generated.

Once the translation from crude birth rates to fertility rates has been effected, some unavoidable complexities in modeling present themselves. As a prelude to their consideration, it is appropriate to begin with the variables which will be used to represent the inducement of attitudinal change and the role of institutional capacity in changing fertility rates. Since decisions concerning family size must be affected by survival expectations, the infant mortality rate or some proxy must be included. This "statistic" must vary with individual circumstances, so that no single family could be expected to have a very precise estimate of survival probability for its children. For the entire society, however, it would be reasonable to expect some intertemporal responsiveness, however sluggish, of the total fertility rate to measured life chances.

In the fertility model to be estimated in this section, the crude

death rate is used as the appropriate index of these life chances. The "dual" of the death rate is, of course, life expectancy. Because it is relatively unaffected by age cohort effects which could be removed from death rates in a multivariate analysis, the life expectancy measure is preferable for a simple illustration of nonlinearity in this context. Consider the following scatter diagram, which portrays the relationship between life expectancy and the fertility rate in a pooled sample for the years 1960, 1970, and 1977.

Figure 6



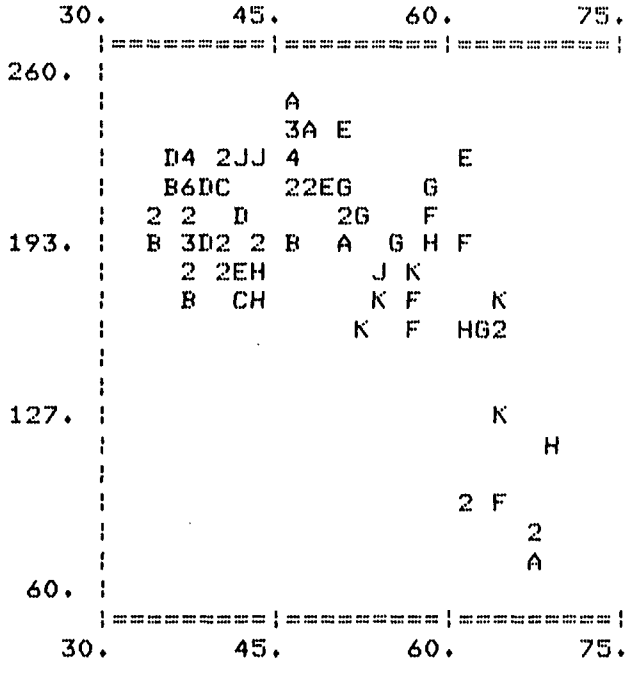
LIFE EXPECTANCY (X), VS. FERTILITY (Y), POOLED DATA

There is an evident threshold effect in these data, with the marginal relationship between life expectancy and total fertility becoming much steeper as the former moves above 50 years. Of course, this scatter may simply be masking a "true" relationship between the total fertility rate and some variable correlated with life expectancy such as per capita income. This possibility is, of course, the whole reason for doing multivariate analysis.

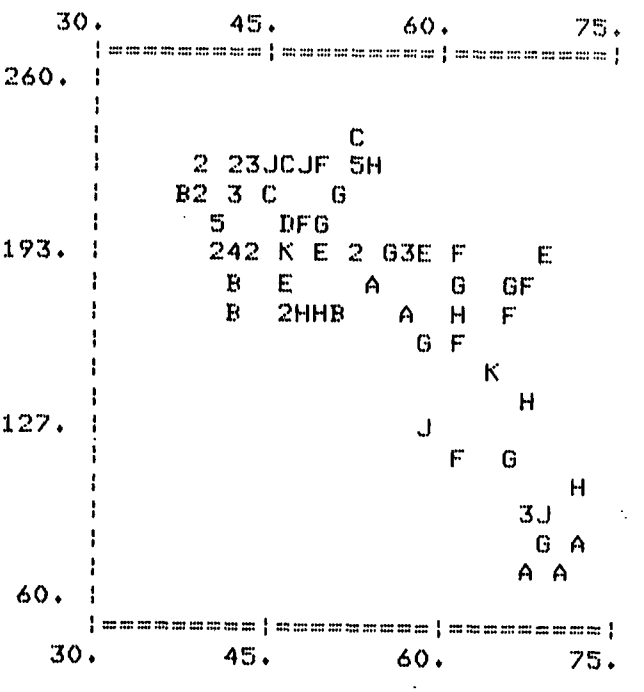
Nevertheless, the scatter diagram illustrates the kind of relationship which can only be captured by a nonlinear specification. This impression is enhanced if we look at the scatters for 1960, 1970, and 1977 as three "snapshots" of a process at work:

Figure 7

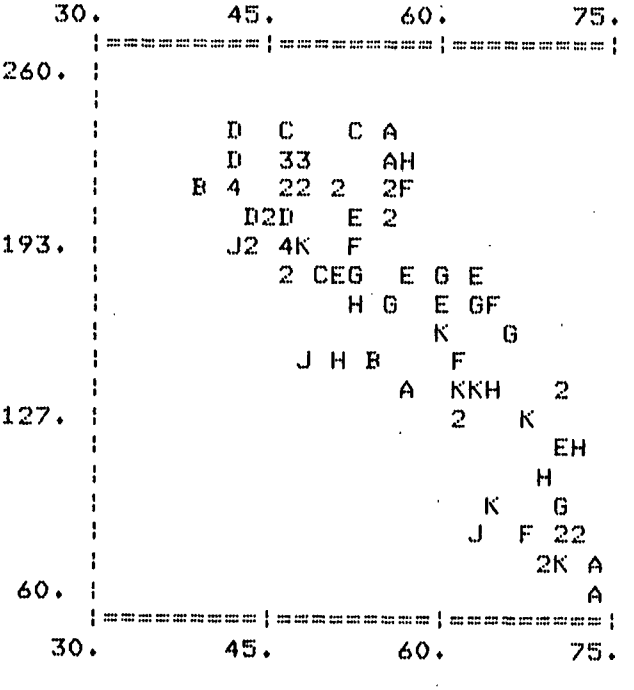
LIFE EXPECTANCY (X) VS FERTILITY (Y)



1960



1970



1977

In considering this sequence of pictures, it is difficult to avoid the feeling that all the societies are flowing over the same waterfall as time passes (20). Note that as the minimum life expectancy in the set increases during the two decades, fewer and fewer countries are upstream from the falls, and the point at which the plunge is taken remains relatively constant. With this as additional evidence, it would seem perfectly sensible to model the relationship between national changes in life expectancies and fertility rates nonlinearly. Although the simple bivariate relationship between death rates and fertility rates is not quite as clear because of complicating age cohort effects in older populations, the same principle obviously applies when these two variables are linked in a multivariate analysis.

If the infant mortality rate is the appropriate expectations-adjustment variable, other variables can be expected to play a role in the decision process itself. The negative relationship between per capita income and fertility across countries is well known. Numerous explanations for this phenomenon have been offered, but at some risk of oversimplification they might be summarized in the statement that the perceived opportunity cost of children seems to rise as family income increases. Part of this undoubtedly has to do with rising human resource investment costs, part with family fragmentation in association with urbanization and industrialization, and part may have to do with the related tendency of societies to shift the burden of retirement assurance from families to government as national wealth increases. Thus, per capita income serves as an index of a set of associated phenomena. It is useful to measure income change in scale-free form, so percent change in per

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(20) It may be this "waterfall" effect which was identified in Kirk (1974) with the attendant observation that the pace of fertility decline seems to have accelerated in poor countries during the past decade.

capita income is adopted as the appropriate measure.

If possible, it is desirable to complement the effects of the death rate and income with some measure of family planning effort in the fertility equation. The level of family planning activity is proxied with an index devised by Mauldin and Berelson after a detailed study of the experiences of many LDC's (21). Besides paying considerable attention to "appropriate education", this index is designed to give weight to institutional capacity, public support, and the provision of contraceptives. Although its scoring system is undoubtedly rather arbitrary in some respects, it is at least an attempt to quantify a complex phenomenon.

It should be noted that the Mauldin-Berelson index is not immune to the danger associated with the construction of any such performance index: It is difficult to be objective about relative effort when observations on performance have already been made. Thus, there is some risk that the Mauldin-Berelson index is actually a "residual." In addition, this index may measure a phenomenon which is determined simultaneously with the fertility rate. If it is true that enhanced family planning effort should yield some observable benefits over time, it may also be true that such efforts are only likely to become important in countries where the circumstances appear encouraging on other grounds. An explicitly simultaneous specification therefore seems advisable, and a separate equation explaining variations in planning activity must be specified as well.

Since it is desirable to estimate the fertility equation in time-difference form, the Mauldin-Berelson index introduces an additional complication. It is reasonable to suppose that all countries in the set

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(21) See Mauldin and Berelson (1977).

would have received a score near zero on this index in 1960. However, the same assumption would by no means be justified for 1970. Thus, the use of the M-B index forces a seventeen-year specification in changes. This form may well be reasonable on other grounds, since adjustments to changes in other model variables will certainly not be instantaneous. In addition, the use of a relatively long time interval should aid in reducing the relative effect of measurement error on regression results.

As noted in the introduction to this report, any consideration of fertility rates would be incomplete without an attempt to incorporate the impact of differential age cohort proportions across countries. In this study, three alternative specifications of cohort-specific variability have been evaluated econometrically. Although the mathematical details and the extended discussion of results have been relegated to Appendix C, the essence of the modeling approach and the final estimation results will be presented and discussed here.

It can be argued that all of the factors mentioned above should have some impact on the fertility rate of any female age cohort in a particular society. The scarcity of appropriate data, however, has prevented detailed econometric work on the degree to which the impacts differ across cohorts. In this study, an attempt has been made to approach this question as a set of specific hypotheses which can be tested econometrically.

Basically, the statistical "foil" employed is a model which allows variables to have different marginal impacts on the behavior of different age cohorts. With limited degrees of freedom it is difficult to incorporate more than a few such cohorts, and here the relevant female age group (taken to be in the range 15-49) has been divided into three subgroups (15-24, 25-34, and 35-49). The model in which all marginal impacts are allowed to vary by age cohort has been used as the basis for testing a substantially constrained model in which marginal impacts are

identical across cohorts but cohort-specific rates themselves are allowed to differ by a constant term. The test establishes that the equality constraints cannot be rejected, and Occam's razor has been employed in the choice of fertility rate model. In the final specification, the imposition of the marginal equality constraints generates a model in which simple differences in age cohort percentages enter additively along with the variables previously mentioned. The resulting equation fits the data on seventeen-year changes quite well, with all model variables passing the conventional test of significance (one-tailed).

As a complement to the fertility rate change equation, it has been necessary to introduce a second equation to explain the change in family planning activity across countries during the same period. One variable in this equation must be the change in the planning index itself (which is the same as the level in the mid-1970's under the assumption that all national scores were effectively zero in 1960). Another logical candidate would be some index of relevant institutional capacity. Among the available variables the secondary school enrollment ratio has been chosen as the most appropriate instrument, since it simultaneously measures a society's training of potential cadres and the sophistication of the institutional resources available.

In the following Figure, estimates for the final two-equation model of simultaneous determination are presented (22). As in the case of the output response equations, the technique of three-stage least squares has been employed in estimation. The econometric results are quite strong. Only changes in the female age cohort 25-34 had any apparent impact on the total fertility rate during the seventeen-year period, perhaps reflecting

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(22) A full list of intersection sample countries for the demographic equations is presented in Appendix H.

a world-wide upshift in age at marriage (23). This result has been cross-checked in several ways using alternative time-change and cross-section specifications, and the basic conclusion seems to hold up. Therefore, the only age-specific component which shows up in the final estimate for the fertility rate equation is the change in the percent representation of the age cohort previously mentioned.

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(23) The available data on age at marriage are simply too scanty to make their inclusion feasible in time-change regressions of the sort reported here. It is, however, possible to draw some conclusions about the direct impact of age at marriage on fertility using cross-section data. See Appendix D for a full discussion and cross-section results which incorporate age at marriage.

Figure 8

FERTILITY RATE CHANGE, 1960-1977 (*)

3SLS RESULTS

	N	R**2
F{t} - F{t-1} = 187.338*[W2534{t}-W2534{t-1}] (98.439) + 9.6361*[D{t}-D{t-1}] - .2470*[D{t}**2 - D{t-1}**2] (2.8309) (.0665) - 15.4159*[Q/P{t}-Q/P{t-1}]/[Q/P{t-1}] - 1.3122*PL (5.868) (.7308)	62	.76
PL = .3245*SEC - .1218*[F{t}-F{t-1}] (.0764) (.0295)	62	.73

Variables Not Previously Defined

W2534 = Women in age cohort 25-34 as a percentage of all women in age cohort 15-49
D = Crude death rate
PL = Mauldin-Berelson index of family planning activity
SEC = Secondary school enrollment ratio

(*) Standard errors in parentheses beneath coefficients

Modeling Changes in the Death Rate

As in the case of fertility rates, the death rate is a weighted average of age-specific effects. Again, the problem of degrees of freedom has intervened to force the use of a relatively limited number of age groups in the econometric work. For the present purposes it was decided that division into three groups (0-14,15-49,50+) would be sufficient. Alternative impact specifications were evaluated, and again the constrained model with equal marginal cohort impacts was compatible with the data.

It proved rather difficult to identify "non-deterministic" factors which seem to have had a significant impact on death rate changes. Only the availability of medical personnel as indexed by doctors per capita, among several plausible indices (See Appendix G for amplification), has a significant multivariate association with death rate changes between 1960 and 1977. A model which explicitly recognizes the presence of an autonomous component akin to "technical progress," along with changes in the population percentages of children and older people, accounts for about 72 percent of the variation in death rate changes in the sample for the period 1960-1977. The final equation estimate is presented below. The age cohort coefficients can be interpreted to mean that the constant additive component in the death rate attributable to these two vulnerable groups is about the same across the sample countries. As previously mentioned, the full set of results in the death rate equation suggests that the marginal impact of medical personnel is not significantly different across cohorts.

Figure 9

CRUDE DEATH RATE CHANGES, 1960-1977 (*)

	N	R**2
D{t} - D{t-1} = 6.6523 - 1.06705*D{t-1} + .0193*D{t-1}**2	64	.72
(1.6247) (.1949) (.0055)		
+ 2.4956E-5*M{t-1} + 19.3986*[Y{t}-Y{t-1}]		
(1.1442E-5) (8.37428)		
+ 19.8577*[O{t}-O{t-1}]		
(7.5606)		

Variables Not Previously Defined

Y = Children (1-15) as a percentage of the total population
O = Persons aged 50+ " " "

(*) Standard errors in parentheses beneath coefficients

IV. SIMULATING SOCIO-ECONOMIC DEVELOPMENT

In the first three sections of this report, a set of dynamic relations among output, population, and human resource variables has been specified and estimated econometrically. The results are useful in at least two ways. In the first place, they cast some light on the validity of certain hypotheses concerning the links between human resource development and the growth of per capita income. Secondly, they provide a measure of the relative impact of right-hand side variables in the structural equations. Such a measure is appropriate for policy discussion, since it is clear that response sensitivities vary considerably.

Although individual parameter estimates provide the essential foundation for empirical analysis in cases such as this one, the complexity of the system being modeled precludes any reduction of the dynamic equations to a simple set of multipliers. In such complex cases simulation is a natural tool for analysis. Estimated coefficients provide the measures of mean responsiveness which can be used for a simulation of dynamic behavior. It is unrealistic to expect that the future evolution of poor LDC's will exactly reflect the evolution of their slightly better-endowed counterparts in the immediate past. To the extent that the fitted equations account fairly well for observed behavior under reasonable causal hypotheses, however, they provide a more accurate and consistent basis for projection than casual observation.

We will begin our consideration of simulation in this context with an examination of the essential components of the model and the role which they will have to play in a whole-system exercise. The most fundamental distinction which must be drawn is between the elements which are ultimately endogenous and those which are exogenous. Endogenous variables are those whose future values will in the final analysis be determined by

the interaction of model equations. Exogenous variables, on the other hand, are those whose complete future time paths must be specified as a prerequisite for running the model at all.

While this distinction between variable types is certainly the most important one in the modeling exercise, there is another which is also quite significant. Not all variables which are "ultimately endogenous" in the sense defined above have been treated as endogenous in the econometric estimations reported in Chapters II and III. Recall that in many of the fitted equations, initial values of certain variables join lagged changes as "predetermined" variables in the identification of system coefficients. The use of the two-block structure (accumulation-response) reflects a recursive view of the growth process which has already been explained.

Thus, many of the variables which are predetermined in the econometric estimates will themselves change intertemporally as a simulation exercise joins the two equation blocks in dynamic interaction. With the distinction among "endogenous," "exogenous," and "predetermined" now firmly in mind, we can proceed to a discussion of the roles played by particular model variables in the simulation process.

The separation of model variables into categories corresponding to the terms used above depends upon a fundamental view of the world which has been built into the equation system. Basically, this view can be summarized as follows: It may be reasonable to regard public policy instruments as independent levers for influencing the future of a particular system. However, it is unreasonable to suppose that those instruments can be applied in any kind of a vacuum. History counts in the sense that the conditions prevailing in a society at any point in time will have important consequences for the future evolutionary possibilities of the system. A model which aspires to serious consideration must build in these initial conditions in a plausible way.

For convenience of exposition, all of the predetermined variables in the present model are presented along with the endogenous variables in Figure 10.

Figure 10

Predetermined Variables

Policy Variables	Initial Conditions
Medical Personnel	Birth Rate
Schooling	Death Rate
	Population
	Adult Population
	Investment Rate
	Nutrition Level
	Life Expectancy
	Literacy
	Per Capita Income

Endogenous Variables

Accumulation	Response
Population Change	Output Change
Capital Stock Change	Nutrition Change
Age Cohort Change	Literacy Change
Labor Force Change	Life Expectancy Change
	Family Planning

A glance at Figure 10 makes it obvious that our estimation exercise has produced a model whose data requirements are substantial. When the equations are fitted together, the resulting system requires initial values for a large number of variables as well as hypothesized future time paths for several policy variables. Although the list of variables is useful in separating them into intellectual categories, the precise way in which they will fit into the simulation model still warrants discussion.

A look back at the estimated equations will aid considerably here in determining the role played by different variables in the system. Perhaps the most useful way in which to discuss alternative roles is to identify the data which must be specified before a simulation model based on the estimated equations can even be run. Obviously, all of the truly exogenous variables such as policy instruments must be known. As for the rest, the best vehicle for organization may again be sequential consideration of blocks and equations.

In the response block, output growth determination depends on prior knowledge of the labor force growth rate and the growth of the capital stock. Evaluation of the nutrition equation depends upon prior knowledge of the initial level of nutrition, along with the growth rate of population. In the literacy equation, additional information requirements are imposed by the need for data on primary school enrollment ratios during the relevant period for the most recent adult age cohort. The growth rate of the adult population is also required for the evaluation of this equation. Finally, the life expectancy change equation depends upon the initial level of life expectancy, change in life expectancy during the preceding period, change in nutrition during the preceding period, and the initial levels of literacy, schooling, and medical personnel availability. If all of these data are known, then the response equations will generate contemporaneous changes in output, nutrition, and literacy. In addition,

life expectancy change can be calculated.

It is obvious that some of the prerequisite data for the response block are immediate products of the accumulation block. In this block, for example, the determination of the investment rate leads immediately to the capital stock change variable (capital stock change/initial output) which is used in the output change equation. This new investment rate, in turn, depends upon the investment rate in the preceding period and recent changes in per capita income and literacy.

The accumulation block is also the locus for the calculation of the population growth rate, which is the difference between the crude birth rate and the crude death rate. The crude birth rate can be calculated once we know the appropriate female age cohort percentage and recent changes in the death rate, per capita income, and family planning activities. Calculation of the death rate in turn depends upon the prior death rate, age cohort changes, and the availability of medical personnel.

The Model

With all this as prelude, it is now time to turn to the simulation equations themselves. Hopefully, the preceding discussion will have cleared the methodological thickets sufficiently to allow for a relatively clear view of the process being described. The "Closed Economy" model has been used as the foundation for the response block here.

The behavior of the model will be illustrated using data for a "typical" poor country and for hypothetical countries in Sub-Saharan Africa, South Asia, and South America. A series of experiments has been designed to gauge apparent trade-offs between physical and human resource investments. This section will describe the experiments and their

results, while a full description of the model and the solution technique has been included in Appendix E. The model in its current form is built around 10 estimated equations. Many additional equations have been necessary for appropriate variable definitions, the tracking of age cohort groups from birth to death, and other "housekeeping" functions.

Such a model-building effort can be justified if the result holds some promise of providing information which could not be gained by inspection of individual econometric results. In this case, there are simply too many such results for their total implication to be grasped through separate consideration. Rather than calculating a set of fixed multipliers, we are forced to conduct policy experiments with the knowledge that outcomes will be sensitive to initial conditions as well as on-going levels of public activity. Since the notion that "history matters" seems eminently sensible in any case, this indeterminacy should probably be regarded as a strength of the simulation approach.

Obviously, believable policy experiments must be founded on believable initial conditions in this case. Although it is certainly possible to construct a "typical" LDC from central tendencies in distributions of socio-economic data, it also seems advisable to allow for major regional differences by experimenting with typical poor-country data for different regions. For the present purposes, four sets of initial conditions have therefore been constructed. The numbers are broadly representative of the recent historical experiences of poor countries in the areas specified.

Figure 11

INITIAL CONDITIONS -- TYPICAL LDC CASES

	AFRICA	SOUTH AMERICA	SOUTH ASIA	"TYPICAL LDC"
Per Capita Income				
1960	50	210	60	180
1970	57.5	268.8	91.4	207
1977	63.8	330.4	96	227
Literacy Rate				
1960	10	39	15	29
1970	15	50	20	40
1977	20	63	21	55
Life Expectancy				
1960	37	43	44	46
1970	40	48	48	50
1977	42	52	51	54.5
Calorie Sufficiency				
1960	85	69	84	80
1970	78	76	94	82
1977	78	77	93	84.5
Birth Rate				
1960	49	48	49	47
1970	48	47	47	45
1977	44.5	40	44	39.1
Death Rate				
1960	27	23	23	20
1970	24	19	18	17
1977	20.2	16.6	16.5	13.8
Investment Rate				
1960	13	12.4	12.5	15.3
1970	14	18.8	19	18.4
1977	17.7	22.8	18	20.8
Primary School Enrollment Ratio				
1960	10	64	52	65
1970	40	80	69	76
1977	55	93	71	89
Population per Doctor				
1960	37706	8978	31076	8370
1970	32788	7014	20718	7600
1977	29220	5361	19299	7956

Some of the historical indices presented in Figure 11 above are quite different, while others (such as initial birth rates) are similar. While it might have been desirable to incorporate more variance into initial conditions for the sake of comparison, the interest here has been focused on an attempt to use numbers which are representative of regional conditions. With these numbers (and a large additional set of observations on other variables such as the GDP growth rate) as initial conditions, the full 43-equation simulation model has been run through a sequence of 7-year periods to the year 2026. The resulting baseline simulation has been used for comparison with the results of some policy experiments.

Briefly, it can be said that five illustrative simulations have been run for each LDC type. Two are intended to illustrate the consequences of educational policies which differ significantly from those represented by the baseline runs. The other three are an attempt to examine the implications of policies which allocate equivalent resources at the margin to physical investment, education, and family planning. No heroic claims of significance are made for any of these illustrative runs. Although an attempt has been made to use actual cost estimates wherever possible, the numbers are extremely rough (24).

The main purpose of the three trade-off experiments is to confront the central cost-benefit question: Granted that any physical or human resource investment is a "good", what can be said about relative marginal net benefits? In the generation of an appropriate response to this question, nothing less than a consideration of full system dynamics will do. The combination of econometrics and simulation attempted here, with all of its evident simplifications and weaknesses, is intended to provide

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(24) The cost estimates used in these trade-off exercises have been drawn from Burki and Voorhoeve (1977).

the foundation for a consistent answer. The results of the two simulation exercises are presented in the following Figures.

In the first set, the predicted consequences of three different approaches to education are examined. The LOW results reflect the predicted evolution of the hypothetical African and South Asian societies under the assumption that the primary school enrollment ratio is frozen at .20 and no family planning activity is undertaken. The schooling assumption is quite pessimistic, of course, since both societies have primary enrollment considerably above .20 at the present time. The intent is to examine the sensitivity of the model to sharp shifts in important policy variables as well as to predict the implication of a specific policy alternative.

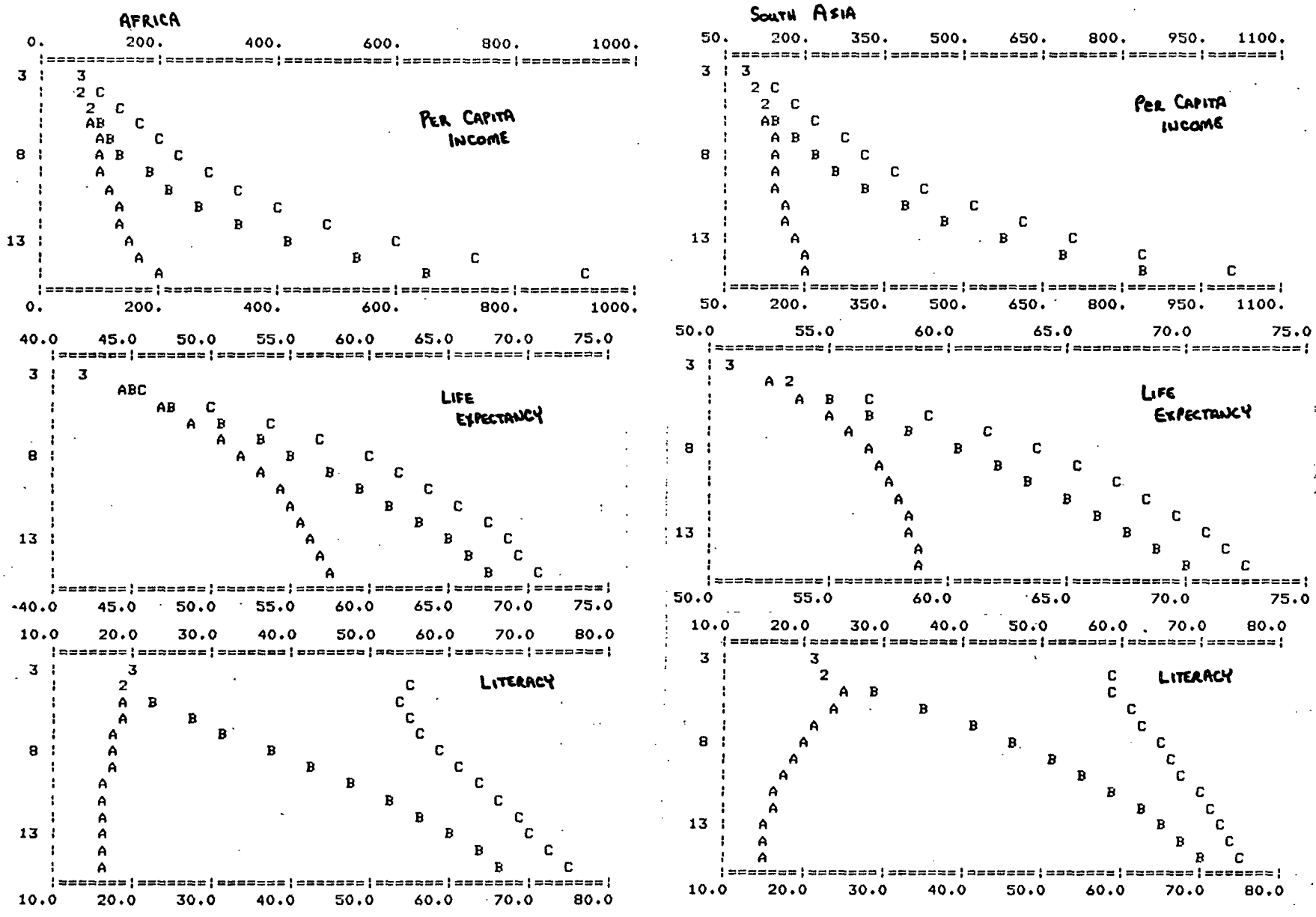
The MEDIUM simulation reflects the "normal" case which has been built into the model. Family planning is determined endogenously in this case. In each period, the primary school enrollment ratio is predicted using the results of a simple asymptotic regression fitted to cross-country data for the year 1977. In the HIGH simulation, the same model is employed, but the literacy rate is given an exogenous boost of 30 percent for the period 1977-1984.

In order for the impacts of these alternative assumptions to be clearly demonstrated, the three education simulations have been run through 12 simulation periods (or 84 hypothetical years). It would obviously be wrong to attach any significance to the final numbers produced by such long runs. Their advantage lies in the pattern of non-linear responses which they clearly illustrate. The excessive length of the simulations is useful in revealing some of the behavioral dynamics implied by the current structure of the model itself.

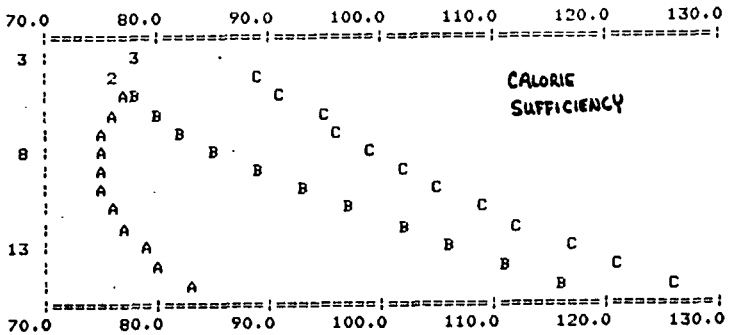
Figure 12

ALTERNATIVE EDUCATIONAL AND FAMILY PLANNING POLICIES:
SOME PREDICTED OUTCOMES

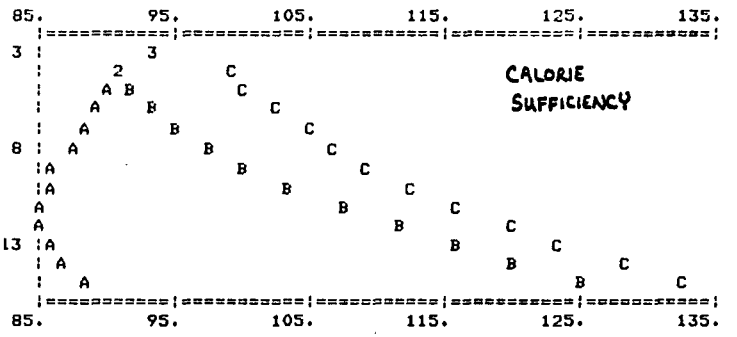
[A = LOW
B = MEDIUM
C = HIGH]

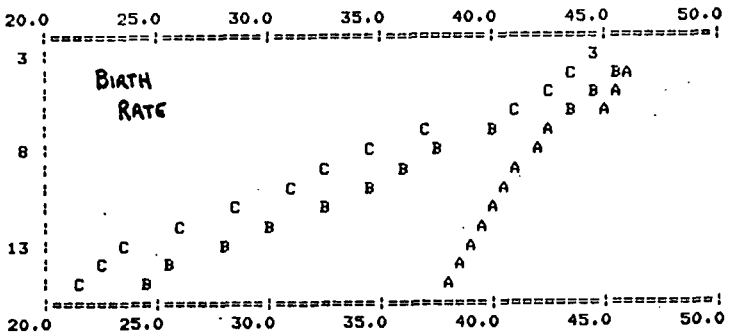


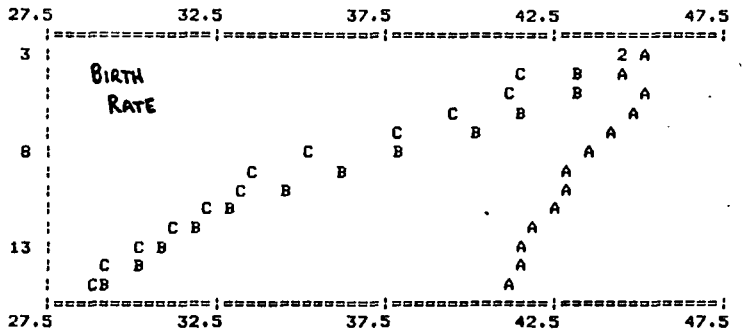
AFRICA



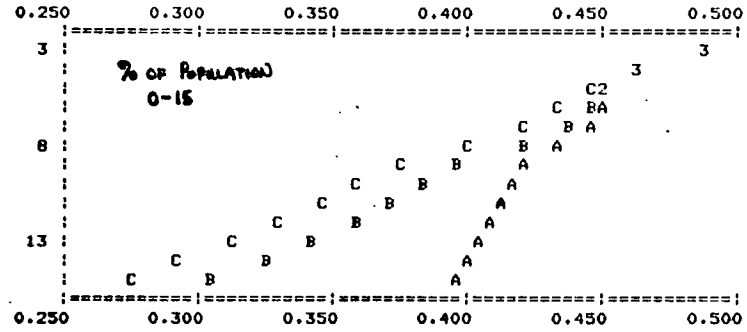
SOUTH ASIA

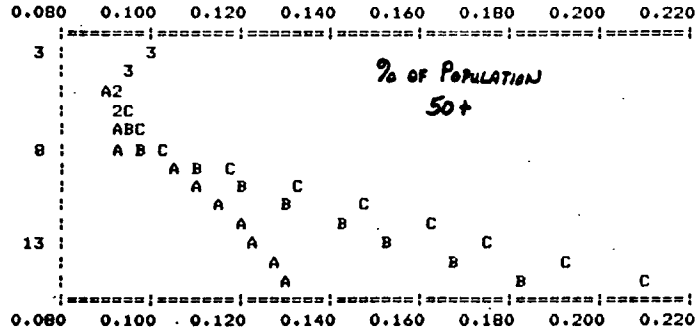




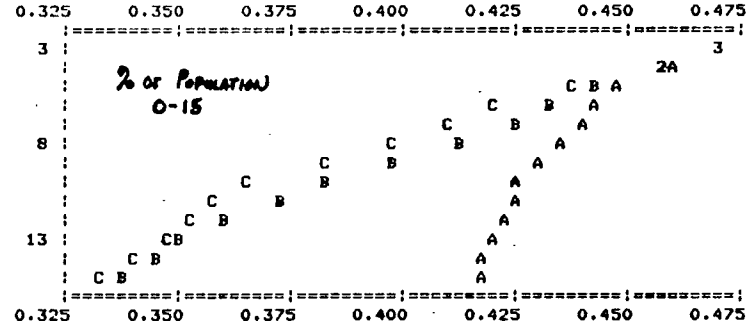


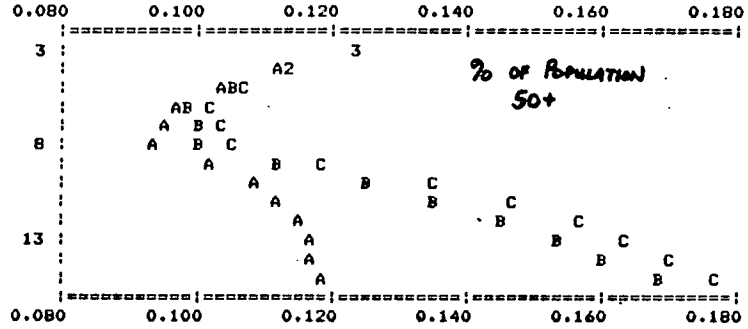
AFRICA





SOUTH ASIA





The time plots of simulation outcomes in Figure 12 reveal some of the implications of such drastically differing approaches to education. The dominant impression in both the African and South Asian cases is the persistent contrast between relative stagnation in the LOW cases and relatively rapid progress in the other two. The impact of the exogenous one-period boost in literacy is also quite striking. The model equations predict that this one shift will generate a time path which diverges substantially from that of the MEDIUM case for most of the crucial model variables. An interesting variation on this theme is provided by the growth of literacy, where inherently asymptotic behavior produces an apparent convergence for time paths in the MEDIUM and HIGH cases.

One advantage of the relatively complex approach to modeling taken in this report is that it allows for a comparison of outcomes along dimensions other than that provided by per capita income. The simulation plots also allow for a comparison of long-run outcomes in three other important determinants of the physical quality of life -- literacy, life expectancy, and nutrition. In the education simulation runs, relative stagnation in the LOW case is also apparent.

Given a basic understanding of the econometric equations which form the core of the model, it is not difficult to trace the reasons for the behavior predicted in these three cases. A sudden surge in literacy has three mutually-reinforcing effects. There are immediate responses predicted for the output growth rate and the investment rate. These reinforce one another in producing income gains, which in turn join with other variables in inducing gains in nutrition, health, and education. At the same time, the induced up-shift in the per capita income level produces a response in death rates and fertility rates. Although the effect of the death rate decline is perverse in the sense that the sluggish responsiveness of fertility to infant mortality changes yields a

positive impact on population growth, the direct impact of income change on the fertility rate has an additional important effect. The net effect of all these forces is a simultaneous upshift in the growth rate of output and a downshift in the growth rate of population. The advantage produced by the initial surge tends to persist through time, as indicated by the comparison with the MEDIUM case.

The relative stagnation apparent in the LOW case can be explained with reference to many of the phenomena mentioned above. With primary schooling frozen at a very low level, successive age cohorts arrive at adulthood with very low literacy rates. At the same time, no outlet is provided for family planning activity as an additional instrument for lowering the fertility rate. The cumulative impact of these two lapses is seen in a birth rate which is so persistently high as to overwhelm the prevailing death rate. In addition, the absence of the self-reinforcing dynamic interaction between output and education growth leaves the economy dependent on the increment provided by changes in the capital stock and the physical quantity of labor, rather than the quality of labor.

The final result of this relative stagnation in per capita income and human resource indices is a country whose population is much larger and much poorer (in per capita terms) than that predicted by the MEDIUM and HIGH cases. The exponential nature of the accumulation parameters produces a long-run aggregate GDP which is larger for the MEDIUM and HIGH cases.

Since the simulation model which has been used to produce these results is quite detailed, it produces time paths for many more variables than those which have been mentioned in this illustrative discussion. As one further example of the workings of the model, it may be useful to consider the evolution of population age structure predicted by its demographic component. For this reason additional simulation plots have

been produced for the population proportions of the groups aged (1-15) and (50+). Here again the apparent evolution is a logical result of the economic and demographic dynamics previously described. As fertility rates and death rates both decline, the population gets relatively older. This phenomenon is reflected, both in the plunge in the proportion of children in the population and in the relatively rapid rise in the oldest age cohort. Some additional complexities are introduced by a mild reversal of the death rate as the older age cohort becomes more dominant in the population and by a mild inflection in the progressive decline of the fertility rate as the relative size of the cohort aged (25-34) increases and then decreases again.

The contrasting simulations reported here are not intended to provide a full illustration of the behavioral dynamics of the model, nor do they provide more than a very partial view of the kinds of behavior predicted by the model under alternative assumptions about initial conditions and public policies. They do suggest that the model as specified and estimated accords a very powerful role to both education and family planning activities in the determination of long-run social and economic outcomes.

From the perspective of public policy analysis, it is of course insufficient to use an apparently powerful impact to justify increased investment in schooling or family planning activities. A consideration of the significance of simulation outcomes must depend on some consideration of relative marginal net benefits, whenever this is possible. A logical alternative to the use of public resources for the promotion of human resources would be their diversion to physical investment. Since an augmented investment rate would increase the growth rate of output, with subsequent impacts on income, human resources, and fertility, it might well be argued that the best approach to the human resource problem is an

augmented growth rate of the capital stock (25).

It is apparent that this kind of debate can be resolved only through a modeling approach which is at least akin to that taken in this project. Because initial conditions clearly count, the way in which resource-equivalent policy interventions occur should have consequences for final outcomes. At the same time, a consideration of marginal net benefits must take dynamic relations explicitly into account. A policy which moves resources directly into physical investment will have an immediate impact on per capita income and visible short-run impacts on other socio-economic variables as the effect of enhanced family income spreads through the system.

Investments in human resources, by contrast, will have general impacts which become apparent over longer periods of time. An expansion of primary enrollments in the 1980's will begin to have a visible impact on socio-economic outcomes during the succeeding decade, as more literate adults join the labor force and make decisions about optimal family size. An intensification of family planning activity might well take even longer to demonstrate its full effect, since the impact of a permanently-lowered

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(25) Discussions of the trade-off between equity and efficiency in this context have encountered difficulty in drawing a precise line between "consumption" and "investment." If the social objective function is expanded to include literacy, health, and nutrition, of course, the very notion of "investment" probably has to be overhauled. Some earlier studies have attempted to examine the question of trade-offs at the aggregate level in a dynamic context. Among economists, notable efforts are due to Ahluwalia and Chenery (1974) and Adelman and Morris (1973). In work which preceded the current effort (Wheeler, 1980), I attempted a simpler set of simultaneous estimates for the 1960's with some attendant benefit-cost analysis.

As could be expected, the work by economists has tended to give short shrift to demographic problems. Among demographers, the opposite tendency has prevailed. Several efforts to model long-run demographic reactions to economic change have been attempted, with little explicit attention given to the economic growth model. The first major work of this type was attempted by Coale and Hoover (1958). For a more recent effort see Dyson, et. al. (1978).

fertility rate on the evolution of per capita income would only become apparent after a succession of smaller age cohort groups had passed into the system.

For all of the reasons just cited, it is difficult to consider policy experiments in this context without the introduction of much disagreeable complexity. Different policies will generate different time paths, not just for per capita incomes but for other variables which are important in determining the physical quality of life (PQLI). Some investments have longer gestation periods than others as well, and again this fact applies to the evolution of PQLI variables as well as per capita income. Thus, trade-off experiments of the type proposed here cannot yield unambiguous conclusions unless the results of one policy dominate the results of others absolutely and at every future point in time.

With this fundamental point in mind, the trade-off simulation results presented in the following Figure are specified as relative rankings at the end of each 7-year simulation period (26). It is clear that relative rankings can shift through time, and that slow starters do not necessarily lose the race. In such long-run processes, of course, entire lives can be lived as the race proceeds and the question of an appropriate discount rate must intrude. If, as some have argued, the long-run social discount rate for an entire society should be zero in such cases, then endurance should always be given precedence over speed in the judgment of final outcomes.

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(26) It is, of course, difficult to evaluate the simulation experiment without some knowledge of the calculations which have been employed to produce value-equivalent activities. A complete accounting of these calculations is given in Appendix F.

Figure 13

TRADE-OFF RESULTS

AFRICA

	Investment	School	Planning
Income			
1984	1	2	2
1991	1	2	3
1998	2	1	3
2005	2	1	3
2012	3	1	2
2019	3	2	1
2026	2	3	1
Literacy			
1984	1	2	2
1991	2	1	3
1998	2	1	3
2005	2	1	3
2012	2	1	3
2019	2	1	3
2026	2	1	3
Life Expectancy			
1984	1	2	3
1998	2	1	3
2005	2	1	3
2012	2	1	3
2019	2	1	3
2026	2	1	3
Nutrition			
1984	1	2	2
1991	1	2	3
1998	3	1	2
2005	3	1	2
2012	3	1	2
2019	3	2	1
2026	3	2	1

South America

	Investment	School	Planning
Income			
1984	1	2	2
1991	2	1	3
1998	2	1	3
2005	2	1	3
2012	2	1	3
2019	2	1	3
2026	3	1	2
Literacy			
1984	1	2	2
1991	2	1	3
1998	2	1	3
2005	2	1	3
2012	3	1	2
2019	3	1	2
2026	3	1	2
Life Expectancy			
1984	2	1	3
1991	2	1	3
1998	2	1	3
2005	2	1	3
2012	2	1	3
2019	2	1	3
2026	2	1	3
Nutrition			
1984	1	2	2
1991	2	1	3
1998	2	1	3
2005	2	1	3
2012	2	1	3
2019	2	1	3
2026	2	1	3

Figure 13 presents the trade-off simulation results for the African and South American cases. These two have been employed as contrasts, since a glance back at initial conditions will reveal that the two cases are in most respects quite different. An intertemporal time path of relative ranking is provided for per capita income, literacy, life expectancy, and nutrition. For each case, the same basic experiment has been run. In the Investment simulation, the investment rate has been autonomously increased by 1 percent of GDP for one 7-year simulation period. For School, equivalent resources are devoted to increasing the primary school enrollment ratio during the same 7-year period, using World Bank estimates of recurrent cost for personnel, materials, and overhead by world region.

Since cost estimates for typical family planning programs are unavailable, the Planning simulation is based on a different approach. From World Bank estimates of the cost of training basic community health teams, the number of teams has been calculated for an expenditure equal to the original investment increment. The resulting number has then been divided into the number of females of child-bearing age in each hypothetical country to produce ratios of "target" females to community health personnel. In no case was the result greater than 200 fertile-age women per 3-person team.

Under these assumptions, it seems reasonable to suppose that such an expansion of community health workers would represent an effort equivalent to a Mauldin-Berelson score of at least 3 (their maximum index score is 30). In the African case, a one-period increase of 3 in the M-B index is sufficient to produce a per capita income higher than that produced by the one-period direct investment alternative. In the South Amerian case, an increase of only 2 is sufficient to produce the same effect. The simulation results reported have been generated by these "lower bound"

increases. In view of the apparent possibilities for population coverage associated with resource increments of the magnitude considered, it is entirely possible that the suggested one-period impacts on the family planning index are conservative. In any case, the intertemporal results for per capita income and the PQLI variables have been included.

The pattern of intertemporal fluctuation in rankings for Africa makes it obvious that any policy conclusions cannot be divorced from explicit valuation of PQLI outcomes, as well as a discount rate. Except for an intermediate period in which the School variant dominates absolutely, there are no clear winners in this experiment. During the first periods, the results of the Investment and School simulations exhibit approximate parity, while the balance shifts from Investment to Planning in later periods. Since the assumptions underlying the Planning simulation may well be overly conservative, the balance might be expected to shift sooner than this particular experiment would indicate.

In the South American case, the final judgment can be made with more certainty. In all but the first period, the School result dominates absolutely. Again, however, the same evolutionary pattern is evident in the rankings for the other variants. During the first periods, Investment clearly dominates, but Planning has overtaken it in two categories by the final period.

Certainly, the set of illustrations presented here provides no conclusive evidence concerning the trade-offs which would be confronted by policy-makers in actual cases. Although careful attempts have been made to estimate the parameters of all model equations in appropriate ways, the simulation results are inevitably sensitive to the specifications which have been adopted. In the final analysis, the conclusion which emerges from the simulation seems sensible, however. In brief summary, this conclusion might be stated as follows.

There can be no definitive statements about which of a set of hypothetical resource allocations is absolutely superior. Initial conditions will create different short-run marginal productivities, and the long-run consequences of alternative policies may well be quite different than their short-run results. In its current form, the simulation model illustrates these lessons without necessarily providing a definite basis for analysis in particular national cases. It is true that the initial conditions for a particular society could be used along with alternative policies for specific predictions. Since the non-availability of appropriate data has greatly handicapped the construction of such models in the past, the predictions yielded by this model could provide a useful basis for discussion concerning apparent future trends. In the final analysis, however, the model in its current form still contains too many simplifications for any great confidence to be placed in its predictions.

APPENDIX A

SIMULTANEOUS ESTIMATION OF THE RESPONSE EQUATIONS: PROBLEMS OF SPECIFICATION AND MEASUREMENT

1) Data Scarcity and Model Specification

It would be incorrect to assert that no empirical work has focused on the effects of basic human resource development on productivity across countries in the 1970's. Some analysts have done cross-section studies of the intercorrelation among measures of economic performance, public policy decisions, and basic social indicators. Most of the published studies, however, are actually static exercises. That is, they attempt to draw inferences about causality within countries from data which have only been taken across countries. Since many socio-economic indices are roughly correlated, it is relatively easy to obtain good cross-section results which tempt the researcher to draw broad policy conclusions.

As any practicing econometrician who has worked in this area can affirm, unfortunately, cross-country correlation and within-country causality are definitely two different things. Characteristically, regression exercises which suggest high degrees of intercorrelation in cross-section lose most of their "explanatory power" when within-country changes are considered (27). And yet, this type of modeling exercise must in the final analysis be concerned with changes. Most professional

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(27) Recent work by Morawetz (1977) illustrates this phenomenon. Morawetz presents results for a large number of regressions relating indices of basic needs fulfillment to levels of per capita GNP. For 30 of 32 regressions run using levels for 1960 and 1970, a statistically significant relationship is evident. When changes (1960-1970) in basic needs indicators are regressed on changes in per capita GNP, however, only 5 of 16 regressions exhibit a significant relationship.

economists are unlikely to be persuaded by cross-section regressions estimated on levels alone.

It is precisely this necessary juxtaposition of simultaneity in modeling and time-changes in the data which makes the econometric problem so difficult in the present context. At the very least, for example, an appropriate growth model should be explicitly simultaneous in changes in output, nutrition, and education. Such a model would include indices for these three endogenous variables, as well as a relatively large set of predetermined variables. If all the data for all of the variables in question were available, there would be no problem. Unbiased, efficient estimates for the parameters of simultaneous equations can be obtained with the aid of systems estimation techniques such as three-stage least squares (28). Unfortunately, the spottiness of the data presents a severe problem.

The available World Bank data for 88 countries are focused on measured levels of various socio-economic indices at three points in time: 1960, 1970, and "the mid-70's" (1974 through 1977 in various individual cases). The most recent data are fairly plentiful, but there are still many gaps in the full 88-country matrix for the mid-1970's. As the data move back in time, they get spottier. The result is that measurable changes in key indices are rarer than corresponding levels. In a simultaneous model, many of the crucial changes must be taken from the same set of countries. Only the intersection of available measures counts. The size of this intersection diminishes steadily as the number of simultaneously-measured changes mounts, and the result can be disastrous for system-modeling techniques such as three-stage least

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(28) The classic discussions of three-stage least squares estimation can be found in Zellner and Theil (1962) and Madansky (1964).

squares.

Thus, reality once again presents the econometrician with a situation which has not been anticipated in the textbooks. The need for a simultaneous model and the need to measure model variables in changes are in clear conflict with one another here. For equations which are not explicitly part of the simultaneous system, simple linear equation techniques will suffice, and each equation can be fitted using the data which are needed only for it. To the extent that simultaneity is abandoned, degrees of freedom in estimation will be maximized for individual equations in the model. At the same time, the artificial decoupling of truly simultaneous relations will result in inconsistent parameter estimates in the equations in question. Since the spottiness of the data cannot be remedied, this problem cannot be avoided. Some compromise has therefore been unavoidable in model specification.

2) Measurement Problems

The data for this study have been drawn from 88 poor countries in Africa, Asia, Southern America, and Southern Europe. In most cases, the variables employed for estimation can only be defended as the best available. The input and output measures in the three human resource response equations are all national averages, so that substantial differences in distribution are masked by the data. This problem is apt to be more severe for the measurement of availability of medical personnel than for the other indices. Aggregative measures of population per doctor say nothing about differences in the length or efficacy of training programs or the geographical distribution of medical personnel within countries. Thus, this measure is not very satisfactory as an index of generalized access to medical care.

The measures of nutrition and education, on the other hand, may not be too bad. As a measure of nutritional status per capita calorie availability is a reasonable approximation. It is now generally accepted that calorie sufficiency is much more likely to indicate nutritional adequacy than any other index. At the same time, available microeconomic studies always show a rapid drop in the income elasticity of calorie consumption across income classes within countries, so that it is reasonable to link expansion in calorie consumption with increases in the nutritional status of the poor as per capita income rises (29). Among measures of the change in embodied basic education, the change in the adult literacy rate is undoubtedly the best available index.

The conventional economic indices in the study are subject to many of the usual strengths and weaknesses. The measured change in gross domestic product seems acceptable, aside from the usual index number problems. Similarly, the change in total population presents no particular problem. The way in which <dk> and <dl> are employed in the simple production model is unfortunately much less satisfactory. The use of percent changes in capital and labor in a production model incorporates the assumption of constant utilization of the available services. This is obviously wrong (and particularly so for labor in poor countries), but nothing can be done about it because reliable information on capacity utilization rates and unemployment rates for these countries simply does not exist.

In addition, the available labor force data seem to be very unreliable. As a result, the growth rate in the labor force in this report is indexed by the growth rate in the adult population. Although admittedly

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(29) Complete discussions of these and related issues can be found in Reutlinger and Selowsky (1975).

crude, this index at least is based on data which have been gathered with relative accuracy. It would be difficult to argue that it does not capture the dominating age cohort effect in labor force growth. At the same time, the use of percent changes in the model makes the implicit exclusion of the labor force participation rate much less damaging, since it is likely to remain relatively constant over short periods and therefore washes out of a percent change measure.

An additional complication is introduced by the complete non-availability of reliable and comparable capital stock figures for these countries, so that it is impossible to obtain direct measures of percent changes for the period 1970-1977. Available data on yearly investment and output do allow for estimation under the assumption (admittedly heroic) that the general capital-output ratio for the countries in question did not change significantly during the estimation periods. Some manipulation of the production model yields:

$$[dQ/dt]/Q\{o\} = [dA/dt]/A\{o\} + g11*[Q\{o\}/K\{o\}]*[(dK/dt)/Q\{o\}] + g12*[dL'/dt]/L'\{o\}$$

or

$$(2) \quad \langle dq\rangle = \langle dA\rangle + g11*[(Q/K)*\langle dk\rangle] + g12*\langle dl'\rangle$$

where

Q = Output
A = An appropriate index of technical progress
K = Capital
L = Labor
<dq>,<dk>= As previously defined
<dA> = Percent change in technical progress index
<dl'> = Percent change in effective (augmented) labor
{o} = Initial period

Since we can observe [(dK/dt)/Q{o}], estimation with some unknown degree of bias is possible. It is comforting to note that the mean

capital output ratio must be somewhere in the range (2-5) and the combined output elasticities for capital and effective labor can be somewhat greater than one at most, so the econometric results must conform to certain obvious restrictions.

3) Output Modeling in a Simultaneous Context

In modeling the production process, it is necessary to give simultaneous attention to the roles of factor-augmenting inputs and to the roles of effective capital and labor in determining output. In the determination of effective labor, the contribution of nutrition is assumed to be characterized by unitary elasticity of substitution. The contribution of education, on the other hand, is specified log-linearly. The partial equation for augmented labor is as follows (30).

(3) L'{t} = L{t} * (N{t}**b1) * exp(E{t}*b2)

where L = Labor
L' = Augmented Labor
N = An appropriate measure of nutrition per worker
E = An appropriate measure of basic education per worker
{t} = Time subscript

Two alternative specifications of the production function have been

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(30) The symbol ** denotes exponentiation in this report.

considered:

(4a) Augmented CES:

```
Q{t} = A{t} * [a*(K{t}**p) + (1-a)*(L'{t}**p) ]**(1/p)
```

where A = An index of technical progress
K = Capital
a,p = CES parameters
Q = Output

(4b) Augmented Cobb-Douglas:

```
Q{t} = A{t} * (K{t}**g1) * (L'{t}**g2)
```

Empirical testing has yielded the conclusion that (4a) is not significantly better than (4b) as a representation of production in this case. Thus, production is assumed to exhibit the following behavior throughout:

```
(5) Q{t} = A{t} * (K{t}**g1)
        * [ L{t}*(N{t}**b1) * exp(E{t}*b2) ]**g2
```

Here g1 and g2 can be interpreted as the output elasticities of capital and effective labor, while the b's are labor-augmenting parameters for nutrition and education.

Equation (5) would be appropriate for estimation if time series for a single country were being considered. In this case, however, only two primary observations (for 1970 and the mid-'70's) are available for each

country in the sample, along with one additional set of past observations (for 1960). The model must therefore be specified to reflect the consequences of single-period changes across countries. The time derivative of (5) is used as the production equation.

(6) $\langle dq \rangle = \langle dA \rangle + g1*\langle dk \rangle + g2*\langle dl \rangle + g2*b1*\langle dn \rangle + g2*b2*\langle de \rangle$

where $\langle dx \rangle = [dX\{t\}/dt]/X\{t\}$

This equation is linear in percent changes, with the exception of the literacy component (which is linear in changes). For compatibility, identical change specifications have been imposed on the social indicator equations (31). The health and nutrition equations are relatively self-explanatory. Since the literacy equation has been specified appropriately in absolute changes, however, it requires a little more attention. The functional form employed here follows directly from an explicit specification of the process of "literacy production."

The variable which is basically of interest in this context is the number of literate adult labor force members. Some of these adults may well educate themselves, and we would expect the demand for self-education (or for commercial forms of adult instruction) to be positively related to per capita income. For the vast majority of adults, however, literacy will have come about as a result of primary schooling.

For two time periods ({t} and {t-1}), then, we can model the

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(31) It should be noted that although factors have been identified as capital- or labor-augmenting in the discussion of specification, they are indistinguishable from "neutral" sources of technical change in the Cobb-Douglas specification.

increase in the number of literate adults as:

(7) $LAD\{t\} - LAD\{t-1\} = Pr(E)*S*[AD\{t\} - AD\{t-1\}]$

where

LAD = Number of Literate adults
AD = Number of Adults
S = Primary school enrollment ratio during the period when the adult age cohort received primary schooling
Pr(E) = Probability that some experience of schooling results in literacy

We know that the adult literacy rate is equal to the ratio (LAD/AD). Some mathematical manipulation therefore gives us the following relationship:

(8) $E\{t\} - E\{t-1\}*[1/(1+\langle da\rangle) = Pr(E)*S*[\langle da\rangle/(1+\langle da\rangle)]$

where

E = The adult literacy rate
<da> = Percent change in the adult population from {t-1} to t

APPENDIX B

LITERACY AND PRODUCTIVITY: A TWO-EQUATION MODEL

The response equations estimated for this report have all incorporated the change in calories consumed as a conplement to literacy change in the determination of intraperiod output change. As noted in Chapter II, the nutrition results are rendered ambiguous by the possibility that they measure the efficiency impact of differential agricultural growth as well as the impact of nutritional improvement.

One possible response to this ambiguity could be an arbitrary rejection of the calorie consumption measure as a valid component of the output equation. If nutrition were excluded, the resulting growth model would identify basic education as the only contributor to productivity growth. In the following Figure, results for an education-augmenting growth model are presented. Although only the output equation results are presented, all three-stage estimates have been produced in association with a literacy change equation identical to the one employed previously.

It is clear that the exclusion of nutrition change from the output equation has no real consequence for the remaining estimates. Again, the estimated effect of literacy change in the output equation exhibits an apparent decline between the first and second decades. Although the 95 percent confidence intervals for the two estimates overlap slightly, it may well be that the impact of reported literacy change has declined.

It is not clear, of course, that the true impact of literacy has declined. During the decade of the seventies, a general enthusiasm for rapid human resource development may have led to widespread optimism in national self-evaluation of educational performance. As previously

mentioned, Tanzania and Somalia have been excluded from all estimates because the reported impacts of their adult literacy campaigns seem neither plausible nor appropriate as measures of the kind of educational achievement which is of interest here. In any case, the results in all three sets of estimates are again consistent with the hypothesis that basic education has a significant impact on productivity.

Figure 15

LITERACY AND PRODUCTIVITY CHANGE:

A TWO-EQUATION MODEL (*)

1960-1970 (**)

	N	R**2
<dq> = .0147 + .161*<dk> + .222*<dl> + .0254*[E{t}-E{t-1}]	40	.37
(.1278) (.030) (.341) (.0055)		

1970-1977

<dq> = -.0855 + .187*<dk> + .498*<dl> + .0080*[E[t}-E{t-1}]	44	.47
(.0798) (.037) (.342) (.0041)		

Pooled Data

<dq> = [.006 - .069*D70] + .168*<dk> + .346*<dl> + .018*[E{t}-E{t-1}]	82	.54
(.087) (.044) (.022) (.237) (.0041)		

(*) Standard errors in parentheses beneath coefficients
(**) Each of the three equations presented below has been estimated by three-stage least squares along with the literacy change equation whose specification has been seen several times. Since the results for the second equations are essentially identical with those for previous models, they have not been included here.

APPENDIX C

AGE COHORTS IN DEMOGRAPHIC CHANGE EQUATIONS

In the discussion of fertility and death rate determination which absorbed Chapter III of this report, a relatively simple model of age-cohort impact was specified and estimated. Although mention was made of more intricate models, a full discussion was deferred to this Appendix in the interest of readability.

At first, it may seem illusory to suppose that the differential impacts of causal variables across age cohorts can be estimated without cohort-specific data. While it is true that the absence of such data prevents the specification and estimation of completely general models, it is certainly possible to use the available numbers to good effect. The key to this possibility lies in the fact that the total fertility rate and the crude death rate are weighted averages of age-specific rates. A brief mathematical development can be used to show that cohort-specific sensitivities can be measured once a model of responsiveness has been imposed. Although either accumulation parameter could be employed for the demonstration, the fertility rate will be used here.

We will define the total fertility rate as:

$$(9) \quad F = (W1/W)*f1 + (W2/W)*f2 + \ldots + (Wn/W)*fn$$

where

F = Total fertility rate
Wk = Number of women in fertile age cohort k
W = Total women of child-bearing age
fk = Fertility rate of women in age cohort k

We are in possession of crude birth rates from World Bank data and age cohort estimates from United Nations data, but we lack cohort-specific fertility rates. This sort of problem is not uncommon in econometrics. The standard

response is to replace the unknown with its known determinants in a mathematically-specified relationship whose parameters can be estimated.

In order to develop some plausible fertility determination models, we will suppose initially that fertility in each age cohort responds to one variable, X. In addition, we will lend flexibility to the model by supposing that the marginal effect of X differs across cohorts. Thus, for the kth cohort, we would have a simple linear model of fertility determination:

$$(10)\quad fk = ak1 + ak2 * X + uk$$

where uk is a random, additive error term and the ak's are parameters

If we substitute into the expression for the total fertility rate, we obtain:

$$\begin{aligned}(11)\quad F &= (W1/W)*[a11 + a12*X + u1] + (W2/W)*[a21 + a22*X + u2] \\ &\quad + \ldots + (Wn/W)*[an1 + an2*X + un] \\ &= a11*(W1/W) + a12*(W1/W)*X + a21*(W2/W) + a22*(W2/W)*X \\ &\quad + \ldots + an1*(Wn/W) + an2*(Wn/W)*X \\ &\quad + [u1*(W1/W) + \ldots + un*(Wn/W)]\end{aligned}$$

Since it is clear that W = W1 + ... + Wn, the above reduces to:

$$\begin{aligned}(12)\quad F &= (a11-an1)*(W1/W) + (a12-an2)*(W1/W)*X \\ &\quad + (a21-an1)*(W2/W) + (a22-an2)*(W2/W)*X + \ldots \\ &\quad + an1 + an2*X + e\end{aligned}$$

where e = the additive sum of weighted error terms previously specified

An unconstrained linear model which allows X to have a differential impact

across age cohorts will be specified as (12) above. This model can usefully be contrasted with a simpler version, which constrains all marginal impacts of X to be equal:

(13a) $a12 = a22 = \ldots = an2$

All difference coefficients of X-terms in the former equation become zero in this constrained specification, and we have:

(13b) $F = (a11-an1)*(W1/W) + (a21-an1)*(W2/W) + \ldots$

$+ an1 + an2*X + e$

The constrained and unconstrained versions of the linear model can be compared statistically. With multiple age cohorts and several causal variables, it is clear that the number of right-hand terms in the unconstrained version of this model is likely to be burdensome. A statistical test on the multiple coefficient constraints implied by the simple version of the model is therefore appealing. If the simple linear model cannot be rejected statistically, we are bound to gain precision in estimation by adopting it.

The two models of cohort-specific determination proposed thus far incorporate assumptions about responsiveness which are at opposite extremes. In the unconstrained version, estimated marginal impacts are left completely free to vary as the data dictate. In the constrained version, they are all forced to equality. It is also possible to specify an intermediate alternative which accords some flexibility to coefficient estimates without sacrificing degrees of freedom. Instead of constraining all marginal coefficients to be equal, this intermediate form imposes a constant multiplicative relationship across cohorts. Thus:

$$(14)\quad F = (W1/W)*f1 + (W2/W)*f2 + \ldots + (Wn/W)*fn$$
$$= (W1/W)*f1 + (W2/W)*c2*f1 + \ldots + (Wn/W)*cn*f1$$

where the c's are taken to be unvarying multiplicative constants

With age cohort relationships specified in stochastic form as before (and noting that the female age cohort ratios sum to 1), we have:

$$(15)\quad F = (W1/W)*[a11 + a12*X] + \ldots + (Wn/W)*cn*[a11 + a12*X] + e$$
$$= [cn + (1-cn)*(W1/W) + (c2-cn)*(W2/W) + \ldots] * [a11 + a12*X] + e$$

This intermediate model is nonlinear in the parameters, but it can be estimated using maximum likelihood methods.

Some Comparative Estimates

The discussion in the first part of this Appendix was focused on the problem of estimating differential marginal impacts across age cohort groups for fertility rates. It is clear that exactly the same reasoning could be applied to the design of cohort-sensitive death rate models. In this section, the models developed previously will be compared statistically for fertility rates and death rates, using cross-section data for 1977. In each case, the variables employed are those which are already familiar from the difference equations presented in Chapter III.

Fertility Estimates

In the fertility equations, the total fertility rate (F) across countries

is related to data on family planning activity (PL), the crude death rate (D), per capita income (Q/P), and three age cohorts for childbearing females (W1524,W2534,W3549). Since the three age cohort percentages sum to one, W3549 has been selected as the residual percentage.

All three models developed in the previous section have been estimated using the same data. The results are presented in the following Figure:

Figure 16

COMPARATIVE RESULTS - FERTILITY EQUATIONS (*)

Linear Unconstrained Model

```
F = -942.688 - 8.2886*PL - 4.9425*D + 2.2174*D**2 + .83249*(Q/P)
    (1833.27) (25.0729)    (221.7)      (7.20)         (.8099)

  + 2192.44*W1524 + 8.9219*PL*W1524 - 57.985*D*W1524 - .3824*D**2*W1524
   (2397.65)          (32.62)           (270.2)             (8.34)

   - 1.5604*(Q/P)*W1524 + 227.466*W2534 + 9.6382*PL*W2534 + 159.22*D*W2534
    (1.369)               (4060.1)         (55.18)             (497.8)

   - 8.501*D**2*W2534 - .6227*(Q/P)*W2534
    (16.40)             (1.162)
```

N = 65 R**2 = .85 SSR = 13613.2 F(14/50) = 26.1

Constrained Linear Model

```
F = -560.866 + 982.780*W1524 + 706.839*W2534 - 1.7762*PL
   (108.718) (131.328)        (217.582)          (.4713)

     + 15.9139*D - .3897*D**2 - .01402*(Q/P)
       (3.017)     (.0919)       (.0114)
```

N = 65 R**2 = .86 SSR = 14431.7 F(6/58) = 66.1

Nonlinear Model

```
F = [ -1.520 + 3.555*W1524 + 2.576*W2534 ]
      (.597)   (1.212)        (1.212)

          * [ 98.312 - 2.4192*PL + 19.963*D - .4824*D**2 - .0216*(Q/P) ]
              (.7322)  (.6268)      (10.418)  (.2723)        (.0134)
```

N = 65 R**2 = .84 SSR = 15857.8

(*) Standard errors in parentheses beneath coefficients

The results in Figure 16 indicate that the more complex models do not make a significant marginal contribution to the explanation of fertility rate differentials. The unconstrained linear model is obviously plagued by multicollinearity, and individual estimates seem to wander randomly. An application of the standard F-test yields the conclusion that the full set of constraints implied by the hypothesis of equal marginal impacts cannot be rejected (The small increase in the sum of squared residuals makes this an obvious result). At the same time, all available measures of goodness of fit (R**2, SSR) suggest that the constrained linear model fits better than its nonlinear counterpart.

Certainly, the experiments undertaken here do not exhaust the econometric possibilities which could be considered if actual cohort-specific fertility data were available. In the absence of such data, it has still been possible to compare three different models of responsiveness. The statistical evidence points toward the provisional acceptance of the simplest model, which imposes equal marginal impacts of causal variables on cohort-specific fertility rates. It should be noted that the results still suggest constant cohort-specific differences.

Death Rate Estimates

The crude death rate and the total fertility rate for a population are similar in the sense that both are weighted averages of cohort-specific rates. Thus, the theoretical development of three comparative models of fertility rate determination can be essentially replicated in the case of the death rate. Again, cross-section data for 1977 have been employed in the comparative analysis. The regression equations have been fitted using the variables which proved to have a significant association with death rate changes in a cross section of time

differences. The results are presented in the following Figure.

Figure 17

COMPARATIVE RESULTS - DEATH RATE EQUATIONS (*)

Linear Unconstrained Model

```
D = -16.692 + 6.782E-4*M + 53.512*Y - 7.99E-4*Y*M + 46.735*O - .0010*O*M
    (14.159) (.0015)       (24.84)    (.0027)        (32.85)    (.0029)

              N = 68   R**2 = .56   SSR = 805.8   F(5/62) = 18.0
```

Linear Constrained Model

```
D = -14.085 + 2.203E-4*M + 49.009*Y + 40.624*O
    (11.736) (2.670*E-5)   (20.583)   (27.240)

              N = 68   R**2 = .57   SSR = 807.4   F(3/64) = 30.8
```

Nonlinear Model

```
D = [-1.0184 + 3.9832*Y + 3.1664*O] * [10.9809 + .00021*M]
    (.8174)    (1.244)     (1.803)      (1.085)   (3.72E-5)

                   N = 68   R**2 = .56   SSR = 810.7
```

(*) Standard errors in parentheses beneath coefficients

Once again, the evidence suggests provisional acceptance of the constrained linear model. The F-test on the multiple coefficient constraints fails resounding to reject the hypothesis of equal marginal impacts. At the same time, the nonlinear fixed-ratio alternative seems inferior by the standard measures of goodness-of-fit. On the basis of the evidence currently available, it seems appropriate to conclude that cohort-specific death rates across countries differ significantly only by a constant term. The hypothesis that medical personnel affect all cohorts equally at the margin certainly cannot be rejected at any reasonable level of statistical confidence.

APPENDIX D

AGE AT MARRIAGE AND FERTILITY: SOME CROSS-SECTION RESULTS

At the present time, data on age at marriage across countries are quite scarce (32). Since this study focuses on changes rather than levels, the scarcity problem is compounded. It has not been possible to incorporate age at marriage into the fertility change equation without reducing degrees of freedom to absurdly low levels. However, the possible effect of this variable on fertility has been considered sufficiently important to warrant an independent look in cross-section. The following Figure reports a set of regression results which have been used to evaluate the apparent impact of age at marriage. Again, the particular nature of the Mauldin-Berelson index has allowed data pooling only for the years 1960 and 1977. In all regression equations, the constrained linear specification of age cohort impact has been employed.

---

(32) The data on singulate age at marriage used for econometric work in this report have been supplied by the World Bank.

Figure 18

CROSS-SECTION RESULTS:

SINGULATE AGE AT MARRIAGE, HUMAN RESOURCE VARIABLES,

AND FERTILITY RATE DIFFERENTIALS (*)

(Pooled Data, 1960 and 1977)

	N	R**2
F = -941.83 + 525.407*W1524 + 1083.72*W2534	40	.66
(245.58) (153.37) (298.51)		
+ 69.1413*SAM - 1.93422*SAM**2		
(22.549) (.571)		
F = -629.80 + 588.41*W1524 + 732.64*W2534	40	.74
(230.85) (134.35) (277.63)		
- 3.079*PLAN + 44.012*SAM - 1.249*SAM**2		
(.873) (20.833) (.532)		
F = -648.51 + 476.11*W1524 + 689.22*W2534	40	.76
(221.98) (138.00) (267.16)		
- 2.4274*PLAN + 26.710*SAM - .767*SAM**2 + 9.761*H - .102*H**2		
(.892) (22.51) (.569) (5.740) (.054)		
(Including Oil-Producers) (**)		
F = -593.21 + 366.76*W1524 + 525.26*W2534 - 2.613*PLAN	44	.80
(189.03) (123.78) (235.51) (.775)		
+ 12.447*SAM - .351*SAM**2 + 16.145*H - .157*H**2 - .525*E		
(20.643) (.528) (5.580) (.052) (.226)		
SAM = 8.756 + .210*H + .011*E	45	.64
(1.298) (.025) (.008)		

Variables Not Formerly Defined

SAM = Singulate Age at Marriage

(*) Standard errors in parentheses beneath coefficients
(**) For the sake of consistency, all econometric work for this study has avoided the use of the major oil-producing countries. With both literacy and SAM in the same equation, however, degrees of freedom are at a premium. In this case, an exception to the general rule seems warranted.

It is apparent from the first set of regression results that singulate age at marriage (SAM) has a strong effect on the total fertility rate when it is used along with age cohorts in a simple equation. Inspection of the scatter associating SAM with fertility makes it clear that the marginal impact rises at higher marriage ages. An exponential term has been employed to capture the impact of this increasing negative association. When the Mauldin-Berelson index is added to the equation, the SAM terms are still highly significant by the classical criteria. These two variables alone appear to account for much of the observed variation in the total fertility rate across countries.

It is not sufficient, of course, to introduce only SAM and the planning index into the cross-section equation. In Chapter III, a major role in fertility changes was discerned for changes in infant life chances. Unfortunately, the introduction of life chances into the fertility equation leads to a fundamental ambiguity in measuring the impact of age at marriage. As previously noted, the crude death rate and life expectancy are essentially dual measures which can be used interchangeably in the fertility rate equation. However, there is also good reason to suppose that life expectancy is an important determinant of age at marriage.

It is quite plausible to suppose that people will choose to marry later if they can expect to live longer. The reasoning underlying this hypothesis resembles the life-cycle interpretation of consumption and savings behavior. The experience of more advanced economies suggests a significant tendency to defer marriage for investment in education, coupled with an apparent desire to postpone family responsibilities until later in life. The last regression equation, which attempts to account for variations in age at marriage, is resoundingly consistent with this hypothesis. The estimated coefficient for life expectancy suggests a high

degree of responsiveness, and the confidence bound around the estimate is obviously quite narrow. Since it was supposed that education might play a role which could be distinguished from that of life expectancy, literacy was also included as an explanatory variable. The literacy result is considerably weaker, although the suggested level of responsiveness is again fairly high. When per capita income is considered along with literacy and life expectancy, it explains no additional variance in age at marriage. Both literacy and life expectancy, on the other hand, retain the approximate levels of association suggested by the two-variable regression result.

Obviously, the pattern of association suggested by the SAM regression implies a serious multicollinearity problem in the fertility regressions. The last two fertility equations confirm the existence of this problem. When life expectancy and literacy are included with SAM in the fertility equation, the apparent contribution of SAM becomes negligible. Two alternative explanations for this result are plausible. It might be argued that literacy and life expectancy are the two systematic determinants of age at marriage, so that nothing but a random relationship could be expected between fertility and the residual component of SAM (that is, the part which is not collinear with the combined effect of literacy and life expectancy). On the other hand, it might be argued that life expectancy is the dual of the death rate and that the apparent impact of literacy on fertility operates directly through attitudinal change (As we have seen, this apparent impact of literacy does not hold up in the more demanding fertility change specification). If this viewpoint were adopted, then the evidence would be consistent with the hypothesis that age at marriage has no impact on fertility.

In the final analysis, this second viewpoint seems unreasonable.

Both casual observation and common sense suggest that people who marry later do have fewer children, on average. Even if a role for SAM is accepted, however, the available evidence suggests that it can be identified only to the extent that age at marriage operates as an intermediary for the effects of life expectancy (primarily) and education (possibly).

APPENDIX E

SIMULATION

1) A Perspective on Simulation Modeling

In policy research, a simulation model generally serves three main purposes: It forces the analyst to think comprehensively; it enforces consistency; and it facilitates detailed intellectual experiments with public policy instruments. In the initial phase of a project, it forces the researcher to consider carefully which features of a particular system seem to be understood and which require further study before the total behavior of the system can be explained. It is an unfortunate tendency of the human imagination to leave difficult issues in the realm of the implicit whenever possible. When the growth process, for example, is studied in partial academic exercises, the researcher can focus on a few aspects and ignore the degree to which the results are sensible when viewed from the perspective of the whole system.

When a simulation model is being designed, this luxury is no longer available. The full set of relations among endogenous and predetermined variables must be worked out. If the model is to have any credibility at all, all of the hypothesized relations must be estimated econometrically under conditions in which the standard strictures dictated by statistical theory are respected.

Once the equations of a simulation model have been estimated and fitted together, the second major role of simulation comes into play. No matter how rigorous and comprehensive the intellect of the analyst, any first attempt to design equations which explain the operation of a particular system will suffer from conceptual errors. Most of these will

be due to the fact that the mind is best suited for the consideration of problems in partial form. In considering the aggregate implication of an assembled set of partial views, the computer-driven simulation model is a singularly unforgiving associate. Inconsistent reasoning and incompatible specification of different relations in the model are quickly exposed, since attempted simulation exercises yield absurd results. It is in the tracking down of these absurdities and subsequent reconsideration of partial relations from a systemic perspective that the utility of the simulation model as an intellectual tool becomes most apparent.

Finally, once both of the preceding steps have been completed successfully, the simulation model can be employed for policy experiments. Since the computer does most of the work in this stage, it is in most respects the easiest and most enjoyable part of the process. At this point the full implications of the modeling exercise become clear. Generally, policy simulation models are designed under the assumption that public policy instruments are exogenous to the system being considered. This specification leaves the analyst free to examine the hypothetical evolution of the system under alternative assumptions concerning the time paths of the policy variables. At this stage, attention usually focuses on "sensitivity analysis," in which one policy instrument is changed while the others are held constant.

Implicitly, sensitivity analysis is a form of cost-benefit analysis. Policy research is usually undertaken because public administrators are interested in effective approaches to the governance of systems in environments where several competing goals are valued and resources are limited. One important notion underlying the design and use of dynamic simulation models is that complex, interactive systems have behavior patterns characterized by marked nonlinearities and discontinuities. If this is the case, then all cost-equivalent policy packages are very

unlikely to have the same consequences for the attainment of valued goals. It is easy to see that some approaches will be superior to others if they give relative weight to outcomes which have relative priority in the minds of administrators. What may be less immediately obvious is that in highly nonlinear systems some cost-equivalent policy approaches can dominate others absolutely (that is, they can yield superior results along all of the valued dimensions).

It is this latter possibility which is undoubtedly the ultimate source of the evident allure of simulation models. Unfortunately, too much can be made of this. It is all too easy for public administrators to throw up their hands in the face of daily pressures and leave the design and interpretation of models of the complex systems which they must confront to the "experts." This "black box" syndrome has become quite common, and it can be the only possible explanation for the widespread acclamation and acceptance given to the conclusions of such evidently-flawed models as the Urban Dynamics and World Dynamics systems used by the Systems Dynamics Group at MIT to justify sweeping conclusions concerning problems as diverse as urban renewal and the philosophy of limited growth for the world as a whole (33).

In fact, simulation models can only be valuable to the extent that they are not "black boxes." "Counterintuitive" results are useful results only if they can be shown to be intuitive once the structure of the system is clearly seen. In order for this to be possible, over-complexity in the

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(33) This group has been the source of such notable recent exercises as Urban Dynamics, by Jay Forrester, and The Limits to Growth, by Dennis Meadows, et. al. Anyone who thinks that these models truly produce "answers" to the world's problems has only to examine them closely. Unfortunately, their equation systems are lengthy if not particularly complex, and few have taken the trouble. Such exercises are frequently ballyhooed as yielding "counterintuitive" results, but this always turns out to be far from the case if the time is simply taken to consider the equation systems closely.

design of model equation systems is best avoided. The true value of simulation exercises lies in their ability to test the internal consistency of a set of ideas about a particular process. If seemingly-plausible sets of estimated relations yield peculiar results when they are fitted together into a model, then two conclusions are possible: First, the thinking of the researcher may suffer from some important inconsistency which must be corrected. Secondly, it may be that the peculiar results are themselves reasonable when the behavior of the entire system is considered.

In either case, it is obvious that no conclusions can be drawn from simulation exercises if the equations on which they are based are too complex to be sorted out retrospectively. In a good simulation model, the source of any peculiar results can be traced down and analyzed. At this level, the model becomes tremendously valuable as an aid to learning because it uses the speed of the computer to augment the analytical capabilities of the policy analyst. Hopefully, however, this argument will help to persuade the reader that any simulation experiment should be considered carefully in the context of model design and the potential role of factors which have been excluded from the model altogether.

2) Simulation Model Equations and Solution Techniques

In the simulation model equations the symbols are precisely those which have been employed in the estimation section, so that redefinition does not seem to be necessary. Wherever possible, the estimation results reported in Chapters II and III have been transfered exactly into the simulation. Some adjustments have been necessary for the completion of the model, however. Most of these are designed to compensate for the fact that the "period" used for modeling here is 7 years. Thus, the projected

capital growth variable is produced by multiplying the anticipated yearly investment rate by 7 (recall that the capital growth measure in the fitted output equation is defined as (capital change)/(initial output), so that the simulation equation is tailored to the econometric approach).

Besides the adjustment for 7-year periods and some necessary divisions by 100 or 1000 to produce appropriately scaled rates, the equations are either definitions, year-to-year adjustments of initial conditions, or directly transcribed econometric results. Three improvisations have been necessary for the replication of "normal" performance in schooling and family planning over long simulation runs. Equations 2 (primary schooling) and 3 (population per doctor) have been generated by asymptotic regression models fitted to cross-country data for 1977. For the prediction of "normal" progress in secondary schooling, a log-linear model has been fitted to 1977 cross-section data to produce simulation equation 31.

Figure 19

SIMULATION MODEL EQUATIONS

```
(1)  Q/P = Q/P(-1) * (1 + DQ(-1) - DP(-1))
(2)  S = 102.53 - 3030.69/(Q/P)
(3)  M = -346.02+1885320/(Q/P)
(4)  PM1 = 1 - D(-1)/1000
(5)  PM2 = (1 - D(-1)/1000)**7
(6)  P17 = P(-1) * B(-1)/1000 * (1 + PM1 + PM1**2 + PM1**3 + PM1**4 + PM1**5
         + PM1**6)
(7)  P814 = P17(-1) * PM2
(8)  P1521 = P814(-1) * PM2
(9)  P2228 = P1521(-1) * PM2
(10) P2935 = P2228(-1) * PM2
(11) P3642 = P2935(-1) * PM2
(12) P4349 = P3642(-1) * PM2
(13) P5056 = P4349(-1) * PM2
(14) P5763 = P5056(-1) * PM2
(15) P6470 = P5763(-1) * PM2
(16) P7177 = P6470(-1) * PM2
(17) P = P17 + P814 + P1521 + P2228 + P2935 + P3642 + P4349 + P5056 + P5763
         + P6470 + P7177
(18) Y = (P17 + P814)/P
(19) O = (P5056 + P5763 + P6470 + P7177)/P
(20) PWT = .5 * (P1521 + P2228 + P2935 + P3642 + P4349)
(21) PF2534 = .5 * (4/7*P2228 + 6/7*P2935) / PWT
(22) DP = (P - P(-1))/P(-1)
(23) A = P - P17 - P814
(24) DA = (A - A(-1))/A(-1)
```

```
(25) D = 6.1121 + .01746*D(-1)**2 + 2.6041E-5*M(-2) + 18.8983*(Y-Y(-2))
         + 20.2856*(O-O(-2))
(26) DFR = 187.338*(PW2534 - PW2534(-2)) + 9.63614*(D-D(-2))
         - .2470*(D**2 - D(-2)**2) - 15.4159*[Q/P - Q/P(-2)]/Q/P(-2)
         - 1.3122*PL
(27) PPL = PPL(-1) + PL(-1)
(28) PL = IF PPL GE 30 THEN 0 ELSE .3245*SEC(-2) - .1218*DFR
(29) FR = FR(-2) + DFR
(30) B = FR * (PWT/P)
(31) SEC = EXP(-2.4124)*(Q/P)**.9348
(32) N = N(-1) * (1+DN(-1))
(33) LN = LOG(N)
(34) E = SE(-1)
(35) H = H(-1) * (1 + DH(-1))
(36) LH = LOG(H)
(37) I = 11.0502 + .2158*I(-2) + 5.3056*[Q/P - Q/P(-2)]/Q/P(-2)]
        + 3.1372*[E - E(-2)]/I(-2)
(38) DL = DA
(39) DK = 7 * I
(40) DQ = .012 + .146*DK + .565*DL + 1.011*DN + .0096*(SE - E)
(41) DN = -.04 + (3.259 - .674*LN)*(DQ - DP) + .042*LOG[(Q/P)/N]
(42) SE = E*[1/(1+DA)] -.996 + .755*[S(-1) + S(-2)]/2*[DA/(1+DA)]
          + 12.291*(DQ - DP)
(43) DH = -.124 + 6.948*1/H + .142*DH(-1) + (.573-.144*LH)*(DQ - DP)
         + .077*DN(-1) + .027*E/H + 1.10E-5*M/H + .01*S/H
```

The simulation model reflects the dynamic, block-recursive structure of the original model. Thus, initial levels of accumulation parameters join with exogenous and lagged endogenous variables to determine output and human resource variable responses in each period. The induced changes in the response variables in turn generate new accumulation parameter levels.

Since the model is a combination of simultaneous and recursive components, the simulation problem is not trivial. Fortunately, the work for this project was done using the TROLL system at MIT. The simulation routine in TROLL automatically structures model equations into simultaneous blocks and iterates to a convergent solution in each period using a variant of the Gauss-Seidel method. Since all model equations are inherently linear, no convergence problems were encountered in the simulation exercises.

APPENDIX F

THE CALCULATION OF EQUIVALENT PHYSICAL AND HUMAN RESOURCE EXPENDITURES

In Chapter IV, the results of several trade-off experiments were presented and discussed. Although reference was made to World Bank cost estimates, detail was suppressed in the interest of readability. In this Appendix, the estimates themselves will be considered. All of the representative numbers have been drawn from Burki and Voorhoeve (1977), as previously mentioned.

The methodology underlying the equivalent cost estimates in the trade-off experiments is not at all elaborate. The criterion for judgment has been "essential equivalence," given the approximate, aggregative nature of the data. Across investment categories, only performance at a considerably higher level should really be judged "superior" in any meaningful sense. Even in the case of superior performance, the results must be judged in the context of the simplifying assumptions which have been made. Finally, as previously mentioned, judgments about relative performance cannot escape value weightings. The responses of income and the PQLI variables differ by investment category, and the intertemporal response paths vary as well, so that some discount rate (explicit or implicit) is inevitable in the formation of final judgments.

Because of the relative simplicity of the calculations which have been made for the trade-off exercises, it seems sufficient to explain the methods employed in a general way. Once the methodology has been presented, the numbers for specific regional cases will be presented in tabular form.

The "foil" for comparison in these experiments is the 50-year

behavior of the baseline model for each regional case, under the assumption that the investment rate is raised by one percent only for the seven-year period from 1977 to 1984. The calculation of this increment is perfectly straightforward. Given the measured national income and investment rate in any particular year, the value of a one-percent increment in the investment rate can be obtained by simple multiplication.

While per capita income levels in this study have been measured in 1960 U.S. dollars, the World Bank cost estimates are denominated in 1975 U.S. dollars. Since the U.S. price index went up by somewhat more than 100 percent between 1960 and 1975, all cost estimates have simply been halved to reflect 1960 equivalents. Given the index number problems which plague this sort of calculation and a common preference for currency overvaluation, this deflator may be quite conservative. Once the cost corrections have been made, the generation of equivalent activity numbers is quite simple. Since the assumptions underlying comparisons for schooling and family planning are quite different, it undoubtedly makes sense to discuss them separately.

In the case of schooling, the World Bank data are divided (by region) into four cost categories -- teachers' salaries, materials, administrative overhead, and capital costs. The appropriate unit for cost measurement is a little difficult to define in this context, but the Bank estimates are standardized per student-place. Since multiple-shifting is quite common in schools, there can obviously be more students than student-places in the system at any one time. Teachers' salaries are calculated per 50 student-places; materials costs are simply set at 7 percent of salaries, and overhead is calculated as an additional 3 percent of salaries. Separate figures for capital costs per student-place have been included in the Bank estimates.

The need for rough comparability between the investment experiment

and the re-allocation to schooling introduces a problem in the appropriate treatment of capital cost in this context. Since the seven-year boost should be regarded as a one-time increase for the sake of equivalence, it does not seem appropriate to allocate all capital cost per new student to the expansion. For simplicity, the following compromise has been adopted: Only recurrent costs have been employed in the schooling calculations, but student-places have been adopted as the basic unit for cost estimation. The use of a conservative deflator along with student-places should approximately balance the suppression of capital costs from the calculation, since recurrent costs are heavily dominant in the determination of total education costs and capital costs would have to be spread over several student generations in a full intertemporal calculation.

In the case of family planning, the determination of "essential equivalence" has been even rougher. Although use has been made of the Mauldin-Berelson index of family planning activity in the econometric work, no apparent basis exists for converting M-B scores into cost estimates. For the present purposes, therefore, the opposite tack has been taken. Under the assumption that family planning teams in rural areas would be in many ways comparable to community health workers, the World Bank cost estimates for health teams were used for the conversion of investment values to team-equivalents. These team-equivalents were then compared with the female population in fertile-age cohorts to determine the capacity for coverage provided by such an expenditure. In no case was the ratio higher than 200 females per three-person team -- seemingly quite a modest ratio.

With these relatively low ratios in hand, I proceeded to the second part of the family planning exercise. Some experimentation with the simulation model by region was used to determine the minimum value of an

exogenous boost to the M-B index which would generate a final (50-year) per capita income growth higher than that achieved by the investment increment. In most cases, the requisite boost was only 2 (out of a total possible M-B score of 30); in one case, it was 3. My own conclusion is that family planning investment at the margin is at least equivalent to physical investment if long-run outcomes are most highly valued. In fact, the awarding of an M-B score of only 2 to such a drastic expansion of family planning personnel seems quite conservative.

Since the family planning experiment involved the prior calculation of nearly-equivalent income outcomes, it may seem unnecessary to include any simulation runs which can be compared with those for schooling and investment. The family planning simulations do seem to be of interest, however, for two reasons: First, they reveal the extent to which "essential equivalence" in income outcomes is matched by relative performance for the valued PQLI variables. Secondly, they facilitate a clearer perception of the different pattern of relative outcomes at different points in time.

All relevant calculations are presented in the following Figure. In the Schooling set, per capita income and population are combined to yield total national income. One percent of this figure is taken as the hypothetical investment increment. Total recurrent cost per student-place is then calculated using the indicated estimates for teachers' salaries and mark-ups for materials and overhead. Division of the increment by the unit recurrent cost yields the number of new students supported by the additional revenue (under the heroic assumption, of course, that no constraint exists in teaching capacity). Finally, the new students can be combined with total children in the primary-age population to produce the one-period boost in the primary enrollment ratio. In two cases (South America and "ypical), the resulting estimates are much greater than 1.00.

Numbers larger than one are quite common in LDC's, because older uneducated children are attracted to primary schools as capacity expands.

The basis for the family planning numbers in the following Figure should be relatively clear. The indicated investment increment has simply been divided by the cost per three-person team to yield the number of team-equivalents. This result is in turn divided into the number of fertile-age females to produce a ratio of females to teams.

Figure 20

COMPARATIVE COST ESTIMATES - SIMULATION EXPERIMENTS

(1) Recurrent Education Cost Estimates

Region	Salary	Materials (a)	Overhead
Africa	1146/50	.07 X (a)	.03 X (a)
S.America	1334/50	" "	" "
S.Asia	899/50	" "	" "
Typical	1044/50	" "	" "

CALCULATION OF EQUIVALENT SCHOOLING EFFORT

Region	Income/Capita	Population (mill.)	Increment (mill.)
Africa	63.77	6.866	4.379
S.America	330.36	5.734	18.944
S.Asia	95.97	69.376	66.580
Typical	227.08	6.929	15.733

	Primary-Age Population (mill.)	Primary School Enrollment Ratio	New Students (mill).	Increment to Primary Enrollment Ratio
Africa	1.474	55.00	.175	11.85
S.America	1.112	93.36	.649	58.41
S.Asia	14.074	70.95	3.387	24.05
Typical	1.331	89.18	.685	51.48

(2) Family Planning Calculations

Region	Increment	Cost/Team	No. of Teams
Africa	4.379	599.5	7304
S.America	18.944	599.5	31,600
S.Asia	66.580	599.5	111,059
Typical	15.733	599.5	26,244

	Fertile-Age Women/Team	M-B Score for Equivalency
Africa	193	3
S.America	39	2
S.Asia	127	2
Typical	57	2

APPENDIX G

UNSUCCESSFUL EXPERIMENTS

No econometric study ever proceeds from start to finish in the clean, precise way suggested by textbooks in the field. In the consideration of behavior in any socio-economic system, there are always many hypotheses which compete in the mind of the researcher. When the research effort involves substantial discussion with others who can themselves suggest many plausible and ingenious ideas (and this was certainly the case in the current effort), the competitive field becomes crowded indeed.

Under these circumstances, the econometrician must contend with two substantial sources of uncertainty in the research process. The first is the problem of equation specification. While standard economic production functions have been much studied, and the properties of contending specifications are pretty well understood, the same cannot be said of the functions which "produce" life expectancy or literacy in a society. For that matter, the simultaneous specification of output and social indicators is itself relatively unconventional, and existing work provides little prior guidance concerning the appropriate specification of combined production functions.

Thus, experimentation with alternative functional forms becomes an inevitable part of undertakings like the present one. Much experimentation of this kind lies behind the results which are presented in this report, although Occam's razor was applied in most cases when the temptation to venture into truly exotic specifications became strong. Basically, my concern has been to work with cross-section changes rather than cross-section levels, for reasons which have been discussed in detail

in the report. In most cases, then, attention has been confined to the competition between percent changes and absolute changes. There are problems with either measure, but consistent specification moved the proceedings toward percent changes in the response block. In the accumulation block no such constraint applied, and absolute changes seemed to do quite nicely.

It should be re-emphasized that the main difference between percent and absolute change specifications lies in the underlying assumption concerning the degree to which right-hand side variables are substitutable for one another in determining outcomes. A specification in absolute changes asserts that right-hand side variables are perfect substitutes in the process, while the use of percent changes is equivalent to asserting that the variables are "very good" (unit-elastic) but not perfect substitutes.

It is, of course, entirely possible that neither assumption is appropriate. In using asymptote-modified forms of relations in the accumulation and response specifications, I have moved away from these simple forms, but toward specifications whose properties have not been completely thought through at this point. This kind of thinking needs to be done, but it is a separate research project in itself. It certainly deserves entry in the category "Priority for Future Research."

There is, of course, a second source of uncertainty in this kind of study which interacts with the first one. In each of the processes which were examined in the preparation for this report, the explanatory power of many seemingly-plausible variables turned out to be negligible. "Negligible" is a loaded term in econometrics, of course, since some variable which theoretically has a role to play should not be excluded from an equation just because the standard error of its coefficient is relatively large in a particular sample result. Econometric art

definitely merges with science in this particular domain, since the intersection of available data shrinks with the inclusion of more and more variables in a model. In cross-section work on a relatively limited sample, the fundamental discipline imposed by the degrees-of-freedom problem is severe.

Although the final results represent equations fitted using variables which seem to "work," therefore, it is certainly important to mention the also-rans as well. Sherlock Holmes' dictum concerning the dog which didn't bark is as important in this kind of detective work as in any other. In the interest of comprehensibility, our gallery of failures will be presented sequentially.

In the output equation, there has actually been remarkably little evolution as the project has proceeded. The one major exception is provided by a series of experiments with life expectancy, all of which failed to provide any evidence of a direct link between contemporaneous life expectancy change and output change. This was somewhat surprising, since previous work on the 1960's which I had undertaken did suggest an important role for life expectancy change. For the seventies, this materialized neither in percent nor in absolute change specifications. It is true, of course, that the initial level of life expectancy seems to have an impact through its effect on manufacturing export growth (in the 1970's, at least), but no change relation can be discerned. This presents one of the more interesting puzzles to emerge from the modeling exercise. Since the model results for the 1960's and 1970's are similar in many other respects, why not in this one? Perhaps the result for the 1960's was spurious, and perhaps not. In any case, this question remains to be resolved.

The other major set of experiments performed on the output equation involved the comparison of the performance of published labor force growth

data with the performance of adult population change as a proxy. As mentioned in the body of the report, few would argue with the contention that the adult data are more carefully collected. Over short periods, labor force participation and unemployment rates must come very close to being constant multipliers, and they should therefore wash out when percent changes are employed. In any case, the experiments certainly seemed to go in favor of the adult data. Estimates based on the labor force data were very unstable from sample to sample, and they frequently yielded estimated elasticities so large as to be very unreasonable. The estimates obtained with the adult population growth rate, on the other hand, are quite stable from sample to sample and very reasonable.

Like the output equation, the nutrition equation has not been the object of a tremendous amount of experimenation. Absolute changes have been tried, but they do worse than percent changes (This is also true for the contribution of nutrition change in the output change equation, so the percent change specification had no competition in this case).

The literacy equation has been subjected to two experiments which were not fruitful. There is a plausible argument which asserts that self-education should be positively related to life expectancy as well as per capita income, and various specifications of life expectancy change were duly tried. None worked. In addition, it seemed plausible to suppose that the literacy-production-probability coefficient would be sensitive to existing levels of per capita income, health, and literacy in different societies. The appropriate experiments with interaction terms were undertaken, and all the results were robustly insignificant.

In the case of the health equation, the present product is the result of very substantial experimentation. When life expectancy change is measured in percent terms, it is necessary to introduce some control for asymptotic behavior on the right-hand side of the equation. If such a

term is not included, sadly enough, an absolutely beautiful life expectancy change equation emerges. In this fragile but exquisite construct, seemingly important roles emerge for almost every variable which might plausibly be supposed to have an impact on life expectancy change. Present and lagged changes in medical personnel, present and lagged changes in nutrition, present and lagged changes in schooling--all show up strongly, with seeming significance, and with correctly descending lag weights in every case. Unfortunately, the whole thing is totally non-robust. With the common-sense introduction of a simple hyperbolic term (1/E) to control for asymptotic behavior, the whole thing collapses and only lagged nutrition emerges from the rubble.

Now, there are two possible responses to a situation such as the one just described. One plausible argument would hold that structural explanations are better than non-structural explanations, and that if the choice is between a set of plausible explanatory variables and a simple hyperbolic term the former should be chosen. On the other hand, when this simple term "explains" as much variation in the data as a whole host of contenders, Occam's razor comes readily to mind. In this case, the flowery construct has been suppressed because it is so non-robust. The variables which remain in the equation, on the other hand, are very resistant to specification change, and their presence has been justified in detail in the text. In passing,it should also be noted that several other plausible variables were tried in the life expectancy equation, and none of them had any apparent impact. Present and past changes in population per hospital bed and population per "nursing person" (a vaguely-defined concept at best) failed to produce any meaningful results, as did the initial levels of the same variables. In addition, the available measure of "safe water" availability had no effect.

In the manufacturing export equation, very little experimentation

has been done. All of the variables in the equation seemed plausible, given the argument about human resources which formed the basis for this exercise and the evident importance of relative wages in a competitive environment. The bad result for the 1960's introduces a major ambiguity, of course.

We now pass to the chronicle of experiments with the accumulation block equations, where the number of attempts again varied considerably from problem to problem. The investment rate change equation was not the subject of many experiments other than those already reported in the text. The one exception involved a plausible argument about the role of "extraversion" of the economy in the determination of the investment rate. It was hypothesized that a change in the ratio of exports to GDP should elicit some response in the investment rate, on the theory that large enterprises (public or private) are disproportionately involved in trading activities and find it easier to mobilize savings. Although the export-ratio term generally had the correct sign in the investment rate change equations when it was included, the associated standard error was always quite large. This variable was therefore excluded from the final estimates.

Work on fertility rate determination in this report was guided by the extensive previous work of demographers, so it was relatively easy to choose appropriate right-hand variables. A major exception was provided by the literacy rate, which generally does quite well in cross-section studies of fertility rate determination. When time changes are employed, the direct contribution of this variable to changes in fertility apparently vanishes. Since literacy change contributes to output change, of course, the effect of this variable is still indirectly present.

As previously noted, the approach to fertility function estimation taken in this study may draw some claim to novelty from the use of time

changes, age cohort effects, and a simultaneous specification of the relationship between family planning activity and fertility change. The obviously nonlinear relationship between the death rate (a proxy for the infant mortality rate) and the fertility rate was incorporated in the final equation specification. In passing, it should be noted that the relatively superior performance of the constrained linear fertility model (see Appendix C) suggests that the crude death rate is a good proxy for the infant mortality rate. If the data had suggested a differential pattern of marginal impacts across cohorts, this would not have been the case.

Before passing on to the death rate experiments, it should be noted that the near-duality of life expectancy and the death rate applies to the role of the associated infant mortality factor in the fertility rate equation, as well. When life expectancy change is used in the fertility rate equation in place of the change in the death rate, it performs equally well. Since the death rate is a more direct index of the phenomenon being modeled (the response of fertility decisions to the survival probability for children), it has been used in this study. The death rate coefficient has the advantage of ready interpretation, as well. Both the model results and the scatter diagrams displayed in Chapter III demonstrate the strong nonlinearity in this coefficient. The coefficient which measures response to expected infant survival moves rapidly toward unity as the death rate declines.

Finally, we arrive at the death rate change equation. In this modeling exercise, the utility of this equation lies principally in its necessity for a complete specification of the population growth rate in the simulation model. For all other purposes, the life expectancy equation does as well or better. In any case, the guiding principle in experiments with the death rate change equation was the theoretical

necessity of near-parity with the specification of the life expectancy change equation. The variables which remain in the reported equation are those which "worked." Only age cohort changes and changes in the availability of medical personnel seem to have had significant impacts on observed death rate changes across countries. Among the large set of other possibly-relevant present and lagged changes and initial levels, no other variables emerged unscathed. Obviously, death rate changes as measured are not the easiest things in the world to explain. A large portion of the "explanation" in my equation is provided by the asmymptotic term and the lagged endogenous term which represents the continuity of peculiar local patterns of death rate decline. A major problem may well be presented by errors in measurement in this case.

APPENDIX H

SAMPLE COUNTRIES

In Appendix A, considerable attention is paid to the problem of data scarcity when time-change equations are estimated in this context. Each intersection of variables contains a different subset of observations from the full 88-country group. Under such circumstances, it is unwise to ignore the risk that a particular intersection sample may be entirely unrepresentative of the full set. In this Appendix, the intersection samples for the principal output and demographic models are listed. It might have been supposed a priori that data availability was positively associated with per capita income. Fortunately, this does not seem to have been the case. The smaller samples bear a surprising resemblance to random draws, with no detectable bias in favor of a particular region or income level.

Figure 21

CLOSED ECONOMY SAMPLE COUNTRIES

1960	1970
PORTUGAL	PORTUGAL
GREECE	TURKEY
SPAIN	YUGOSLAVIA
TURKEY	MOROCCO
YUGOSLAVIA	TUNISIA
MOROCCO	CHAD
TUNISIA	ETHIOPIA
CAMEROON	GHANA
ZAIRE	IVORY COAST
GHANA	KENYA
IVORY COAST	MADAGASCAR
KENYA	MALAWI
LIBERIA	MAURITANIA
SENEGAL	SENEGAL
SOMALIA	SIERRA LEONE
SUDAN	SUDAN
TANZANIA	TOGO
TOGO	UPPER VOLTA
DOMINICAN REPUBLIC	ZAMBIA
EL SALVADOR	DOMINICAN REPUBLIC
JAMAICA	EL SALVADOR
MEXICO	JAMAICA
PANAMA	MEXICO
ARGENTINA	NICARAGUA
BOLIVIA	PANAMA
BRAZIL	ARGENTINA
CHILE	BOLIVIA
COLOMBIA	BRAZIL
PARAGUAY	CHILE
SYRIA	COLOMBIA
AFGHANISTAN	PARAGUAY
SRI LANKA	URUGUAY
INDIA	SYRIA
PAKISTAN	AFGHANISTAN
HONG KONG	SRI LANKA
SOUTH KOREA	INDIA
MALAYSIA	PAKISTAN
PHILIPPINES	HONG KONG
THAILAND	SOUTH KOREA
	MALAYSIA
	PHILIPPINES
	SINGAPORE
	THAILAND

Figure 22

LIFE EXPECTANCY EQUATION

PORTUGAL
GREECE
SPAIN
TURKEY
YUGOSLAVIA
MOROCCO
TUNISIA
CAMEROON
CHAD
ZAIRE
ETHIOPIA
GHANA
GUINEA
IVORY COAST
KENYA
LIBERIA
MADAGASCAR
MALAWI
MAURITANIA
SENEGAL
SIERRA LEONE
SOMALIA
SUDAN
TANZANIA
TOGO
UPPER VOLTA
ZAMBIA
DOM. REP.
EL SALVADOR
HAITI
JAMAICA
MEXICO
NICARAGUA
PANAMA
ARGENTINA

BOLIVIA
BRAZIL
CHILE
COLOMBIA
PARAGUAY
URUGUAY
ISRAEL
SYRIA
AFGHANISTAN
INDIA
NEPAL
PAKISTAN
HONG KONG
SOUTH KOREA
MALAYSIA
SINGAPORE
THAILAND

Figure 23

SAMPLE COUNTRIES - FULL INVESTMENT EQUATION

TURKEY
YUGOSLAVIA
MOROCCO
TUNISIA
EGYPT
BURUNDI
BENIN
GHANA
IVORY COAST
KENYA
RWANDA
SENEGAL
TOGO
DOMINICAN REPUBLIC
EL SALVADOR
GUATEMALA
HONDURAS
JAMAICA
MEXICO
PANAMA
BOLIVIA
BRAZIL
CHILE
COLOMBIA
PARAGUAY
PERU
AFGHANISTAN
BURMA
SRI LANKA
INDIA
PAKISTAN
BANGLADESH
TAIWAN
HONG KONG
SOUTH KOREA
MALAYSIA
PHILIPPINES
THAILAND
PAPUA NEW GUINEA

Figure 24

SAMPLE COUNTRIES - FERTILITY CHANGE MODEL

TURKEY
MOROCCO
TUNISIA
EGYPT
CAMEROON
CENTRAL AFR. REP.
ZAIRE
ETHIOPIA
GHANA
GUINEA
IVORY COAST
KENYA
LESOTHO
LIBERIA
MADAGASCAR
MALAWI
MALI
MAURITANIA
NIGER
RWANDA
SENEGAL
SIERRA LEONE
SOMALIA
SUDAN
TANZANIA
TOGO
UGANDA
UPPER VOLTA
ZAMBIA
COSTA RICA

DOMINICAN REPUBLIC
EL SALVADOR
GUATEMALA
HAITI
HONDURAS
JAMAICA
MEXICO
NICARAGUA
PANAMA
BOLIVIA
BRAZIL
CHILE
COLOMBIA
PARAGUAY
PERU
JORDAN
LEBANON
SYRIA
AFGHANISTAN
BURMA
SRI LANKA
INDIA
NEPAL
PAKISTAN
BANGLADESH
HONG KONG
SOUTH KOREA
LAOS
MALAYSIA
PHILIPPINES
SINGAPORE
THAILAND

SAMPLE COUNTRIES - DEATH RATE EQUATION

PORTUGAL	UPPER VOLTA
GREECE	ZAMBIA
SPAIN	COSTA RICA
TURKEY	EL SALVADOR
YUGOSLAVIA	GUATEMALA
MOROCCO	HAITI
TUNISIA	JAMAICA
EGYPT	MEXICO
BURUNDI	NICARAGUA
CAMEROON	PANAMA
CENTRAL AFR. REP.	ARGENTINA
CHAD	BOLIVIA
ZAIRE	BRAZIL
BENIN	CHILE
ETHIOPIA	COLOMBIA
GHANA	PARAGUAY
GUINEA	PERU
IVORY COAST	URUGUAY
KENYA	JORDAN
LIBERIA	SYRIA
MADAGASCAR	AFGHANISTAN
MALAWI	BURMA
MALI	SRI LANKA
MAURITANIA	INDIA
NIGER	NEPAL
RWANDA	PAKISTAN
SENEGAL	HONG KONG
SIERRA LEONE	SOUTH KOREA
SOMALIA	LAOS
SUDAN	MALAYSIA
TANZANIA	SINGAPORE
TOGO	THAILAND
	PAPUA NEW GUINEA

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