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ACCELERATED MODERNIZATION AND THE POPULATION EXPLOSION

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by

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This paper is intended as a contribution to investigating how much, in the less developed countries, intermediate to high rates of economic growth unaided by population control policies can bring down fertility and defuse the population explosion. The approach followed consists in simulation experiments using a long run model of economic growth with population endogenous.[1/] In the model (1) the growth of GNP per capital contributes to the declines of fertility and mortality according to equations with parameters estimated from empirical data, which are designed to reflect major aspects of the historical experience, and (2) the growing population contributes to the economic sector via labour inputs which are related to population size and sex-age composition. The paper focusses upon two growth performances, referred to as normal modernization (NM) and accelerated modernization (AM), and upon a range of ideal less developed countries with distinct initial levels of fertility and development.

The model used is made of demographic and economic modules. The demographic module takes an initial population differentiated by sex

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and into seventeen age classes and projects it over time. The technique is well known: it consists in multiplying a projection matrix by a population vector to obtain a new population vector which specifies the number of people by sex and age classes at the end of a five years interval. The coefficients of the projection matrix are age specific fertility rates, and survival coefficients. The latter indicate which fraction of each sex-age class will be alive after five years. In this study the coefficients of the projection matrix are not time invariant. Instead the age specific fertility rates and the survival coefficients are respectively function of the gross reproduction rate G, and of the life expectancy at birth E. Both G and E are functions of level of development, represented by GNP per capita y, and of time t. The parameters of the functions relating G and E to y and t, have been estimated from a time series of cross sections spanning the period 1860 to 1959. In particular, the G equation may be presumed to reflect the effects of economic growth on fertility in a context characterized by the absence of population control policies.

Summing up, the demographic module inputs time, a population vector and GNP per capita, and outputs an updated population vector specifying the population by sex and age classes five years later.

The economic module was based on the following assumptions. Growth of GNP results from growth of capital and labour inputs, and from neutral technolgical progress.

A labour force equation converts population vectors into measures of labour force by multiplying each age-sex class by time invariant labour force participation coefficients. Capital formation results from gross savings minus capital consumption, and no capital movements across international boundaries are allowed. The fraction of GNP that is saved increases as GNP per capital increases. The contribution of the growth of labour inputs to the growth of GNP is also assumed to increase as GNP per capita increases. Returns to scale are constant.

The technological progress is low at low level of GNP per capita; as GNP per capita increases, it increases up to a maximum level of 8 percent. For levels of GNP per capita beyond a threshold the rate of technological progress declines until it reaches a lower limit of 2 percent. The rationale of these assumptions is that the rate of technological progress depends upon the existence of a stock of technologies that a country has not applied, and upon the country's ability to begin or to extend their application. At low levels of GNP per capita a large stock of unused technologies is available but the ability to take advantage of them is very limited. Throughout the development process the ability to apply existing scientific and technological knowledge increases but the stock of unused technologies decreases, so that countries become increasingly dependent upon the extension of the existing stock of scientific and technological knowledge, rather than upon the application of unused portion of it. In the limit, the developed countries' rate of technological progress is set at 2 percent per year, which is assumed to correspond to the rate of growth of the aggregate stock of scientific and technological knowledge. In this study two schedules of rates of technological progress versus GNP per capita were used, which differ in the extent to which at lower levels of development, increases in GNP per capita bring about an increase in rates of technological progress (Table 2). The schedule with lower rates corresponds to a state of affairs in which traditional ways and structures yield more slowly to modernizing pressures. The other one instead identifies a phase of accelerated progress corresponding to a situation in which the resistence of a country's traditional society to modernization has been broken down, and a modernizing elite is firmly in control of the country's socio-political structures. The two schedules identify the normal and accelerated modernization (NM and AM).

The economic module inputs a population vector and time and outputs a measure of GNP per capita. The simulation experiments that form the object of this paper generate a time path of a number of economic and demographic variables corresponding to the normal and accelerated modernization, over a time horizon of 100 years starting with the year 1970. The effects of modernization are explored for less developed countries with initial levels of GNP per capita ranging from one to four hundred U.S. 1970 dollars and with initial gross reproduction rates ranging between 2.5 to 3.25.

The basic questions asked may be phrased as follows: within the framework considered are optimistic rates of economic development enough to reduce significantly the initial "explosive" rates of population growth within a 100 years time span? How much do populations increase in the process? How sensitive the simulation results are to differences in the initial conditions concerning fertility and level of development?

The Demographic Equations

First, the general structure of the demographic module will be outlined. Then, the functional relations in it will be specified and the procedures for the estimation of their parameters described. A closed system is assumed, with no immigration or emigration.

Let P(t) be a vector specifying numbers of people by sex and age classes. Let

$$P^T(t) = (F^T(t),\ U^T(t)) \tag{1}$$

$$F^T(t) = (F(1,t),\ F(2,t),\ldots\ldots F(17,t)) \tag{2}$$

$$U^T(t) = (U(1,t),\ U(2,t),\ldots\ldots U(17,t)) \tag{3}$$

where the superscrip T stands for "transpose", the vectors F(t) and U(t) indicate respectively the number of females and males in 17 five years age classes at time t, and F(i,t) and U(i,t) are the elements of these vectors and specify the female and male population in the ith age class at time t. The age classes range from the first, including people aged 0 to 5, to the 17th, with people aged 80 to 85. Time is measured in five years time intervals. The relation between the population at the beginning and at the end of five years time intervals is given by the following matrix equation:

$$P(t+1) = AP(t) \tag{4}$$

where A is a projection matrix. Indicate by the notation

$$A = A(G, E) \tag{5}$$

that the elements of A are a function of gross reproduction rate G and of life expectancy at birth for both sexes E, so that the projection matrix A at time t is specified if the values of G and E at time t are given. Both G and E are assumed to be function of GNP per capita y and time t.

$$G = G(y,t) \tag{6}$$

$$E = E(y,t) \tag{7}$$

Given (a) a specification and parametrization of the relations listed above, (b) an initial population vector P(0), and (c) values of y and t at five years intervals, a population projection can be generated. Here y is "endogenous" since it is determined by economic variables and parameters, and by labour inputs generated using labour participation coefficients and the vector P(t). The matrix equation (4) incorporates two sets of dynamic relations which specify respectively (a) the flow over time of the surviving members of each age class into the next age class, and (b) the addition of new born male and female babies to the population. The structure of the projection matrix A will not be discussed in detail. The reader is remainded to the exhaustive treatment of the subject by Keyfitz (1968, p. 27 ff.) which has been followed here. It will suffice to note that the non zero entries in A are based on (a) age specific female fertility rates indicating the number of female children born over a 5 years period to females in the ith age class, (b) survival coefficients specifying the population of the male/female population in the ith age class at time t which will be alive 5 years later, at time t+1, and (c) a constant indicating the ratio of the male new borns to the female new borns (set to 105 males to 100 females). The age specific fertility rates were defined as the product of the schedule of age specific female fertility rates corresponding to a gross reproduction rate of one times the actual value of G. The age specific female fertility rates used in this investigation are annual female births per woman corresponding to a gross reproduction rate of one, and to a mean reproductive age of 29 years, published in Coale and Demeney (1966, p. 30) and shown in Column 5 of Table 1.

The survival coefficients were assumed to be a function of life expectancy at birth for both sexes E. These functions are defined "empirically" as follows. The survival coefficients of the "West" Model Life tables published by Coale and Demeny for mortality levels 13, 15, 17, 19, 21, 23, and 24 were used. For each mortality level the mean of the female and male life expectancy at birth indicated in the life tables, was calculated. The following E values were obtained for the mortality levels 13 to 24 listed above: 48.56; 53.42; 58.24; 63.11; 68.01; 73.09; 75.70. For life expectancies corresponding to these values the survival coefficients were taken from the corresponding life table; while for other values of E the survival coefficients were calculated by linear interpolation between two consecutive life tables. In other words, the survival coefficients for each age class and sex was defined as a piecewise linear function of values of E ranging from 48.56 and 75.70. At the beginning of each of the five years intervals for which the simulation was carried out the values of G and E were calculated from values of y and t, on the basis of these the age specific fertility values and survival coefficients were evaluated, and then the population vector was projected across the interval. The total population at time zero (the year 1970) was assumed to be one million people. Its disaggregation by sex and into age classes was accomplished using the female and male stable age distribution and the percentage female and the percentage male in the stable age distribution, corresponding to the West model life table, for a mortality level 13, a gross reproduction rate of 3, and an average reproductive age of 29 years (Coale and Demeny 1966, p. 98, 194). A listing of the elements of the initial population vector is given in Table 1, columns 3 and 4. The same vector was used as initial condition also for the simulation runs involving gross reproduction rates different from 3.

The G and E Equations

Let us consider the G equation first. In order to derive an equation suitable to describe the dynamics of the gross reproduction rate let us begin by assuming that G is some well behaved function of product per capita[2] and time:

$$G = G(y,t)$$

Time is included so that the relation between G and y be not required to be time invariant. In fact, the empirical analysis discussed later in this paper appears to justify such inclusion. Here and hereafter a hat superscript indicates the instantaneous percentage rate of change of the superscripted variable with respect to time, so that, for instance

$$\hat{G} = \frac{1}{G} \frac{dG}{dt}$$

Taking the derivative of G with respect to time and after a few manipulations we have

$$\hat{G} = \eta_{G,y} \hat{y} + \hat{G}_t \qquad (8)$$

where $\eta_{G,y}$ is the elasticity of the G with respect to y:

$$\eta_{G,y} = \frac{y}{G} \frac{\partial G}{\partial t}$$

and

$$\hat{G}_t = \frac{1}{G} \frac{\partial G}{\partial t}$$

In the specification of the G equation let us consider first the elasticity term of equation (8). In investigations of the relation between GNP per capita and fertility the literature has distinguished between short and long run effects of economic growth, and between GNP per capita as index of households income and as index of the structural changes associated with economic growth (Simon 1969, 1974; Heer 1966).

A short run increase in GNP per capita reflects an increase of households' income unaccompanied by changes in preferences or in socioeconomic structure. If children are regarded as superior goods and households maximize the satisfaction of their preferences subject to budget and time constraints, (Becker 1960; Willis 1973; De Tray 1973) an increase in income, everything else being equal, should bring about an increase in fertility. In fact, empirical research has confirmed that short run increases of GNP per capita are associated with increases in fertility (Galbraith and Thomas 1941; Kirk 1956; Silver 1966; Basavarajappa 1971; Ben Porath 1973).

The long run effects of growth of GNP per capita hinge on a host of structural changes which appear to be responsible for two opposing effects on fertility. On one hand modernization and economic growth (1) increase the income of households, which may lead to increased demand for children, (2) it dissolves traditional structures and mores some of which had fertility inhibiting effects and (3) it brings about improved health which leads to higher fertility (Habakkuk 1953; Krause 1957; Petersen 1966; 1969 p. 608 ff.). On the other hand they (1) lead to a preference for smaller families, (2) raise the cost of children including opportunity costs in all kinds of social structures, and (3) involve a transfer of large masses of people out of social strata and environments that, because of values, preferences or costs, are characterized by high fertility. The fertility enhancing and fertility depressing effects perhaps coexist throughout the process of development with the former ones being stronger and dominant in the first, and, perhaps, in the last (Easterlin 1962) stages of the development process. These considerations suggest that the fertility elasticity of development should include additive terms representing respectively a fertility enhancing effect and a fertility depressing effect such that at least for low y's the first would dominate. However, the data did not suggest any significant fertility-enhancing effect, perhaps because "noise" obliterates it. Consequently, it was decided to use a specification which includes only the fertility depressing effects of development, and for simplicity $\eta_{G,y}$ was set equal to a negative constant.

Also the term $\hat{G}_t$ of equation (8) was specified as a negative constant in order to allow for declines of G that do not depend upon economic development in the country in which they take place, and that perhaps linked to the acceleration of the "demographic transition" suggested by Kirk (1971).

The specification of equation (8) selected on the basis of the considerations above is

$$\hat{G} = -p_G\hat{y}-q_G \tag{9}$$

where p and q are positive constants. In order to derive a suitable life expectancy equation a similar approach will be followed. First a well behaved function of y and t is assumed.

$$E = E(y,t)$$

then, its total derivative with respect to time is derived:

$$\hat{E} = \eta_{E,y}\hat{y}+\hat{E}_t \qquad (10)$$

where, again η is an elasticity, and $\hat{E}_t = (1/E)\partial E/\partial t$

As regards equation (10) we should require (1) that $\hat{E}_t$ be greater than zero to allow for an increase in life expectancy even in the absence of increases in GNP per capita; (2) and the $\eta_{E,y}$ be greater than zero since improved health sanitation and nutrition associated with economic growth have been factors of the historical decline in mortality. The simplest specifications of equation (10) satisfying these requirements is that in which $\hat{E}_t$ and $\eta_{E,y}$ are positive constants, namely

$$\hat{E} = p_E\hat{y} + q_E \qquad (11)$$

In the course of the estimation of the life expectancy's equation, however, it seemed appropriate to experiment with transformations of E designed to force the life expectancy to remain within asymptotic limits, which were set to 20 years and 74 years respectively. The formulation using the transformed variable TE (transformed life expectancy) is

$$\hat{TE} = -p_{TE}\hat{y} - q_{TE} \qquad (12)$$

where

$$TE = \frac{74 - E}{E - 20} \qquad (13)$$

The solution of (12) and (13) is:

$$E = \frac{54}{1+e^{C-qt}\,y^{-p}} + 20 \qquad (14)$$

where C is an integration constant. Clearly, according to equation (14) life expectancy E approaches 74 years as y and t are increased and tends to 20 years as y goes to zero and t approaches minus infinity. Equation (12) was eventually chosen for use in this study because it seemed more satisfactory from a theoretical point of view and also gave better fits to the empirical data.[3/]

Estimation of the Parameters of the Demographic Equations

Direct estimation of p's and q's in equations (9) and (12) from percentage change data was discarded because the amplification of noise produced by the differentiation of a noisy signal appeared to be especially relevant here. Instead the estimation procedure employed consisted in fitting functions which are the solutions of equations (9) and (12). These solutions are:

$$\ln G = -p_G \ln y - q_G t - C_{G_i} \qquad (15)$$