AN ECONOMETRIC ANALYSIS OF LIFE EXPECTANCY

by

S.B. JONES-HENDRICKSON

Social Research Center
Caribbean Research Institute
College of the Virgin Islands

January, 1982

An Econometric Analysis Of Life Expectancy

Abstract

This work develops a model which seeks to determine the dependence of life expectancy on birth rate, death rate, infant mortality and per capita Gross National Product. The estimates are based on a single equation regression analysis for sixty-seven "developed" and "developing" countries. The cross sectional data are drawn from a World Bank Publication The Assault on Poverty (1975, Annex 2 pp. 414-415).

All of the estimates parameters are significant at the conventional 1 and 5 percent level of significance, except infant mortality. Ninety-seven percent of the variation is explained, and two-thirds of the observed values of the dependent variable, life expectancy, are within $\pm$ 1.74 of their respective values as estimated by the regression.

This work is a first analysis of data from which we will subsequently discuss the issues in developing countries and spacifically Microstate Economies.

I. Introduction

The essential qualities or features of this work emanate from our concern with the quality of life, the nature of life and the factors which impinge on health care delivery. In 1946, when the World Health Organization's (WHO) constitution was signed, one key point was very clear: "health," the constitution stated, "is a state of complete physical and social well-being, and not merely the absence of diseases and infirmity."

The WHO definition is useful. But, we are cognizant of the point developed by Stewart and Siddayao (1973) that the

> demand for health services is a function of the individual, and the health of the individual could at some income levels be directly related to his income. (Furthermore), the lowest income groups are more likely to have poor nutrition and inappropriate health habits, and may require health attention more frequently than higher income groups (p.8).

On reflecting on this passage, and when it was placed in the context of nations, it began to shed some light on the nature of length of life in the so-called developed and developing countries. Fundamentally, we began to recast the demand-for-health scenario along the lines of a length-of-life point of view. Our concern was to determine what causal factors may be linked, operationally, to the length of living experienced by individuals in both economically demarcated groups of countries.

Several approaches were considered in order to establish our first approximation to long life differences between developed and developing countries. At first, ratios such as doctors to population, nurses to population, hospital beds to population, and the rest, were considered. These were not considered in a direct sense. They were considered in a derived sense. Once again, Stewart and Siddayao (1975) provided the line of departure in the development of our approach.

> The demand for health services note Stewart and Siddayao (1973) is, in effect, a demand for good health. Yet, it cannot be assumed that the amount of expenditures on medical care has a direct relationship with achieving the level desired, just as it cannot be assumed that the number of physicians relative to the population is indicative of the level of health of any segment of the population (p.57).

Spurred on by this thought, it occurred to us that the length of life one lives must be related to other factors beside the conventionally accepted high level health manpower ratios. Furthermore, we thought that length of life is critical to the perspectives of countries, particularly developing countries (notably low income Microstate Economies). Length of life and planning for the people who live long lives are of vital import in developing countries. What really turned the thought into substantive action was a passage from Chiang (1972) who contends that

> in planning health services for a nation, or for a community, we need some objective criteria on which to base our judgement, to guide our decision, and to evaluate the accomplishments of our performance. A planning (sic) without a model is futile, a health service program without a measure of the outcome is ineffective (p.19).

To us, the concept of long life provides some criterion on which a country could be assessed. The single equation model which we develop in Section IV follows the Mathematics of Life Expectancy in Section II and a review of the literature in Section III. In terms of the structural analysis of the model, we believe that hypotheses could be tested to determine concrete empirical links between life expectancy and per capita income, for example. The model also could provide some useful measures for forecasting given the death rates, infant mortality, and per capita gross national product of nations. From a policy point of view, these microanalytic features could be fed back into the overall macroeconomic systems provided the model stands replication, and provided accurate data are readily available.

The fifth section presents the data in a descriptive frame of reference. This section is followed by the estimated model in Section VI, the econometric results in section VII, uses of the estimated model in section VIII and the overall conclusions in section IX.

II. Mathematics of Life Expectancy

Life expectancy at a given age is a summary of the mortality conditions at that age plus all subsequent ages.

Life expectancy calculations depend, to a large extent, on age-specific mortality rates. Consequently, reliable data, as they pertain to the mortality and distribution of populations by age and sex, are of tremendous importance.[1] From a simple example, we can illustrate the concept of life expectancy.

Life expectancy at age thirty, for instance, summarizes mortality conditions at age thirty and the years beyond age thirty. The mortality rate at any given age is a measure which indicates that a person selected at random will die at the given age.

Let us consider the following:

Four persons have age characteristics such that A lives for one week; B lives for 28 years; C lives for 72 years and D lives for 90 years. All four individuals lived a total of 190 years. Life expectancy at birth is approximately 47.5 years. Messrs B,C,D reached the age of one year. From that age they lived for a total of 187 years, hence their life expectancy at age one is 62.3 years. Messrs C and D reached the ages of 30 and 60. Mr. C. lived until 72 and Mr. D. lived until 90. Thus, life expectancy of Mr. C at ages 30 and 60 is 42 and 12, respectively. Likewise, life expectancy for Mr. D at those same earmarked ages is 60 and 30, respectively. What should be clear is this: life expectancy at a given age is not the same thing as expected age at death.

Our illustration is simplistic. Life expectancy is more complex than our simple illustration above. Let us first start with life tables. Life tables are developed in the framework of probabilities for individuals. For the entire population, life tables are, technically viewed, deterministic models of mortality and survivorship.[2]

The substantive features of life tables, as far as we are concerned, center on the answers we can derive from them. We can derive answers pertaining to the probability of Mr. B, age 50, surviving until he reaches age 70, or what is the probability that he will outlive Mr. B junior, who is currently age 20.

From the point of view of groups born at a given time, we can determine what proportion will survive to reach some age in the future. Finally, we could also get answers from the life tables which would tell us what proportion of a population will be at retirement age, given certain set-specific conditions of birth rate and death rate.

For developing countries which depend on their human resources, as a critical input in the production process, these answers from the life tables are of tremendous import. They will not eliminate the problems of barriers to development. The answers, however, can be useful in the long run planning strategies of the countries. For developing countries, and particularly Microstate Economies, therefore, some accurate knowledge of life expectancy of their people and what affects the life expectancy are crucial.

How is life expectancy derived, mathematically? Following Keyfitz (1972,pp.34-35) we note that the probability of one surviving from birth to some age may be defined as

$s(a)$ .... $(1.^{0})$

for a continuous function of a, and

s_a .... $(2.^{0})$

for a discrete case. The change in the number of people who survive between s_a and s_{a+1} is designated d_a. In the general case, if the people live until y years in the future,

$s_a - s_{ay+y} = yd_a$ .... (3.0)

The probability of Mr. A dying during the succeeding y years given that he is age a is obtained by our dividing (3.0) by

(2.0). Hence we obtain

$$\frac{s_a - s_{a+y}}{s_a} = 1 - \frac{s_{a+y}}{s_a}$$

$$= \frac{yda}{s_a} \qquad (4.0)$$

If we wish to determine the cumulative number of years lived for y years in the future for a cohort which is currently age a, we simply write

$$ {}_y s_a = \int_a^{a+y} s(x)\, d\, x \qquad (5.0)$$

Expression (5.0) represents the number of people aged, precisely, a to a+y in the "stationary" population. If we let y equal ω, where ω is the maximum age of any body in the society, we obtain

$$ {}_\omega S_a = R_a = \int_a^\omega s\ (x) dx \qquad (6.0)$$

R_a represents the cumulative remaining years for the group of individuals who have reached age a, one of whom will survive to age ω. The expected proportion for an individual in the cumulative proportion is obtained by our dividing expression (6.0) by the probability of someone surviving from birth to age a, say. In other words we can divide R_a by s_a.

$$\frac{R_a}{s_a} = \int_a^\omega s\ (x) dx [s_a^{-1}] = e^o_a \qquad (7.0)$$

From a probability frame of reference, e^o_a which is "the mean of the distribution of years to death for persons age (a) is called the <u>expectation of life</u>" (Keyfitz, 1972, p.35).

III. Literature Review

One would have imagined that with all of this instructive demographic information at hand, that analyses of life expectancy would have been integral to theories of development, or at least that the subject matter would have occupied the attention of many economists. Unfortunately, the previous literature of life expectancy, as it pertains to economic development, is sparse.

Some articles have explored features closely related to life expectancy and some of the intrinsic factors that we are attempting to identify in this work.

Weintraub (1962) believes that the "relationship between the birth rate and per capita income (is) negative"[3] (pp.812-817). Adelman (1963) argues that there is a "homogeneity" in the response of population pressure in both "developed" and "less developed countries" (pp. 315-339). Simon (1969) claims that the birth rate falls in "less developed countries" as the average income rises (pp.327-341). Gregory and Campbell (1973) dismiss Adelman (1963) homogeneity assumptions and argue that "population planning at the aggregate level must proceed differently in developed and developing countries" (pp.233-241).

In the Caribbean, Roberts (1957, pp.264-265), Roberts (1968) and Sinclair (1974) are concerned with demographic issues, and specifically fertility patterns.[4] Even though they have a full grasp of the fertility situation in the region, their concerns, like their metropolitan counterparts, are not with life expectancy per se.[5] In our view, none of the previously mentioned literature dealt explicitly with life expectancy. But, there are some inchoate references to life expectancy and economic developmental issues in the literature.[6]

In the World Bank Report (1975, pp. 348:50), life expectancy is given a brief treatment. It is discussed in relationship to wealth and infant mortality. The life expectancies of developing countries are discussed. However, there is no profound treatment of the subject matter. The discussion on the "health conditions of developing countries" recognizes that "life expectancy at birth and at selected ages is the most reliable measure of health status available" (World Bank, 1975:348).

Michael Todaro (1977:171-172) discusses "fertility and mortality trends" comparing in passing, birth rate, in developing and developed countries and the relationship of the birth rates to life expectancy.[7] Coale and Hoover (1972, p.34 and pp.376-377), briefly discuss life expectancy at birth under two general topics: (a) prospective changes in Indian Population during a 30-year period (1956-1986), and (b) 'recent trends in Mexican fertility and mortality.' In the case of the latter, mortality rates are compared with life expectancy. But the thrust of the section centers on the "typical association between the level of life expectancy and the annual increments to life expectancy" (Coale & Hoover, 1972, p.377).

The simple correlation analysis developed by Coale and Hoover (1972) has a conclusion which states that there is a correlation between the average annual increase in life expectancy and its level of - .91 for males, and - .85 for females. The relationship was obtained from observations over a twenty-year period for 20 countries.[8] The authors were interested in pointing out that a "linear association between level of expectation of life implies a typical pattern to estimate the course of improving chances of survival in Mexico until 1985"(p.377).

In the Caribbean, Harewood (1974, pp.31-42) compares life expectancies of females with males presenting data from 1901-1970. His focus was on Trinidad and Tobago, but he also makes some references to the rest of the Caribbean. Here, too, the emphasis is a static view of life expectancy. No causal links are established. It is purely a demographic exercise.

By and large, most of the literature which touched on life expectancy did not come to grips with the fundamentals of why life expectancy differed among nations. In a scathing attack, Salas (1978,pp.276-282) points out the gap between life expectancies in the developing world and the developed world. The figures ranged from 42-54 years in the developing world to between 65 and 71 years in the developed world. Salas points out that the figures hide the distributional problem because there were some life expectancies from 38 to 73 years. Latin America was represented by an average of 62 years, Asia by 56 years, and Africa by 45 years. These rates have increased by one or two years since the mid-nineteen seventies data which Salas used. However, he makes an important point when he says (Salas, 1978)

> that a gap of 26 years in life expectancy should exist between Africa and the developed world is a tragic comment on the latter's inability to give substance to the rhetoric of global independency (p.278).

This disparity in data requires some explanation. Our paper is a first step towards that explanation. We will first consider what are the links between life expectancy, on the one hand, and some well established demographic and economic variables on the other. We now turn to the model in section three.

IV. Life Expectancy Model

A model is an attempt to come to grips with the links between reality and manageability. But modeling could, conceivably, be located in the framework of an art and a science (Intriligator, 1978, p.14-15). The model we offer below is our attempt to determine the impact of birth rate (BR), death rate (DR) Infant Mortality (IM), and per capita Gross National Product (PY) on life expectancy.

$$LE \quad = \quad LE(BR, DR, IM, PY) \qquad (8.0)$$

The behavioral conditions that we have attached to the equation are:

$$\frac{\delta LE}{\delta BR} < 0; \quad \frac{\delta LE}{\delta DR} < 0; \quad \frac{\delta LE}{\delta IM} < 0; \quad \frac{\delta LE}{\delta PY} > 0 \qquad (9.0)$$

Essentially, we are arguing from (9.0) that there is on the one hand a positive relationship between life expectancy and per capita income. On the other hand there is an inverse or negative relationship between life expectancy and birth rate, death rate, and infant mortality. We have defined life expectancy before. We define the other variables as follows:

Birth rate

(BR) is the number of births per year per thousand population in a given state, country, district or group.

Death rate

(DR) is the percentage of deaths, normally counted at per thousand among the population of a country or some other geographical or political entity, over a given period.

Infant Mortality Rate

(IM) is the number of deaths of persons from age one and below relative to the number of live births in a country, and so on, over a period of time.

Per Capita Gross National Product

Per Capita Gross National Product is the Gross National Product of a country divided by the population. This datum is traditionally thought of as a measure of economic growth, and sometimes, of the level of living in a country. Linearizing equation (8.0) we have

$$LE = a + b_1 BR + b_2 DR + b_3 IM + b_4 PY + U \quad (10.0)$$

where (1) the variables are the same from earlier definitions, (2) the behavioral characteristics are now illustrated by b's and U is the stochastic disturbance term. LE is the dependent or endogeneous variable, BR, DR, IM, PY are the independent or exogenous variables. These variables, along with the assumptions regarding the distribution of the stochastic term, U, represent the basic linear regression model.

The stochastic assumptions concerning the disturbance term U, namely the "disturbance assumption," the "assumption of homoskedasticity," the heteroskedasticity and the "absence of serial correlation" are all well known and well developed in the literature. Some basic references include Christ (1966), Malinvaud (1970), Theil (1971), Schmidt (1976), and Intriligator (1978). Consequently, we need not reproduce those assumptions here.

In all econometric problems, we need to bear in mind the problems of multicollinearity, heteroskedasticity serial correlation, qualitative dependent variables, specification errors in variables, structural breaks, among other econometric shortcomings. The most important issues in the case of single-equation econometric studies are multicollinearity, heteroskedasticity and serial correlation.

Multicollinearity could occur as a result of several factors: (a) a constant across sample variable; (b) one explanatory variable as a combination of other variables; (c) a dummy variable which is all inclusive of other dummy variables, and so on. In all cases, the normal equations of the least squares will not be solved. It should be noted, however, that multicollinearity is not a major problem if forecasting is the objective of the analysis. Good fo ecasts can be obtained from estimates even though multicollinearity is present. In our case, structural analysis is of greater importance than forecasting. An evaluation of the separate effects of the individual variables is our task. Multicollinearity is a serious problem in this case; however, we did not detect any evidence of multiple collinearity in our equation.

Heteroskedasticity develops when there is a breakdown in the assumption of homoskedasticity; in other words, when the variances of the stochastic disturbance term are not finite and constant over the sample, homoskedasticity will be present. When this problem exists, the least-squares estimates will not be efficient and not be the best estimations--even though they may still be linear. In addition, a certain degree of bias will be built in the estimates, hence the conventional t and F tests will not be valid tests of statistical significance.[9] Here, too, we did not detect any instance of heteroskedasticity.

Finally, we turn to serial or autocorrelation. This common problem in applied econometrics refers to the situation wherein the disturbance terms are not independent of one another. When serial correlation exists, its inadequacies are similar to those which obtain in the presence of heteroskedasticity. The Durbin-Watson test provides the kind of "prescription" to accept or reject serial correlation. Once again, our equation has passed the test. Let us now turn to the data.

V. Data Used

The data used were obtained from a World Bank Publication, The Assault on World Poverty (1975). As presented in the appendix, the data are from annex two (1975, pp.414-415). The original sources for the variables are for (i) per capita GNP, World Bank Atlas (1973, pp.6-14); (ii) crude birth, death rates, and life expectancies, United Nations projections, unpublished data; averages for 1970-1975; (iii) infant mortality rates, World Health Organization (1979). Infant mortality in some countries such as Albania, Burundi, Indonesia, Dahomey, Uganda, Senegal, Ghana, Syrian Arab Republic, Honduras, Ivory Coast, Japan, Zambia, and Trinidad and Tobago were obtained from the United Nations Statistical Yearbook 1972 (1973). In some other cases as in Nigeria and Ecuador, infant mortality rates were estimated by the World Bank.

Given the variety of sources from which these data were put together by the World Bank, it is quite possible that the data are afflicted with the usual problems. However, a cross checking of the relevant data did not show too many deviations from those generally in use in some of the countries checked. We believe, therefore, that any inaccuracies or biases in the data used, are on the order of small.

The means of the variables are:

Life Expectancy	55.0433
Birth Rate	39.2731
Death Rate	14.2985
Infant Mortality	169.6269
Gross National Product	498.2091

VI. Estimated Model

The estimated model and its relevant test statistics are given below, where the standard errors are in parentheses below the estimated coeficients:

$$\underset{}{LE} = \underset{(1.1816)}{82.7413} - \underset{(0.0336)}{0.2445BR} - \underset{(0.0004)}{1.2440DR} - \underset{(0.0636)}{0.0090IM} + \underset{(0.0058)}{0.0010PY}$$

R^2 = 0.9763

F (4,62) =637.4561

D-W (Adjusted for 0 gaps)= 1.9606

Number of Observations = 67

Sum of Squares =186.8849

Standard Error of the Regression = 1.7362

Birth rate, death rate, and per capita gross national product are all statistically significant at the one percent level of statistical significance, using a two-tail test.

The R^2 indicates an explanation of over 97 per cent of the variation in the variables; and with the Durbin-Watson statistic hovering around two, there is no indication of serial or autocorrelation. With a standard deviation of 1.7362, our results indicate that the estimates of the standard deviation of the coefficients fall within 1.7362 standard deviation of their respect values.

VII. Econometric Results

The signs of the estimated coefficients are in accordance with the predicted or theoretical signs which we outlined in equation nine. In the cases of Infant Mortality (IM) and Per Capita Gross National Product (PY), their magnitudes are smaller than we anticipated. Particularly in the case of the latter, we thought, apriori, that it would have been of the order of the coefficient of the death rate.

Our concern in this paper is to get a first approximation of the relationship between life expectancy and the right hand side variables of death rate, infant mortality, per capita gross national product, and birth rate. For the future, however, the model could be reformulated to come to grips with future implications as they impact on other variables. In this respect the single equation model may be reformulated to account for a simultaneous equation system. Here we may wish to have life expectancy as a function of the present set of variables. In turn, each of the independent variables could themselves depend on other variables.

For illustration, birth rate could be a function of health expenditures per capita; the health budget relative to Gross National Product, and so on. Death rate could also be a function of these variables. Likewise, infant mortality could be a function of health expenditures devoted to prevention of diseases; the population per bed ratio; the population per physician ratio: the support services per physician; and the rest. In essence, there are several other instances wherein we can reformulate our model to capture more explanatory power in the choice of variables.

In addition to the reformulation of the model, we could also develop alternative structural prescription in future work. We may wish to use log analyses as well as disaggregation of the data according to income strata among the countries in question. From the log analyses we could interpret the parameters estimates, directly, as elasticities. Disaggregation of the data according to income strata would filter out some noise in the results. Suffice to say, that our single equation system is merely a first attempt at coming to grips with some of the underpinning features of life expectancy as it relates to birth rate, death rate, infant mortality, and per capita gross national product.

VIII. Uses of the Estimated Model

In considering the uses of the estimated model, we will focus on the structural analysis of the model. Here the relevant multipliers, the elasticities, forecasting and policy evaluation are crucial for us.

The Impact Multipliers are given in Table I.

Table I: Impact Multipliers

Exogeneous Variable \ Endogeneous Variable	Life Expectancy
Birth Rate	- .2445
Death Rate	- 1.2440
Infant Mortality	0.0089
Per Capita GNP	0.0010

The first line indicates that if the birth rate is increased by 1 per thousand, life expectancy will decline by .2445 years or a little over three months. The second line suggests that if death rate increases by 1 per thousand, life expectancy will decline by 1.2440 year or about 15 months. Line three implies that if infant mortality increases by 1 relative to the population, life expectancy will decline by three days. Finally, if per capita income increases by one dollar, life expectancy will increase by less than a day.

A few observations seem pertinent at this stage relative to the impact multipliers. The estimate of the death rate has largest impact on life expectancy. The small impact of life expectancy derivable from infant mortality changes may be due to some integrative effects between infant mortality and death rate. Likewise, the very miniscule impact of per capita income on life expectancy, positive though the coefficient is, may be due to the wide variability in data, aggregation problems, and poor measure of GNP variable. In this case, a gini-coefficient may have been more appropriately used. Gini-coefficients are not readily available for all of the countries.

Let us now turn to the elasticities evaluated at the means. In Table 2 we present the results.

Table 2: Elasticities for Birth and Death Rate, Infant Mortality, and Per Capita GNP

Elasticities	Value
$\eta_{LE, BR}$	- 0.1744
$\eta_{LE, DR}$	- 0.3232
$\eta_{LE, IM}$	- 0.0274
$\eta_{LE, Q}$	- 0.0091

From Table 2 we note that line one suggests that the relationship between life expectancy and birth rate is negative, and furthermore it could be characterized as inelastic. Specifically, for every 1 percent increase in birth rate, life expectancy will fall by over 17 percent. Lines two and three are similarly characterized as line one. In these two cases, for every 1 percent increase in death rate, life expectancy will fall by over 32 percent. For every one percent increase in infant mortality, life expectancy will fall by two percent. Finally, for every 1 percent increase in GNP, life expectancy will increase by .91 percent.

IX. Conclusion

In the final analysis, in this paper we were concerned with beginning a systemmatic analysis of the relationship of life expectancy to birth rate, death rate, infant mortality, and per capita gross national product. All of the variables except infant mortality are statistically significant at the 1 percent level. From the point of view of the impact multipliers, the order of impact is death rate, birth rate, infant mortality and per capita GNP. And from the view of the elasticities, the impact order is death rate, birth rate, infant mortality, and per capita GNP.

The results are indicative of a first approximation to work which is critical to developing or Third World Countires. We have some reservations with regards to the impact multiplier and elasticity of per capita GNP. Our concern also centers on infant mortality from the point of view of its impact multiplier. Nevertheless, for the policy maker, it seems that we may state, with some caveats, that a reduction in death rate will have a positive impact on life expectancy. This may create a long-run problem of an aged non-productive problem, in a dynamic framework. A second point could be made, namely, per capita income has a positive relationship with life expectancy. This is really stretching the imagination a bit. It is important to note, again, that the disparate sources of income data may have caused some problems in the results. All things being equal, however, the results are a beginning. Perhaps we are anticipating large parameter estimates when in fact what we have obtained are the best linear estimates.

Future work in this area, may be usefully tackled by evaluating the data in logs, eliminating infant mortality, or merely considering a difference of birth and death rate. In addition, other variables could be incorporated. Some, such as nurses per population, health expenditures per capita and so on, may make the results of the life expectancy model more precise in all variables. Nonetheless, we believe that the results offer a beginning in this vital area of life expectancy. Since the area seems to be inadequately discussed in the literature, there is a great deal of work to be done. For us, we plan to disaggregate the data in "developed" and "developing" countries, as well as make some other structural changes in our basic life expectancy equation. In our future work, too, we will focus on the policy implications to be derived from the study from the point of view of the decision-maker in Microstate Economies.

Appendix

Measures of Health Status by Level of Per Capita Gross National Product (GNP) in Selected Countries

Countries	Per Capita GNP	Crude birth rate	Crude death rate	Infant Mortality	Life expectancy
Burundi	60	41.8	24.9	150	39.0
Upper Volta	70	48.5	24.9	180	39.0
Ethiopia	80	49.5	23.8	162	40.0
Indonesia	80	44.8	18.9	125	45.4
Yeman Arab Republic	90	49.5	20.0	160	45.5
Malawi	90	47.7	23.7	148	41.0
Guinea	90	46.6	22.8	240	41.0
Sri Lanka	100	28.6	6.3	50	67.8
Dahomey	100	49.9	23.0	110	41.0
Tanzania	110	50.1	23.4	122	44.5
India	110	41.1	16.3	139	49.2
Sudan	120	47.8	18.5	130	47.2
Yemen, People's Democratic Republic of	120	50.0	22.7	160	45.3
Uganda	130	46.9	15.7	160	50.0
Pakistan	130	47.6	16.8	130	49.4
Nigeria	140	49.3	22.7	150	41.0
Central African Republic	150	43.2	22.5	190	41.0
Mauritania	170	48.8	23.4	187	41.0
Bolivia	190	43.7	18.0	60	46.7
Liberia	210	50.7	22.3	159	43.5
Sierra Leone	210	41.9	20.2	197	43.5

Countries	Per Capita GNP	Crude birth rate	Crude death rate	Infant Mortality	Life expectancy
Thailand	210	43.7	10.4	23	58.6
Egypt, Arab Republic of	220	37.8	15.0	120	50.7
Viet-Nam, Republic of	230	41.8	23.6	100	40.5
Philippines	240	43.6	10.5	62	58.4
Senegal	250	47.3	22.2	93	42.0
Ghana	250	48.8	21.9	156	43.5
Congo	270	45.1	20.8	180	43.5
Paraguay	280	42.2	8.6	39	61.5
Syrian Arab Republic	290	46.9	14.4	24	53.8
Hunduras	300	49.3	14.6	37	53.5
Ecuador	310	41.8	9.5	87	59.6
Tunisia	320	41.0	13.9	76	54.1
El Salvador	320	42.2	11.1	58	57.8
Ivory Coast	330	45.6	20.6	138	43.5
Turkey	340	39.4	12.7	153	56.4
Algeria	360	49.4	16.6	86	51.5
Iraq	370	49.2	14.8	26	52.6
Columbia	370	40.6	8.8	81	60.9
Zambia	380	51.5	20.3	259	44.5
Guatemala	390	42.8	13.7	83	52.9
Malaysia	400	39.0	9.8	38	59.4
Dominican Republic	430	45.8	11.0	49	57.8
China, Republic of	430	26.7	10.2	18	61.6
Iran	450	45.3	15.6	160	51.0

Countries	Per Capita GNP	Crude birth rate	Crude death rate	Infant Mortality	Life expectancy
Nicaragua	450	48.3	13.9	45	52.9
Brazil	460	37.1	8.8	110	61.4
Peru	480	41.0	11.9	67	55.7
Albania	480	33.4	6.5	87	68.6
Cuba	510	28.9	5.9	28	72.3
Costa Rica	590	33.4	5.9	56	68.2
Mexico	700	42.0	8.6	63	63.2
Jamaica	720	33.2	7.1	27	69.5
Portugal	730	18.4	10.1	50	66.0
Yugoslavia	730	18.2	9.2	44	67.5
Romania	740	19.3	10.3	40	67.2
Chile	760	25.9	8.1	71	64.3
Panama	820	36.2	7.1	34	66.5
Bulgaria	820	16.2	9.1	26	71.8
Hong Kong	900	19.4	5.5	17	70.0
Trinidad & Tobago	940	25.3	5.9	35	69.5
Venezuela	1,060	36.1	7.0	52	64.7
Singapore	1,200	21.2	5.1	19	69.5
U.S.S.R	1,400	17.8	7.9	23	70.4
Japan	2,130	19.2	6.6	12	73.3
Israel	2,190	26.2	6.7	24	70.5
United States	5,160	16.2	9.4	19	71.3

Source: The Assault on World Poverty, Baltimore: Johns Hopkins University Press, 1975, pp. 414-415 (Annex 2).

Notes

1. For a discussion on these, see Health Condition in the Americas (1978).

2. For a discussion of life tables and the mathematical analysis used in this section, see Keyfitz (1972).

3. For another point of view, see (Jones: 1975: 215).

4. For a recent analysis of fertility and development, see Repetto (1979). Repetto argues that intranational and international income redistribution is a feasible mechanism of development to reduce fertility. He tests the hypothesis that, at any stage of economic development, the birth rate will be lower the more equal the distribution of income. See Repetto's earlier work (1978).

5. Other discussions of "fertility" decline can be found in Jay Weinstein (1978). Michael E. Conroy (1974) and Nancy R. Folbre (1976) are concerned with pointing out that there is no direct relationship between fertility decline and public expenditure.

6. Some quasi-linked references to our topic may be squeezed from the fertility development nexus which are found in Alvin J. Harman (1970); John D. Kasarda (1971); Harvey Leibenstein (1974). By and large these authors, and numerous others, are concerned with fertility decline and their impact on economic development. All of them tend to concur with Leibenstein (1974:470-71) that the "determinants of fertility decline are manifold." History, socio-cultural factors, cultural forces all play critical roles.

7. For another view which addresses the question 'what influence do human made conditions have on fertility rate' see JoAnn Kropp Glittenberg (1979).

8. This linearity/non-linearity discussion as it relates to fertility (and indirectly to life expectancy) has been discussed by: T. Paul Schultz (1974). He notes that the character of family size suggests that linear demand models are too restrictive for the study of fertility. Both theoretical and empirical evidence have been presented for non-linearity between explanatory variables and fertility.
Empirical analyses using Microeconomics Data, vis-à-vis fertility; See Robert Willis (1973); Eva Bernhardt (1972); Julian Simon (1974); W. Sanderson and R. Willis (1971). All of these authors have made the claim for non-linearity between fertility and the various variables used.

9. See Goldfield and Quandt (1965) for a discussion of some tests of heteroskedasticity.

REFERENCES

Adelman, I. An econometric analysis of population growth, American Economic Review, 1963, 53, 315-399.

Bernhardt, E. Fertility and economic status in Sweden: some recent findings on differentials in Sweden. Population Studies, 1972, 26, 2.

Chiang, C.L. A stochastic model for health service planning, Systems Analysis Applied Health Services, PAHO Advisory Committee on Medical Research, Washington, D.C. 1972.

Christ, C. Econometric models and methods, New York: John Wiley and Sons, 1966.

Coale, A. Hoover, E.M. Population and economic development in low-income countries, New Jersey: Princeton University Press, 1972.

Conroy, M.E. Recent research in economic demography related to Latin America and the Agenda Latin American Research Review, 1979, 9 3-27.

Conroy, M. and Folbre, N.R. Population growth as a deterrent to economic growth: A repraisal of the evidence, Institute of Society Ethics and Life Sciences, February, 1976.

Glittenberg, J.K. A comparative study of fertility in highland Guatemala: A Ladino and Indian town Caribbean Studies Association Fourth Annual Meeting, Martinique 1979.

Goldfield, S.M. and Quandt, R.E. Some tests for homoskedasticity, Journal of the American Statistical Association, 60 539-547.

Gregory, P. et al. Differences in fertility: development and developing countries, Journal of Development Studies, 1973, 9, 233-241.

Harewood, J. The population of Trinidad and Tobago, CICRED Series, Institute of Social and Economic Research, St. Augustine: Trinidad, University of the West Indies, 1974.

Harman, A.J. Fertility and economic behaviour in the Philipines. Santa Monica, California: Rand Corporation, 1970, (Mimeograph)

Intriligator, M.D. Econometric models, techniques and applications. New Jersey: Prentice-Hall, 1978.

Jones, G. Population growth and educational planning in developing nations, New York: John Wiley and Sons, Inc., 1975.

Kasarda, J.D. Economic structure and fertility: a comparative analysis, Demography 1971, 8 307-317.

Keyfitz, N. Applied mathematical demography, New York: John Wiley and Sons, 1972.

Leibenstein, H. An interpretation of the economic theory of fertility: promising path or blind alley Journal of Economic Literature, 1974, 12 457-479.

Malinvaud, E. Statistical methods in econometrics (2nd Rev. Ed). Amsterdam: North-Holland Publishing Co., 1970.

Pan American Health Organization (PAHO), Health conditions in the Americas, 1973-1976, Scientific Publication (No.364) Washington, D.C., 1978.

Roberts, G.W. Some demographic considerations of federation, Social and Economic Studies, 1957, 6, (2), 264-265.

Roberts, G.W. The present fertility position of Jamaica, in Egon Szabody (Ed), World Views of Population Problems, Budapest: 1968.

Repetto, R. The interaction of fertility and the size distribution of income, Journal of Development Studies, 1978, 14, 22-39.

Repetto, R. Economic equality and fertility in developing countries, Baltimore: Johns Hopkins Press, 1979.

Sanderson, W. and Willis, R. Economic models of fertility: some examples and implications Annual Report, National Bureau of Economic Research, 1971.

Salas, R.M. World population growth: hopeful signs of a slow down, The Futurist, October 1978, XII, (5) 276-282.

Schutz, T.P. Fertility determinants: a theory, evidence and an application to policy evaluation, Santa Monica: Rand Corporation, 1974.

Schmidt, P. Econometrics, New York: Marcel Dekker, 1976.

Simon, J. The effects of income on fertility, Population Studies, 1969, 23, 327-341.

Simon, J. The effects of income on fertility, Chapel Hill: Population Center, University of North Carolina, Monograph 19, 1974.

Sinclair, S. A fertility analysis of Jamaica: recent trends with reference to the parish of St. Ann, Social and Economic Studies, 1974, 23, (4) 588-636.

Stewart, C.T. (Jr.) and Siddayao, C.M. Increasing the supply of medical manpower, Washington D.C.: American Enterprise Institute, 1973.

Theil, H. Principles of Econometrics, New York: John Wiley and Sons, 1971.

Todaro, M.P. Economics for a developing world, London: Longmans Group, 1970.

Weinstein, J. Fertility decline and social services access: reconciling behaviorial and medical models, Comparative International Development, Spring, 1978, XIII, (1), 71-99.

Weinstraub, R. The birth rate and economic development: an empirical study, Econometrica, 1962, 30, (4) 812-817.

Willis, R. An econometric analysis of fertility in Sweden, 1870-1965, Econometrica, 1973, 41.

World Bank, The assault on poverty, Baltimore: John Hopkins Press, 1975.

World Health Organization (WHO), National Health Plannning in Developing Countries, Technical Reports Series, No. 350, Geneva, 1967.