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Income and Inequality as Determinants of Mortality: An International Cross-Section Analysis*

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INTRODUCTION

The determinants of mortality change in less developed countries are not easy to unravel. Improvements in health technology and availability are evidently relevant; education certainly plays an important part; sanitation, clean water supply and a host of other environmental variables have undoubted effects. But empirically, the effects of these different factors are difficult to identify. The variables tend to be collinear with each other, and with many other aspects of development, making their isolation difficult. Moreover, there is a tendency for health programmes to be most intensive in the least healthy places, for obvious reasons, further confusing observed relationships.

Identifying the impact of factors such as these, which are directly associated with health, is well worth while for purposes of policy formulation; but it may not be critical for a description of mortality changes in the process of development. For behind these specific variables, the overall economic status of individuals is likely to dominate health changes-through nutrition and other aspects of consumption, and also because economic status is a close correlate and determinant of many of the more specific variables noted above. Higher incomes may be a precondition for healthier environments and better health services, given competing demands on resources-this is self-evident at the community or national level but is also likely to hold at the individual level. Thus, for a general empirical analysis, it is quite reasonable to propose a sequence of causation which goes from income to mortality via a number of intermediate variables with which we need not necessarily concern ourselves.

THEORY

Let us suppose that at the individual level there is a relationship between income and life expectancy. Observations in developed countries suggest that this relationship is asymptotic; that is, there is a maximum life expectancy beyond which increases in income have no further effect. It is even possible that at very high incomes, diseconomies of excessive income might reduce life expectancy, but this we disregard for present purposes. The relation between income and life expectancy is thus non-linear, and we can reasonably suppose that it will take the form suggested by FF_1 in Diagram 1, with the slope of the curve declining (at a declining rate) with increasing income. This suggests the use of the reciprocal of income as a determinant of life expectancy. There is also some intuitive support for the proposition that a proportional change in income may be required for arithmetic changes in mortality, but the presumption here is weaker. If correct, this would suggest the use of the logarithm of income as the explanatory variable.

The relationship in Diagram 1 is defined for an individual. In practice, however, data for studying this type of relationship are available only at the aggregate level, if only because of the difficulty of generating appropriate, accurate micro-data. Thus, we need to formulate a relation between life expectancy at community or national level, and the incomes of the individuals composing the society concerned. With a linear relation between life expectancy and income, no problem arises; a corresponding linear relationship between mean life expectancy and mean income

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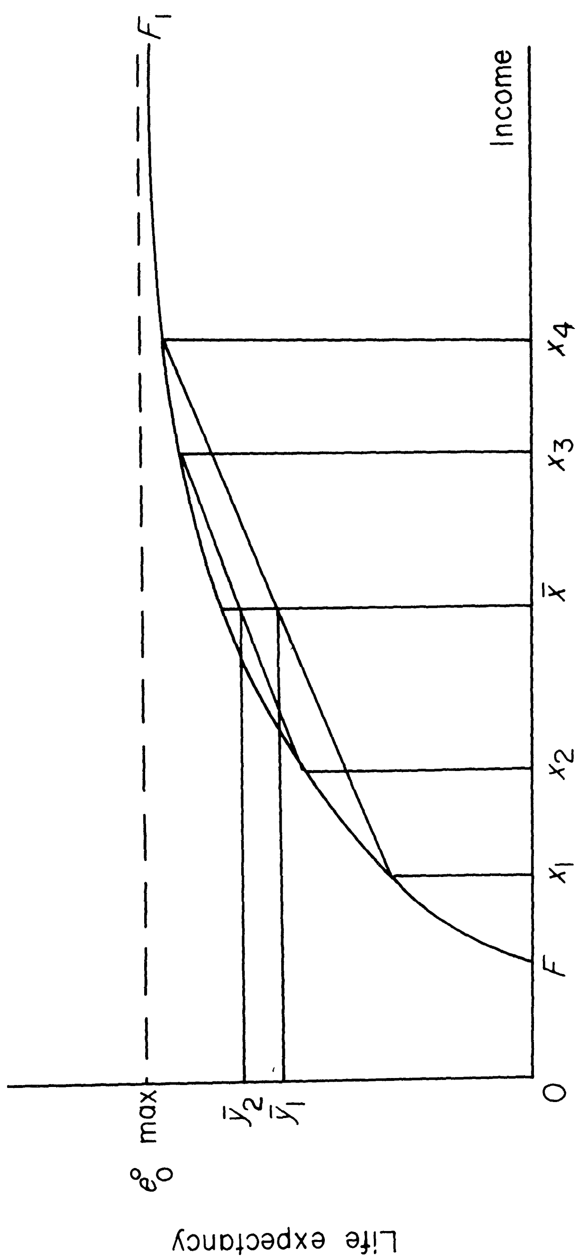

Diagram 1. *Life expectancy as a function of income.*

can be defined. However, our function is non-linear, and mean life expectancy is a function not only of the mean income level, but also of the distribution of income. Without defining the distribution function for income, no complete relation can be established. But it is clear that there will be a tendency for greater dispersion of income to be associated with lower mean life expectancy. This can be seen by taking two income observations in Diagram 1, x_1 and x_4, with mean $\bar{x}$; their mean life expectancy is $\bar{y}_1$. If dispersion is reduced, by raising x_1 to x_2 and reducing x_4 to x_3, while holding $\bar{x}$ constant, mean life expectancy is raised to $\bar{y}_2$. This relationship is discussed in more detail in an appendix.[1] In theory, it holds only for the mean deviation measure of dispersion; in practice, however, different measures of disperson of income are highly correlated, so that under normal circumstances a similar negative relation may be expected between mean life expectancy and measures such as the variance or the Gini coefficient.

Our macro-model can therefore be specified as

$$Y = a + f(X) + bG + \epsilon$$

where Y is mortality or life expectancy

$f(X)$ is a function of mean income

G is a measure of income distribution

ϵ is an error term

The precise shape of this function depends on the joint relation between a number of other variables and income and mortality. General improvements in medical technology, for instance, will shift the asymptote upwards; this could be represented by introducing time explicitly into the function. More specific health improvements (e.g. eradication of malaria, exceptionally large health programmes, etc.) may also shift the function at lower income levels. It might, therefore, be possible to analyse the impact of such variables by looking at deviations from the trend relation with income. However, we do not treat these issues in the present paper.

DATA

The function described above has been estimated using international cross-sectional data from 56 countries. The basic criterion for choice of the countries was that income distribution data were available. The distribution of income data used are those of Paukert,[2] in some cases somewhat updated, with Thailand added and Lebanon deleted for lack of appropriate mortality information. Gini coefficients and quintile distributions were taken from this source.

Mortality data (life expectancy at ages 0 and 5, and infant mortality) were taken either from standard demographic sources[3] or from an ILO compilation.[4]

For the income variable, national income per head in United States dollars was taken for a year approximating as closely as possible to the year for which life expectancy data were available.[5] Some cases where the income and life expectancy referred to very different dates have been dropped.

RESULTS

A variety of different model specifications were tried, using three different dependent variables–

[1] Cf. also S. H. Preston, 'The Changing Relation between Mortality and Level of Economic Development'. *Population Studies,* **29,** 2 (July, 1975), pp. 231–248.

[2] F. Paukert, 'The Distribution of Income at Different Levels of Development', *International Labour Review,* **108,** 2–3 (August–September 1973).

[3] E.g., UN, *Demographic Yearbooks* (New York, various dates).

[4] Due to Richard Anker. Sources for this compilation are given in R. Anker, 'An Analysis of Fertility Differentials in Developing Countries', *Review of Economics and Statistics.* **60,** 4 (February 1978).

[5] From UN, *Yearbooks of National Accounts Statistics* (New York, various dates).

expectation of life at birth, at fifth birthday, and infant mortality. The income variable was tried in a number of different specifications, including reciprocal, reciprocal quadratic and reciprocal logarithm. The income distribution variable used was the Gini coefficient, except that in some runs the mean income of specified population groups was used rather than mean overall income, to combine income and its distribution into a single measure.[6]

(i) *Life expectancy at birth*

Results from three different specifications are given in Tables 1, 2 and 3. In general, it can be seen that both income and income distribution are highly significant, with R^2 mostly over 0.75.

In Table 1 a sequence of specifications based on logarithms of income is presented, parameterizing on a coefficient (p) multiplying income. Maximum explanation is achieved when this coefficient is 0.12. However, this gives an asymptotic life expectancy of about 95 years, which is unrealistic. On the other hand, if we select a value for the parameter p which gives us an asymptote of around 75 years, R^2 diminishes rapidly. Thus, there are some practical reasons for doubting the applicability of the formulation using the reciprocal logarithm and the Gini coefficient as independent variables. However, these are both highly significant.

Table 1. *Dependent variable: life expectancy at birth; whole sample.* Regression coefficients and* t *values* ($N = 56$). p: *parameter multiplying income*

p	Independent variables			Asymptote	R^2
	$\frac{1}{\log (pY)}$	$\frac{1}{(\log Y)^2}$	Gini		
1.00	−136.2 (11.85)	–	–	113.4	0.722
1.00	−132.0 (12.27)	–	−27.46 (3.10)	114.9	0.765
1.00	−3.71 (0.56)	−183.5 (3.79)	−35.26 (3.55)	103.0	0.775
0.01	0.1889 (2.43)	–	−44.30 (2.70)	63.5	0.188
0.02	−3.323 (8.16)	–	−56.01 (4.82)	71.7	0.600
0.03	−11.74 (11.32)	–	−47.52 (5.09)	78.9	0.736
0.06	−28.15 (12.46)	–	−38.85 (4.47)	87.2	0.770
0.08	−35.98 (12.57)		−36.58 (4.23)	90.3	0.773
0.10	−42.49 (12.60)	–	−35.12 (4.07)	92.6	0.7740
0.12	−48.09 (12.60)	–	−34.09 (3.95)	94.5	0.7741
0.15	−55.30 (12.59)	–	−32.98 (3.81)	96.7	0.7738

* Notes to tables are given after Table 6.

[6] Certain other specifications were tried out and dropped. In particular, (a) the year of the life expectancy data proved not to be significant in explaining asymptotic life expectancy; (b) a series of runs using income per adult equivalent rather than income per head gave virtually identical results, and was eliminated by applying Occam's razor; (c) experiments with non-asymptotic specifications of the income variable explained significantly less of the variance of life expectancy.

Table 2. *Dependent variable: life expectancy at birth, whole sample.* Regression coefficients and* t *values* (N = *56*).

Independent Variables			Asymptote	R^2
$\frac{1}{Y}$	$\frac{1}{Y^2}$	Gini		
−4469 (6.40)	149900 (3.38)	–	72.9	0.712
−2236 (12.11)	–	−43.87 (4.94)	73.7	0.760
−3389 (4.93)	76880 (1.74)	−36.47 (3.76)	75.1	0.773

* Notes to tables are given after Table 6.

Table 2 gives the results of an alternative formulation, using the reciprocal of income and its square, together with the Gini coefficient. All three variables are significant and the asymptote is more or less in line with *a priori* expectations. This is, therefore, a rather more satisfactory result.

In Table 3 we present the results of a different approach, using mean income of the lowest 20, 40, 60 and 80 per cent of the population respectively. Mean income for the population as a whole is also given for comparative purposes. The best results are achieved in the 60 per cent to 80 per cent levels in terms of the R^2s, and in the 20 per cent and 40 per cent levels in terms of the t values. When income in the population as a whole (the 100 per cent level) is used, the explanation is noticeably worse, thus further demonstrating the effect of income distribution on life expectancy. The asymptotes all fall within an acceptable range.

(ii) *Life expectancy at fifth birthday*

Much of the international variation in life expectancy is due to infant mortality, and we may

Table 3. *Dependent variable: life expectancy at birth; whole sample.* Regression coefficients and* t *values* (N = *56*). *a: population percentiles*

a	Independent variables		Asymptote	R^2
	$\frac{1}{Y_a}$	$\frac{1}{(Y_a)^2}$		
20	−1334 (8.26)	13751 (4.82)	75.0	0.724
40	−1821 (8.83)	24987 (5.00)	75.0	0.770
60	−2043 (7.41)	30799 (3.56)	73.9	0.781
80	−2505 (7.17)	45466 (3.30)	73.4	0.782
100	−4469 (6.40)	149900 (3.38)	72.9	0.712

* Notes to tables are given after Table 6.

Table 4. *Dependent variable: life expectancy at fifth birthday; whole sample.* Regression coefficients and* t *values* (N = *43*) (*best results and results for comparative purposes*)

a	p	Independent variables				Asymptote	R^2
		$\frac{1}{Y_a}$	$\frac{1}{(Y_a)^2}$	$\frac{1}{\log(pY_a)}$	Gini		
100	–	−1587 (11.10)	–	–	−18.02 (2.49)	70.4	0.758
100	0.05	–	–	−16.40 (11.05)	−15.33 (2.12)	78.2	0.756
100	1	–	–	−89.58 (9.57)	−6.31 (0.79)	97.9	0.700
80	–	−1299 (4.42)	11989 (1.05)	–	–	70.0	0.769
80	0.6	–	–	−31.24 (10.71)	–	82.3	0.737
60	0.8	–	–	−29.02 (10.81)	–	81.6	0.740

* Notes to tables are given after Table 6.

expect the factors affecting infant mortality to be somewhat different from those which influence adult and child mortality. Life expectancy at fifth birthday was, therefore, used as a dependent variable, partly as a proxy for adult mortality. The best results are given in Table 4. For reasons similar to those in the case of life expectancy at birth, the non-logarithmic formulation is preferable, and the most acceptable result is the simplest, using only the reciprocal of income and the Gini coefficient as explanatory variables. The squared reciprocal of income was nowhere significant. The level of explanation, as measured by R^2, is virtually as high as for life expectancy at birth.

(iii) *Infant mortality*

The best results with infant mortality as dependent variable are given in Table 5. R^2 is generally

Table 5. *Dependent variable: infant mortality; whole sample.* Regression coefficients and* t *values (*N = *51) (Best results and result for comparative purposes)*

a	p	Independent Variables				Asymptote	R^2
		$\frac{1}{Y_a}$	$\frac{1}{(Y_a)^2}$	$\frac{1}{\log(pY_a)}$	Gini		
100	–	6275 (7.04)	–	–	112.5 (2.58)	21.1	0.543
100	0.05	–	–	66.61 (7.29)	103.9 (2.43)	−11.5	0.559
100	1	–	–	385.6 (7.58)	64.1 (1.51)	−90	0.577
60	–	7465 (5.45)	−147433 (3.45)	–	–	14.0	0.581
80	1.6	–	–	229.1 (7.82)	–	−55.4	0.555

* Notes to tables are given after Table 6.

lower than for life expectancy at birth or birthday five; but otherwise the pattern is similar. The negative asymptote in the logarithmic form is unsatisfactory, and the best results are found when using income in the lowest 60 per cent of the population as the explanatory variable (with a squared term), and using overall income and the Gini coefficient.

(iv) *Less developed countries only*

In order to test the possibility that the results merely reflect the difference between two groups of countries, one developed, the other less developed, a series of runs was undertaken using only data for countries with incomes per head of less than $1,000. Some results are given in Table 6, where

Table 6. *Less developed countries only compared with all countries; selected regressions for comparative purposes*

Dependent	Independent variables				Asymptote	R^2
	$\frac{1}{Y}$	$\frac{1}{Y^2}$	$\frac{1}{\log Y}$	Gini		
Life expectancy at birth						
(i) less developed countries	–	–	−150.1 (8.47)	−37.96 (3.25)	124.6	0.646
(ii) all countries	–	–	−132.0 (12.27)	−27.46 (3.10)	114.9	0.765
(iii) less developed countries	−3041 (2.95)	56682 (0.94)	–	−41.30 (3.34)	74.6	0.646
(iv) all countries	−3389 (4.93)	76880 (1.74)	–	−36.47 (3.76)	75.1	0.773
Infant mortality						
(i) less developed countries	–	–	352.8 (4.09)	61.3 (1.05)	−84	0.324
(ii) all countries	–	–	385.6 (7.58)	64.07 (1.51)	−90	0.577
(i) less developed countries	4801 (0.91)	12751 (0.04)	–	78.67 (1.26)	38.1	0.333
(ii) all countries	10547 (2.99)	−279611 (1.25)	–	83.30 (1.69)	72	0.558

Y = income per head in US dollars (not deflated for price differences and changes); 'Gini' is the Gini coefficient of income inequality.

Figures in the tables are the estimated coefficients of the independent variables indicated, in a linear formulation, with t values in brackets. The asymptote is life expectancy (or mortality) as income tends to infinity, and equals the regression constant where only income variables are used. Where the Gini coefficient is included as an independent variable, it is assumed that it tends to 0.33 as income tends to infinity (see Paukert, *op. cit.* in footnote 2), and the overall asymptote reflects this.

The a coefficients refer to income in a certain proportion of the population. Thus for $a = 60$ we would have Y_{60} as the mean income per head in the 60 per cent of the population with the lowest incomes.

The p coefficients are merely designed to improve the logarithmic form by making it a three rather than a two-parameter model. The values reproduced are those giving the best or most interesting results.

it can be seen that significance is somewhat reduced by comparison with runs using the whole sample, particularly for infant mortality. However, the results on expectation of life at birth (and also those at fifth birthday, not reported here), hold up quite well, with significance generally retained, and estimated coefficients not significantly different from those on all countries.

CONCLUSION

The most striking result is the consistent significance of the income distribution variable. This is a very robust conclusion which holds across a variety of specifications and with each of the three dependent variables. Although a few specifications led to relatively low significance for income distribution, these were usually unacceptable for other reasons (e.g. poor asymptote), and the sign of the income distribution terms was always as expected-greater inequality being associated with higher mortality. The results for life expectancy at birth suggest that the difference in average life expectancy between a relatively egalitarian and a relatively inegalitarian country is likely to be as much as five to ten years. The distribution of income may not be the only factor operating, of course-inequality in income distribution is likely to be associated with inequality in access to health and social services, in education, and in a number of other aspects of society relevant to mortality.

The highly significant income terms are much more predictable, of course, but here, too, the form of the function is of interest. Asymptotes near the predicted level of 75 years for life expectancy at birth, 70 years at fifth birthday, and 15-20 per thousand for infant mortality are generated by functions using the reciprocal of income, or a quadratic expression in that variable, and these also tend to be among the best in terms of significance. These are functions which are sharply non-linear-in the last function in Table 2, for example, the rate of increase of life expectancy with income declines from 0.185 at \$100 per head to 0.003 at \$1,000 per head. The downward concavity conforms to expectations,[7] and gives indirect support to the conclusions with respect to income distribution.

Finally, it is worth stressing again that the neglect of health, environmental and social variables does not imply that they are unimportant. Rather it is only after gaining an overall appreciation of the relations between mortality and economic status and inequality that their impact can be assessed.

APPENDIX

Take any function, $Y = f(x)$, concave downwards (of which our postulated relationship between life expectancy and income is a special case). Let X be a random variable with unknown distribution. Then we postulate that given $E(X)$, $E(Y)$ is a negative function of the dispersion of X.

The mean deviation of X is given by

$$\sum_{i=1}^{n} (\bar{x} - x_i) + \sum_{j=1}^{m} (x_j - \bar{x})$$

where there are n and m observations below and above the mean respectively.

$$E(Y) = \sum_{i=1}^{n} f(x_i) + \sum_{j=1}^{m} f(x_j)$$

Let there be a number of infinitesimal changes, such that $E(X)$ is unchanged, but that Σx_i is increased and Σx_j reduced (i.e. the mean deviation is reduced).

$$E^*(Y) = \sum_{i=1}^{n} f(x_i + \epsilon_i) + \sum_{j=1}^{m} f(x_j + \epsilon_j)$$

where $\Sigma\epsilon_i > 0$; $\Sigma\epsilon_j < 0$; $\Sigma(\epsilon_i + \epsilon_j) = 0$

[7] The quadratic forms have unpredictable shapes at incomes below the range of the observations, but are of the expected form from a certain income level-\$68 per head in the case of the last function of Table 2.

Now

$$\Sigma f(x_i + \epsilon_i) \simeq \Sigma f(x_i) + \Sigma \epsilon_i f'(x_i)$$

$$\Sigma f(x_j + \epsilon_j) \simeq \Sigma f(x_j) + \Sigma \epsilon_j f'(x_j)$$

So

$$E^*(Y) \simeq E(Y) + \Sigma \epsilon_i f'(x_i) + \Sigma \epsilon_j f'(x_j)$$

By the definition of downward concavity, $f'(x_i) > f'(x_j)$ for all i, j, since $x_i < x_j$.

therefore $\Sigma \epsilon_i f'(x_i) + \Sigma \epsilon_j f'(x_j) > 0$

since $\Sigma \epsilon_i = - \Sigma \epsilon_j$

Whence $E^*(Y) > E(Y)$

i.e. a reduction in the dispersion of X raises the expected value of Y.

Note that this result only applies to the mean deviation. For other measures of dispersion it is usually possible to find counter-examples. However, in general such counter-examples are rather extreme and, in practice, in sico-economic systems different measures of dispersion are usually monotonically related with each other.