

## REPRINTS AND REFLECTIONS

# The changing relation between mortality and level of economic development

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The influence of economic conditions on mortality has been recognized at least since biblical times. Empiricism of the most casual sort was sufficient to establish the link between food supply and mortality. Other components of living standards, such as shelter and living space, awaited a revolution in scientific method before their influence was finally acknowledged. But recent years have witnessed a movement away from economic determinism in mortality analysis. It is widely believed that mortality has become increasingly dissociated from economic level because of a diffusion of medical and health technologies, facilities and personnel that occurred, in large part, independently of economic level, yet this position has its critics who have gained a sympathetic audience.<sup>1–4</sup> This article utilizes readily available evidence in a new but obvious way to estimate the relative contribution of economic factors to increases in life expectancy during the 20th century. The evidence consists of cross-sectional relationships between national life expectancies and national income per head evaluated during three different decades of the 20th century. These relationships are further used to assess the realism of certain economic-demographic models and to re-examine what have become classical distinctions regarding sources of mortality declines in Western and non-Western areas.

There are several reasons for focusing on national income rather than on another socio-economic variable. First, national income is probably the best single indicator of living standards in a country, since it comprises the value of all final products (goods and services) produced in a certain period. A wide range of these products can be expected to influence mortality, and expenditures on all of them are represented, with varying weights, in national income. It is the indicator most comprehensive of these multiple factors. Secondly, as the leading index of level of economic development, income per head is the focus of growth models from which policy measures are derived.

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## Types of relationships

National income per head in constant dollars is an index of the total value of final products produced per inhabitant during a defined period, exclusive of goods which merely replace losses from depreciation of capital equipment. There is no reason to expect a direct influence of national income per head on mortality; it measures simply the rate of entry of new goods and services into the household and business sectors. Its influence is indirect; a higher income implies and facilitates, though it does

not necessarily entail, larger real consumption of items affecting health, such as food, housing, medical and public health services, education, leisure, health-related research and, on the negative side, automobiles, cigarettes, animal fats and physical inertia.

Levels of mortality and economic development can be related to one another conceptually and substantively in a variety of ways. It is useful at the outset to distinguish among at least three different types of relationships that have been proposed by various analysts, although the exact formulation is often only implicit in their work. In order to simplify the task, we confine the review to international studies.

## Level of income influences level of mortality at a moment in time

Attempts at empirical estimation have focused on the cross-sectional relationship between mortality and economic level. Most commonly, the relationship between national infant mortality rates and levels of income has been examined.<sup>5–7</sup> Coefficients of correlation between the variables have been found to be consistently high, of the order of  $-0.8$ . The relationship is sufficiently strong for infant mortality rates on occasion to have been used as indicators of income levels when the requisite data for computing the latter are missing.<sup>8</sup> Gordon *et al.*<sup>9</sup> have suggested that the death rate of children in their second year of life may be a better indicator of general health levels than infant mortality, which responds to a number of influences not present at other ages. Frederiksen<sup>2</sup> provides partial support by showing that death rates at ages 1–4 are more closely correlated with gross national product per head in 15 countries than are death rates at ages 0–1, 20–24, or 65–69.

One study, confined to less developed countries, has demonstrated a close cross-national relationship between an index of mortality at all ages and from all causes, life expectancy at birth and the level of national income. Vallin suggests that no country can attain a life expectancy of more than 60 years without having made very substantial progress out of the category, 'less developed'.<sup>10</sup> At the same time, he stresses that the relationship is not deterministic and that a nation can, within limits, modify its life expectancy independently of its level of income. We shall re-examine the type of relationship studied by Vallin in a subsequent section.

On several occasions the United Nations Population Division has expressed the opinion that the cross-sectional relationship between mortality and level of economic development has become progressively weaker over time.<sup>11,12</sup> Others have echoed this claim and referred to a 'dissociation' of the two types of variables. However, data to support the claim have not been presented, and the present analysis fails to support the contention.

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### Level of income influences rate of change in mortality

Arriaga and Davis<sup>13</sup> suggest that the rate of improvement of mortality can be expected to be direct function of the existing level of mortality in a country. They make it clear that they intend the existing level of mortality to be a proxy variable for a nation's level of income, so that the rate of change of mortality is considered to be a function of level of income. Their path-breaking analysis of developments in Latin America shows that the expected relationship applied prior to 1920 or 1930 but that thereafter the rate of change in life expectancy became independent of levels of income. A lack of relationship was also suggested by Stolnitz<sup>14</sup> in his review of post-war mortality trends in less developed regions.

It is difficult to devise a plausible model in which the rate of change of mortality is a direct function of the level of income. One mechanism that conceivably could produce such a relationship occurs when a positive fraction of additions to current income is invested in various enterprises (such as housing, hospitals and training programme for medical personnel) that exert an effect on subsequent mortality. When the assumption is made that these investments continue to cumulate at a given level of income (rather than simply to replace depreciating facilities and withdrawing personnel), it becomes plausible that higher incomes will produce larger gains in life expectancy. The assumption is treacherous, however, and lacks an empirical basis. It implies that a country at a constant level of income will experience continuous increments in its stock of health-related capital, which it can do in reality only if the proportion of income invested in such capital is constantly rising or if the rate of depreciation of such capital is constantly falling.

A second mechanism that could produce a relationship between the level of income and the rate of change of mortality is dependent upon an association between the level of income and the rate of change of income. If low-income countries typically have slowly growing economies, and if the growth of income is positively associated with the gain in life expectancy, then one would observe larger gains in richer countries. This is probably the mechanism that Arriaga and Davis have in mind. However, the resulting relationship between level of income and change in mortality is clearly dependent upon the more fundamental (and logically separable) relationship between changes in income and changes in mortality.

We could continue to list possible reasons for expecting a relationship between level of income and change in mortality: for example, by assuming that a particular level of income is associated with a particular time-sequence of 'tastes' of health-related services or of health technology. But these mechanisms become increasingly speculative and groundless. There is no persuasive reason for expecting an association with other variables such as income change.

### Rate of change of income influences rate of change of mortality

A cross-sectional relationship between income and mortality, firmly established in the references cited earlier, also implies a dynamic relationship between the two. If the relationship is indeed causal, then a certain change in income should be associated with a particular change in mortality, with relative

magnitudes of change determined by coefficients of the relationship. Additional elements may figure in the dynamic relationship, however. In particular, the cross-sectional relationship between mortality and income may itself be changing in response to new influences.

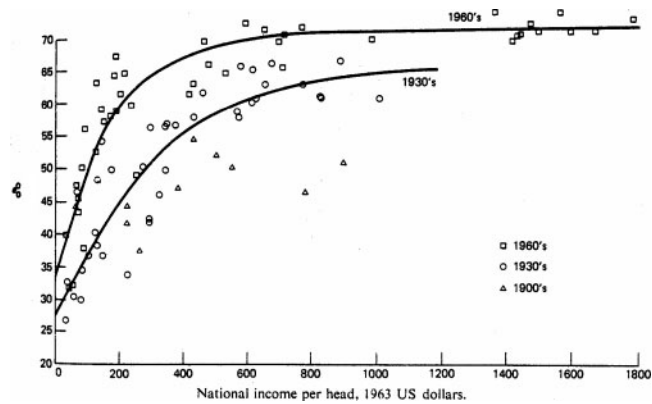
Malthus, of course, postulated a negative dynamic relationship between mortality and income level as a central tenet of his dismal theory. Those who have recently examined the relationship fail to uncover support for the postulated relationship. Stolnitz<sup>14</sup> states that recent mortality trends in Asia, Latin America and Africa have been 'remarkably neutral' with respect to economic events. Demeny states that 'the large amount of statistical material on underdeveloped countries which is available for the past two or three decades reveals the almost complete absence of such a relationship.... There is a high degree of uniformity between mortality trends through time and in different countries—a uniformity not existent as far as trends in per capita income are concerned'. Although perhaps obvious, it may be worth emphasizing that such a pattern is not inconsistent with a tight cross-sectional relationship between mortality and economic level throughout the period under consideration, provided that the structure of the cross-sectional relationship is changing.

### The relations re-examined

It is a straightforward matter to indicate what has happened to the cross-sectional relationship between income and mortality during the 20th century. The accompanying figure presents a scatter diagram of the relationship between level of life expectancy (average, male and female) and national income per head (1963 US dollars) in the 1900s, 1930s and 1960s. The criterion for inclusion was simply the availability of measures of the two variables; however, in the 1960s countries with populations of less than 2 million were excluded in order to reduce sampling variability. The data on which the figure is based are presented in Appendix 1. Life expectancy is computed by standard, direct methods with a few exceptions noted in the Appendix. Income figures are derived from Kuznets for the 1900s, from Kuznets and the United Nations 'Statistical Yearbook' for the 1930s, and primarily from the United Nations 'Statistical Yearbook' for the 1960s.<sup>15</sup> A country's income in a particular year is first converted to U.S. dollars by the series of official US consumer price indexes. This is only one possible way of proceeding, and it is well known that any choice of prices for weighting output in time or space is arbitrary. The present procedure is the only one capable of yielding as much information as is utilized here. As noted further, it seems virtually certain that a different procedure would not change the fundamental conclusions.

Attention is focused on the relationships in the 1930s and 1960s, for which most data are available. A logistic curve, plotted on the figure, was fitted to each set of data.

Placing all three sets of data on the same graph may obscure the fact that a curve fits the data for a particular period quite well throughout their range (Figure 1). The simple correlation between life expectancy and the logarithm of income per head is 0.885 in the 1930s and 0.880 in the 1960s; however, the simple logarithmic curves consistently overestimated life expectancy at lower levels of income, hence a more flexible curve was



**Figure 1** Scatter-diagram of relations between life expectancy at birth ( $e_0$ ) and national income per head for nations in the 1900s, 1930s and 1960s.

adopted. Despite the simplicity of approach, the following points can be made with some degree of assurance.

### 1. The relationship between life expectancy and national income per head has shifted upwards during the 20th century

The point can be made with greatest certainty for the period from the 1930s to 1960s. There are relatively few data points at incomes less than \$100 but such information as exists is broadly consistent with the conclusion. At higher income levels, the shift is unmistakable. It amounts to some 10–12 years of life expectancy at incomes between \$100 and \$500 and progressively less thereafter. The upper asymptotes differ by 4–7 years, suggesting that the maximum average length of life to be attained by gains in income alone was some 66.8 years in the 1930s and 71.5 years in the 1960s. The upper asymptote of 73.9 years assumed by the official UN projection can be attained on a broad scale only if the curve continues to shift upwards (Cf. U.N. 'World Population Prospects as Assessed in 1963.' Population Study No. 41. New York, 1966. There is mounting evidence that the UN Mortality projections are overoptimistic, at least for countries at higher levels of life expectancy. For example, the projection assumed that USA would achieve a life expectancy of 73.0 years by 1970. However, the actual life expectancy for the total population of the US in 1970 was only 70.9 years (US National Center for Health Statistics 'Vital Statistics of the United States,' 1970, Vol. 2). The rate of improvement in Canada, Australia and New Zealand is also behind schedule.).

The curves can be compared horizontally as well as vertically. Such a comparison suggests that, in order to attain a particular value of life expectancy between 40 and 60, a range that includes a large majority of the current world population, a nation required an income level approximately 2.6 times higher in the 1930s than in the 1960s (the constancy of this factor is one of the more intriguing features of the curves). No error in inter-temporal income comparisons seems capable of accounting for a change of anywhere near this magnitude.

There are too few observations in the 1900s to make curve fitting worthwhile. But evidence that a shift occurred during the earlier period as well is persuasive. Of the 10 observations

for the decade of the 1900s, nine lie below the line computed for the 1930s. There is some suggestion that the shift during the earlier period as compared with the later may have been somewhat smaller at low levels of income and somewhat larger at higher levels, but firm conclusions are not warranted. In any case, there is little reason to think that factors exogenous to a country's level of economic development began to affect mortality levels significantly only after the 1930s (The only exception is Japan. The unusually high life expectancy in Japan relative to income per head has also been noted by Taeuber (Irene B. Taeuber, 'The Population of Japan.' Princeton University Press, Princeton, 1958, p.284). She cites personal cleanliness and the assumption of health responsibility by government organizations as important factors in counteracting the adverse effects of poverty in Japan.), or operated with significantly greater impact thereafter. While post-war anti-malarial campaigns are perhaps the most dramatic example of non-economic factors influencing mortality, they were often preceded by small, more persistent campaigns against specific diseases. For example, Balfour *et al.*<sup>16</sup> report that colonial administrations achieved through specific public health measures the elimination of mortality from smallpox and cholera in Indonesia during the 1920s and major reductions from smallpox and plague in the Philippines by 1922. Mandle<sup>17</sup> cites similar developments in British Guiana during the 1920s with respect to malaria and respiratory and diarrhoeal disease. In these instances, the mortality reductions were not accompanied by substantial economic progress and Mandle indicates that the 1920s were a period of economic stagnation in British Guiana. Petersen<sup>18</sup> demonstrates that by 1920 Japanese colonial administrators in Taiwan had succeeded in bringing plague, cholera and smallpox under effective control through a variety of public health activities. Similar developments were unquestionably occurring in Western countries, as indicated below.

Since a country has attained a certain life expectancy in the 1960s at what is generally a much lower level of income than a country achieving that mortality level earlier, one would expect to observe certain differences in the structure of mortality by cause of death in the two populations. In particular, diseases most closely associated with standards of living, and least amenable to attack by specific medical and public health measures, ought to be relatively more prominent in the later population. Diarrhoeal disease, highly influenced by nutritional adequacy and level of personal sanitation, represent such a group. Records of age-standardized death rates leave little doubt that countries achieving a certain level of mortality at a later point in time typically do so with a higher incidence of death from diarrhoeal diseases (and a lower incidence of death from respiratory tuberculosis) than countries achieving that level earlier. Thus, data on causes of death tend to confirm the shift in the income/mortality relationship that has been described.<sup>19</sup>

### 2. Factors exogenous to a country's current level of income probably account for 75–90% of the growth in life expectancy for the world as a whole between the 1930s and the 1960s. Income growth per se accounts for only 10–25%

Evidence for this assertion is developed in the following way: We first assume that the curves fitted to data in the 1930s and

1960s accurately represent the relationship for all countries in those years, including those for which data are not available. We then substitute estimates of national income per head for each region of the world in the 1930s, use the 1930 curve to predict regional life expectancy, and weight the resulting predictions by population to estimate life expectancy for the world in the 1930s. Repeating the process but with income data for the 1960s, we produce an estimate of what life expectancy would have been in the 1960s with current income, but with the 1930 relationship between income and life expectancy still in effect. The difference between the two estimates indicates the gain in life expectancy attributable to income growth per se between the 1930s and the 1960s. We repeat the procedure once again, this time using the 1930 income data but the 1960 relationship; the difference between this estimate and the first indicates the gain in life expectancy attributable to shifts in the curve, or to factors exogenous to a country's contemporary level of economic development. The two differences, when added to the initial estimate, should come close to reproducing actual life expectancy in the 1960s.

Regional income data used in this procedure are presented in Appendix 2. They are, of course, even less reliable than national figures and can be used to give no more than a crude estimate of the relative importance of difference factors.

Results are presented in Table 1. If the 1930 relationship had remained in effect, the observed increases in income would have produced a gain in world life expectancy of 2.5 years between 1938 and 1963; the observed income changes combined with the 1960 relationship produce a gain of 1.3 years. These are estimates of the increase in life expectancy due to rising income during the period. The shift in the curve, on the other hand, produces a gain of 10.9 years when combined with the 1938 income distribution, and a gain of 9.7 years in combination with the 1963 distribution. The total increase estimated through the use of this procedure is 12.2 years during the quarter-century. The predicted life expectancy of 56.4 years for the 1960s can be compared with the recent estimate by the United Nations Population Division<sup>20</sup> of 53 for the period 1965–70 (no comparable estimate is available for the 1930s). The comparison shows reasonable agreement considering the faulty but different data on which both estimates are based. Aggregation of individual countries into regional blocs would tend to produce overestimates of life expectancy, as noted below in Section 3, and could account for the excess in our estimate. However, the need to aggregate

should not significantly bias the trends or the relative weighting of factors responsible.

This analysis implies that around 16% of the increase in life expectancy between 1938 and 1963 for the world as a whole is attributable to increases in average national income per se. A large but unspecifiable margin of error should be attached to this estimate because of faulty data and the simplicity of assumptions. The uncertainty is increased because the estimates are least reliable (based on fewest observations and on observations most susceptible to error) at lowest levels of income where a substantial proportion of the world's population was and is located. Nevertheless, it is almost inconceivable that income could be a factor of no consequence in the trends, in view of the tight cross-sectional relationship between income and mortality and the major improvements in income experienced by most regions during the period; on the other hand, it is implausible that income changes could account for more than one-third of the growth in life expectancy during the period, in view of the massive shift that occurred in the relation between income and life expectancy. The amount of change attributable to income growth varies, of course, from region to region and country to country; our calculations indicate that in Japan, for example, a majority of the expected increase in life expectancy was caused by rapid income growth. But it is doubtful whether a sufficient number of rigorous studies of mortality decline in different countries will soon be available to permit estimates based on a cumulation of state-level examinations. The more aggregative approach pursued here may serve to provide interim estimates of the magnitude of broad international developments.

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Factors exogenous to a country's current level of income are identified as being responsible for some 84% of the increase in life expectancy during the period. The phrase is cumbersome, because the analysis does not account for the possibility that the shift in the curve itself may be partly a product of growth in income. If medical research in country A is facilitated by a large national income and leads to mortality reduction in country B, income has influenced mortality. But neither country's mortality has been directly affected by its own income; the effect shows up as a shift in the curve. Even if country A were to enjoy the fruits of its own research, as long as those fruits were rapidly diffused to others, the originating country would be impossible to identify cross-sectionally; the situation would also find expression as a shift in the curve. In this case, in the vast majority of countries the change in mortality would also have been independent of individual levels of current income. The curves do not adequately reflect factors associated with income in a small sub-set of countries that operate on mortality in a larger set. The major factors likely to operate in this fashion are a diffusion of technological advances and, to a lesser extent, of international transfer payments that distort the proportion of national income spent on health-related services or that affect the efficiency of those services. What the curves do reflect is the influence of a country's 'own' level of income on mortality as it works endogenously through such factors as nutrition, medical and public health services and literacy.

**Table 1** Life expectancy for the world implied by combinations of income distributions and relationships between income and life expectancy

Relationship between income and life expectancy as observed in	Regional income in		Estimated change due to increase in income	
	1938	1963		
1930s	44.2	46.7	2.5	Average 1.9
1960s	55.1	56.4	1.3	
Estimated change due to shift in relationship	10.9	9.7	Total change	12.2
	Average 10.3			

We have 'explained' only some 16% of the rise in life expectancy during the period. Modest as this achievement is, it might be viewed in the context of statements appearing in numerous places that disentangling the separate effect of economic and social progress, as opposed to those of specific health measures is impossible.<sup>11</sup>

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Although we cannot account for the remaining increase in life expectancy, we can essentially rule out nutrition and literacy as major contributors. A graph has been prepared showing the relations between national levels of adult literacy and life expectancy around 1940 and in the 1960s. The same has been done for the relation between calorie consumption per head and life expectancy. There is no question that a vertical shift in the relationship, of a magnitude comparable with that pertaining to income, occur in both of these cases. If anything, the shift appears larger in the relation between calories and life expectancy than in the relation presently under investigation. Income, food and literacy were unquestionably placing limits on levels of life expectancy attained in the 1930s, as they do today. But they are not the only factors operating, and one must look elsewhere to account for the majority of recent trends.

### 3. Mortality has not become progressively dissociated from standards of living at a moment in time

This conclusion follows directly from our equal success in predicting life expectancy on the basis of national income in the 1930s and 1960s, as measured by the correlation coefficients presented earlier. There is virtually no difference between the log-linear correlation coefficients; the logistic form actually fits the points in the 1960s somewhat better than it did in the 1930s (the proportion of variance in  $\log_e (80/e_0^0 - 1)$  explained by income is 0.800 in the 1930s and 0.847 in the 1960s).

More interesting than the correlations is the suggestion that the shape of the relation has changed. The later curve appears to be steeper at incomes under \$400 and flatter at incomes over \$600. In other words, for low-income countries, a given increment in income tends to be associated with a larger gain in life expectancy in the 1960s than in the 1930s. Far from becoming dissociated from income, mortality may have become more responsive to it in low-income countries where economic-demographic interrelations are most critical for economic prospects. Two interpretations are consistent with such a change. First, new health measures may have evolved that are exploitable only by countries in which the lowest levels of income are past. Vaccination against tuberculosis and treatment of infectious diseases by antibiotics and by sulpha drugs are two important examples of technical improvements during the post-war period the potential of which can be realized only by fairly costly expenditure. A second interpretation is that international health programmes, more vigorous during the post-war period, have focused their efforts on those underdeveloped countries with the greatest potential for mortality reduction; in general, these would be the more advanced of the group. There may be nothing callous or sinister about such a procedure. It is easy to demonstrate, for example, that in two

countries with identical age schedules of death rates from malaria, eradication results in more years of life gained in the population with lower death rates from other causes. Unfortunately, documentation of the amount and effectiveness of international aid received for health proved to be a task far beyond the scope of this article.

To claim on the one hand that income has been a trivial factor in recent mortality trends and, on the other, that it is still a critical determinant of mortality levels is not inconsistent. The point is simply that mortality is subject to multiple influences. The demonstration that income has not been important for recent trends is absolutely no justification for removing the relationship from growth models that aspire to realism. If anything, the data suggest that mortality has become more responsive to income in the range of greatest interest.

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#### *3a. Some of the observed scatter in cross-sectional relations is almost certainly caused by differences in national income distributions*

The obvious explanation for the non-linearity of the mortality/income relationship is that it reflects diminishing returns to increases in income. It reflects on a broad scale a wide variety of dose-response relationships at the individual level that themselves exhibit diminishing returns: diarrhoeal disease and nutrition; respiratory pneumonia and antibiotics; tuberculosis and living space and so on. Moreover, it reflects aggregate-level relationships between national income and the success of programmes of sanitation, insect control, disease surveillance and so on.

When individual-level factors are pertinent in mortality and when the individual-level dose-response relations are non-linear, as they almost certainly are in this case, then the distribution of income will affect the aggregate life expectancy. If the dose-response relations were all linear, and identical from individual to individual and nation to nation, it is easy to show that a nation with a particular average income would have the same life expectancy regardless of how incomes were distributed.

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Now suppose, on the other hand, that life expectancy is an increasing function of personal income but subject to diminishing returns.

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At a certain level of average national income, life expectancy is lower the higher is the variance in the distribution of income. The reason for this outcome is obvious: people with incomes below the average lose more years of life than are gained by people at the equivalent distance above the average. The greater the spread, the larger the net loss. The distribution of incomes is clearly a likely source of variance in the basic relation between national life expectancy and average national income and accounts for some of the scatter in the observed relationship.

Unfortunately, the basic data on income distribution are inadequate to incorporate this factor explicitly in the analysis. Nevertheless, it is instructive to note that a country widely cited for large income inequalities, Venezuela, has one of the largest

negative deviations of any population. Actual life expectancy in 1965 fell short of that predicted on the basis of its average income by 4.8 years. Kuznets provides figures on the percentage of income earned by the top 5% of families in 18 selected countries.<sup>21</sup> Mexico and Colombia have the most uneven distributions of income on this index of any countries considered here, ranking 14th and 15th. These countries have life expectancies which are 6.7 and 2.1 years, respectively, below the levels predicted on the basis of average incomes. On the other hand, the Soviet-bloc countries, where income inequalities are expected to be smaller than those in other countries at equivalent average income levels, do not have exceptionally high life expectancies. Using the lower income figures for these countries in Appendix 1, thereby producing lower estimates of expected life expectancy, one finds that the deviations of actual from predicted life expectancy in the 1960s are as follows: Bulgaria, +2.1 years; Czechoslovakia, -0.5 years; East Germany, -0.8 years; Hungary, -2.4 years; Poland, -1.3 years; USSR, -0.2 years; Yugoslavia, -1.6 years. Actual life expectancy falls short of that predicted in every case but one. These deviations of actual from expected life expectancy may be artificially depressed by virtue of the fact that they refer to the period 1960-61, whereas the curve was computed on the basis of points observed throughout the 1960s; if the curve had continued to shift upwards during the period, the earlier points would have fallen increasingly short of the line. On the other hand, the deviations are probably artificially raised by the use of income figures that are almost certainly too low for comparative purposes. Net material product excludes the monetary value of the greater part of general administrative and social services and falls some 10-20% short of GNP.<sup>22</sup> In general, there is no compelling evidence that greater income equality (or better health services) would have raised the life expectancy in Soviet-bloc countries above the level to be expected on the basis of their average incomes.

#### **4. Factors exogenous to a nation's level of income per head have had a major effect on mortality trends in more developed as well as in less developed countries**

It is traditional wisdom that the mortality decline in more developed areas was intimately dependent upon advances in standards of living, and hence proceeded slowly; in less developed areas, it was a result of the importation of medical techniques and personnel and hence was rapid.<sup>23,24</sup>

As a statement of general tendencies this assertion is probably correct, but it requires important qualifications. It is based on a comparison of rates of mortality decline between two equivalent levels rather than between two equivalent points in time and has focused on the most spectacular declines in less developed areas. But the period-specific influences that operated on mortality in less developed areas after the 1930s also operated on mortality in more developed areas. It is clear from the graph that factors exogenous to a nation's level of economic development have affected the level of mortality in both groups. The result is that, during the period, the distributions of mortality decline for the two groups, while favouring the lower income group, overlap. France gained 13.7 years of life expectancy between 1928-38 and

1965, while Indonesia gained 13.3 between 1930-35 and 1961. Austria gained 13.7 years between 1930-33 and 1966; the Philippines, according to official figures subject to considerable error, gained 10.8 between 1938 and 1960, representing about the same annual rate. Spain, an intermediate case, showed a higher rate of improvement than any of these countries, with a gain of 21.6 years between 1930-31 and 1967. It is implausible that the tropical African countries with life expectancies in the high 30s or lower 40s during the 1960s<sup>25</sup> could have gained at a rate as rapid as that in France, Austria, or Spain during the preceding 30 years.

Similarly, the emphasis on the uniqueness of specifically 'imported' health technology in less developed countries appears misdirected when equivalent periods rather than stages are considered. To be sure, the nature of imported technologies differed. It seems to have been predominantly broad-gauged public health programmes of insect control, environmental sanitation, health education and maternal and child health services that transformed the mortality picture in less developed areas, while it was primarily specific vaccines, antibiotics and sulphonamides in more developed areas. But the technologies were not, for the most part, indigenously developed by countries in either group. Universal values assured that health breakthroughs in any country would spread rapidly to all others where the means for implementation existed.

The importance of exogenous, largely imported, health technology in the now-developed countries may have been underestimated for earlier periods as well. The disappearance of the plague during the 17th and 18th centuries was probably the first major event in three centuries to transform Western mortality patterns systematically. The reasons for the disappearance are obscure, but it does not appear to have been closely related to a nation's rate or level of economic development. Shrewsbury<sup>26</sup> suggests that a change in housing patterns may have been responsible in England, but Cipolla<sup>27</sup> points out that the plague essentially disappeared from Italy during a period when housing patterns were stable and in the face of an economic decline. The decline of the plague was followed by major reductions in mortality from smallpox in many countries, unquestionably a product of inoculation in the latter half of the 18th century and vaccination throughout the 19th century.<sup>28,29</sup> The techniques, once proved effective, spread rapidly from country to country. Inoculation itself appears to have been introduced from China, providing an ironic variation on the theme of transferring health technologies from Western to non-Western areas.

For the period after 1850, the emphasis on endogenous factors appears even less appropriate. As Stolnitz suggests,<sup>30</sup> it is difficult to account for the simultaneity of unprecedentedly rapid mortality declines after 1880 in many Western countries except by reference to factors that cut across national boundaries. The most obvious such set of factors was a result of the empirical validation of the germ theory of disease during this time. Thomas McKeown<sup>31</sup> has been the most outspoken advocate of improved living standards as the motivating factor in Western mortality declines. He argues that a rising standard of living was the principal cause of increased life expectancy in England between 1838 and the present. But his arguments are based principally upon a consideration of the period 1851-60 to 1891-1900, during which time life expectancy increased by only about six to

seven years. The increase of 24–25 years during the 20th century is essentially unaccounted for. [Life expectancy (average, male and female) is estimated to be 41.76 in 1861 and 47.40 in 1901; in 1838–54, 40.8 (Coale and Demeny collection of national life tables); and in 1967, 72.12; Nathan Keyfitz and Wilhelm Flieger, 'World Population: An Analysis of Vital Data,' University of Chicago, Chicago, 1968; 'Population: Facts and Method, of Demography.' W.H. Freeman, San Francisco, 1971.] He may be correct that specific drugs were not a factor until after 1935, but such a result does not require that most of the remaining explanation be based on advances in living standards. The germ theory of disease stimulated many innovations other than drugs and vaccines, such as improved antiseptic practices, quarantines and segregation of infectious patients, and it gave impetus to the movements for cleaner food and water, better personal sanitation and improved infant feeding. The logistic curve for the 1960s suggests that, even if England and Wales had experienced no improvement in living standards between 1901–10 and the present, its life expectancy could be expected to have increased from 50.4 years to 69.6 years. This is the figure achieved by Hong Kong in 1966, at a lower national income than that of England in the first decade of the century, and is considerably exceeded by Greece in 1966–68, at a slightly higher level. The expected increase in life expectancy on the assumption of no growth accounts for 88% of that which actually occurred. There is no guarantee that such an increase would have taken place, of course, and the estimate merely says that economic advance was not an essential prerequisite to a major increase in life expectancy, rather than assigns weight to the factors actually operative. But it surely adds credibility to the view that economic advance was not a major factor in that increase.

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