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An Imputation to the Measure of Economic Growth for Changes in Life Expectancy

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ONE of the principal uses of national income statistics is to determine whether and to what extent people are becoming better off over time. For instance, the central piece of evidence cited by Pearson in *Partners in Development* [1] to support his case that poor countries need more aid than they are getting is a table showing growth rates of real GNP per head of rich and poor countries to be 3.6 and 2.5 per cent, respectively, over the years 1960–67. The argument is that the disparity in growth rates, if it continues, will in time prove detrimental to rich and poor countries alike, and that aid is a means of reducing the disparity.

I am not concerned in this paper with Pearson's argument per se but with the role of statistics in that argument. To serve as evidence in the kind of case Pearson is making, income statistics must reflect well-being, and it must be at least approximately true that people are better off in countries where incomes are high than in countries where incomes are low. From this it follows that the scope of income should be comprehensive, for if a substantial component of well-being is excluded from income and if that component of well-being grows at different rates in different countries, then it may happen that income as conventionally measured grows faster in country A than in country B despite the fact that people in country B are becoming relatively better off.

The aspect of well-being that is to be examined in this paper is longevity. If you ask a man whether he prefers economic conditions as they are today to those of fifty or a hundred years ago, he would prob-

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[1] L. B. Pearson, *Partners in Development*, Pall Mall Press, 1969, p. 55.

ably answer that he prefers conditions as they are today, and his preference might well have less to do with the material things we possess than with the fact that we live longer. He may add that he might not have survived to his present age had his date of birth been pushed back fifty or a hundred years to a time when mortality rates in infancy and childhood were very much higher than they are now. In Canada, from 1926 to 1968, the infant mortality rate fell from about 1 in 10 to about 1 in 50 and the mortality rate of children aged 1 to 4 fell from 1 in 100 to 1 in 1,000. It is possible that no increase in goods and services would induce us to accept a return of mortality rates as they were as recently as 1926.

One can understand why the increase in life expectancy is not normally included as an element in the measure of economic growth. Life expectancy, or the mortality rates from which it is composed, is a peculiar commodity. Mortality rates are partly private goods and partly public goods, partly purchased and partly free, and some expenditures tending to increase life expectancy are already included in the accounts so that an imputation for increased life expectancy would result in double counting if the rest of the national accounts were left unchanged. The imputation would constitute a major departure from the convention that only marketable or potentially marketable items be included in the national accounts. That convention is appropriate for statistics designed as an aid in determining fiscal or monetary policy, and the decision to impute for increased life expectancy would involve us in having to keep two time series of income statistics, one for stabilization policy and another as a social indicator.

The first step in the development of an imputation for increased life expectancy is to make life expectancy commensurate with the rest of the data in the national accounts. Like any value, the value of increased life expectancy must be amenable to representation as the product of a quantity and a price. Quantities present no difficulty because age-specific mortality rates may be looked upon as though they were quantities, and we have adequate historical data on age-specific mortality rates for many countries.

The difficulty is in determining price. The price data do not come ready-made from the national statistical offices as do the data on mortality rates, but we may draw on a fairly extensive and growing body of economic literature on the value of life; for the price that is required to construct an imputation in the accounts is the same price that is appropriate in cost-benefit analysis of medical expenditure, road safety, and the like.

At the outset of this discussion, it is important to distinguish between three questions which are perhaps related but which are nonetheless distinct. The first of these, which might be called the insurance question, is "What is my life worth to my wife and children?"; and the expected answer is "A sum of money that would enable my wife and children to be as well off financially in the event of my death as they would be if I remained alive." The second, which might be called the birth control question, is "How much better or worse off would the community at large be if I ceased to exist or if I had never been born?" The answer to this question might well be that the rest of you would be better off financially without me. The third question, which is the true "valuation-of-life question," is "How much would I pay to avoid a small probability of my death?" If I were prepared to pay $500 to avoid a 1 in 1,000 probability of death through disease or accident, then it might be said that my valuation of my life is $500,000. The valuation of life in the community is some average of the valuations of individuals. Whatever the answer to the valuation-of-life question, that answer is distinct from the answers to the insurance question and the birth control question.

Dublin and Lotka,[2] though by no means the first to examine these issues, are generally taken as the starting point for modern work. It is significant that they were employees of an insurance company. Their problem was to determine the amount of insurance a man ought to carry. They computed the difference between the present value of a man's earnings and the present value of his consumption and called that difference the value of his life. Given their purpose, their procedure was correct to the best of my knowledge.

Recently, Dublin and Lotka's methods have been used for an altogether different purpose. Weisbrod, Klarman, Fein, Rice, and others [3] have dealt with the problem of determining the cost of disease. The cost of a disease is the sum of direct cost, including medical expenditures and loss of a man's earnings while he is alive, and indirect cost, which these authors take to be the present value of the forgone earnings of the men who die of the disease.[4] The general principle in these computations

[2] Louis I. Dublin and Alfred J. Lotka, *The Money Value of a Man,* Ronald Press, 1946.

[3] The recent history of attempts to evaluate the costs of disease is presented in J. A. Dowie, "Valuing the Benefits of Health Improvement," *Australian Economic Papers,* June 1970, pp. 21–41. A useful bibliography is included.

[4] There is an interesting discussion in Dowie's article of whether the present value of a man's consumption should be deducted from the present value of his income in computing the value of his life, a problem which is symptomatic of the confusion over the interpretation of the phrase "value of life."

is that declines in mortality rates can be evaluated according to the forgone earnings of the dead. The principle, if correct, would provide us with a simple way of evaluating the historical decline in mortality rates. In my opinion the principle is incorrect, because it supplies the right answer to the wrong question. It answers the insurance question in place of the value-of-life question. The present value of the forgone earnings of the dead is the right amount of insurance for a man to carry, but it is not indicative of the amount of money he would pay to avoid a small risk of losing his life, and it is not indicative of the amount of money rational men would be prepared to pay to eradicate a disease.[5]

A man who has insured his life for the full value that Dublin and Lotka have put upon it is not indifferent to whether he lives or dies, and the value he puts on his life in forestalling risks of losing it may be greater or less than the amount of his insurance.

The use of discounted future income as a measure of the value of one's life is sometimes justified on the grounds that one's earnings are a measure of one's value to the rest of the community. This is a confusion between the valuation of life question and the birth control question. A consensus has emerged in the literature on the cost-benefit analysis of birth control that the benefits derived from preventing a birth are very great and that the eventual per capita income of the community is a decreasing function of the birth rate. The reason is the Malthusian one that the smaller the population, the greater the capital-labor ratio. This argument applies with less force to adults than to unborn children, but it applies nonetheless. Imagine a family complete with children and all heirs destroyed in an automobile accident. Notwithstanding the loss of forgone earnings, this event makes the rest of us better off because we acquire title to all the family's assets including their rights to use schools and other public property. By definition, if the family is typical, any excess of its earnings over its consumption would accrue to its heirs and not to the rest of us. There is some dislocation in the economy if a departure is less orderly, but there is no reason to suppose that the costs to the survivors of having people go separately rather than in families outweighs the effect of a man's death

[5] My views on this issue are very close to those of Thomas Schelling, "The Life You Save May Be Your Own," in S. Chase, ed., *Problems in Public Expenditure Analysis*, Brookings, 1968, pp. 127–161. A more complete exposition of this approach to life saving is contained in E. J. Mishan, "Evaluation of Life and Limb: A Theoretical Approach," *Journal of Political Economy*, July–August 1971, pp. 687–705. Mishan evaluates the saving of lives by means of the concept of consumer surplus and, formally at least, incorporates externalities into the analysis, but he makes no attempt to specify functional forms of his curves or to produce numerical estimates.

on the capital-labor ratio. Certainly we are concerned as a community to keep each other alive but that concern is based on something other than the maximization of GNP, in total or per head.

To equate the value of life to discounted earnings forgone is to suppose that the lives of housewives and old people are worthless. In one sense this is quite true. Dublin and Lotka's calculations would imply that old people and wives ought not to carry insurance, and this may well be the case. It is not the case that old people and wives place no value on prolonging their lives or that society as a whole is unconcerned with the matter.

The present value of earnings is not a measure of the value of a man's life, in the sense of reflecting the amount of money a man would spend to reduce age-specific mortality rates. To find a value of life for converting reductions in age-specific mortality rates into an imputation in the national accounts, we need to consider carefully what it is that is maximized in expenditures to reduce age-specific mortality rates and to seek evidence on what people actually pay for this purpose. We begin with an examination of utility maximization in circumstances where the length of life is variable. Then we attempt to generalize the concept of income to incorporate changes in mortality rates as benefits. Finally, on the strength of some very crude assumptions, we construct an imputation for the increase in life expectancy, and compare growth rates of income with that imputation and without it.

MAXIMIZATION OF UTILITY WITH A LENGTH-OF-LIFE VARIABLE

Ignore the fact that men live in families and that families are imbedded in communities of people who are concerned with each other's well-being. Suppose instead that each man seeks to maximize his own welfare represented by the function

$$U = U(U_0, P_0, U_1, P_1, \ldots, U_n, P_n), \tag{1}$$

where U is his welfare in the present circumstances, P_i is the probability of his living for exactly i years, U_i is his welfare if he lives for exactly i years, and n is the postulated upper limit to the length of his life. The probabilities must sum to 1.

$$\sum_{i=0}^{n} P_i = 1. \tag{2}$$

Values of the terms U_t, P_t, and n depend on a man's age. If the maximum length of life is assumed to be 90 years, the n relevant to a 50-year-old man is 40. The value of P_{10} for a 50-year-old man depends on mortality rates between age 50 and age 60; the value of P_{10} for a 60-year-old man depends on mortality rates between age 60 and age 70, and so on. In deriving an imputation for the national accounts, values of U will have to be averaged over the age distribution of the population.

The utility function, U_t, corresponding to a life of t years depends on consumption in each of those years

$$U_t = U_t\,(C_0, C_1, C_2, \ldots, C_{t-1}), \tag{3}$$

where C_0 is consumption in the current year, and C_i is consumption in the year i.

The functions (1), (2), and (3) form a discrete representation of what is in reality a continuous process. It is convenient to think of consumption C_i as evenly spread out over the year i, and of death occurring if at all on the first day of the year. It is as though the whole risk of dying in a year were concentrated on one's birthday. A man alive in the year 0 is presumed safe until the first day of the year 1, and if he survives that day he is safe again until the first day of the year 2, and so on.

It is useful to define two additional mortality variables: D_t is the mortality rate t years hence, and S_t is the probability of surviving up to the year t. The variables P_t, D_t, and S_t are related by the formulas

$$S_t = \prod_{j=0}^{t-1} (1 - D_j); \tag{4}$$

$$P_t = D_t\,S_t = D_t \left[\prod_{j=0}^{t-1} (1 - D_j) \right]. \tag{5}$$

Obviously, $0 < D_t < 1$, $0 < P_t < 1$, and $0 < S_t < 1$, and $D_n = 1$ if n is the maximum length of life.[6]

[6] Equations (2) and (5) are consistent as long as $D_n = 1$. From equation (4) it follows that $S_t = S_{t-1} - D_{t-1}S_{t-1}$ for all values of t.

$$\begin{aligned}
\sum_{t=0}^{n} P_t = \sum_{t=0}^{n} D_t S_t &= D_n S_n + \sum_{t=0}^{n-1} D_t S_t \\
&= S_{n-1} - D_{n-1} S_{n-1} + \sum_{t=0}^{n-1} D_t S_t \\
&= S_{n-1} + \sum_{t=0}^{n-2} D_t S_t \\
&= S_{n-2} + \sum_{t=0}^{n-3} D_t S_t \\
&= S_1 + D_0 S_0 = S_0 = 1.
\end{aligned}$$

The utility functions can be expected to have the following properties:

$$\frac{\partial U_t}{\partial C_i} > 0 \text{ for all } i < t \tag{6}$$

$$\frac{\partial U}{\partial U_t} > 0 \tag{7}$$

$$\frac{\partial U}{\partial D_t} < 0. \tag{8}$$

These properties jointly imply that a man thinks himself better off if consumption in any year is increased or if his probability of dying in any given year is reduced. For simplicity we are also assuming that the consumption C_t takes on the same value in every utility function U_j in which it appears.

The assumptions represented by the inequalities (6), (7), and (8) are reasonable and for the most part innocuous, but they are not strong enough to connect the theory to the available data so as to permit us to incorporate an imputation for increased life expectancy into the statistics of economic growth. As a first step toward constructing this imputation, let it be assumed that the utility function of equation (1) takes the special form

$$U = \sum_{t=0}^{n} P_t U_t. \tag{1'}$$

This specification which we shall refer to as "the expected utility assumption" fits exactly into the terms of reference of the "states of the world" approach to the theory of choice under uncertainty. All possible lengths of life t correspond to mutually exclusive states of the world and the P_t are probabilities of their occurrence.[7] It is a well-known property of utility functions of this sort that they are cardinal rather than ordinal and may be defined up to a linear transformation;[8] given values of any two utility functions U_i and U_j for the years i and j and for any given time paths of consumption, all values of all utility functions U_t for all years t and all time paths of consumption could be determined by a conceptual experiment of the sort used to determine the shape of an ordinary indifference curve.

[7] See J. Hirshleifer, "Investment Decisions Under Uncertainty," *Quarterly Journal of Economics*, November 1965 and May 1966.

[8] For a justification of this assertion see Robert D. Luce and H. Raiffa, *Games and Decisions*, Wiley, 1957, Chap. 2.

The price a man would pay for a reduction in any age-specific mortality rate may be derived from his utility function. Taking current consumption as the numeraire, the value of a reduction in the mortality rate of the year t is[9]

$$-\frac{\partial C_0}{\partial D_t}=\frac{\sum_{j=t}^{n}\frac{P_j}{1-D_t}(U_j-U_t)}{\sum_{j=1}^{n}P_j\frac{\partial U_j}{\partial C_0}}, \qquad (9)$$

which is independent of the two arbitrary values used to establish a scale for the utility function U, because these values cancel out between the numerator and the denominator of equation (9).

In principle, the value of a reduction in any age-specific mortality rate could be determined from equation (9) if the right conceptual experiment were performed to determine the shape of U. No attempt at such an experiment is made in this paper.[10] Instead we postulate the general shape of the function U_t and endow the function with a parameter the value of which may be determined from independent evidence on, or

[9]

$$\left.\frac{\partial C_0}{\partial D_t}\right|_U=\frac{\partial U}{\partial D_t}\div\frac{\partial U}{\partial C_0}$$

$$\frac{\partial U}{\partial C_0}=\sum_{j=0}^{n}\frac{\partial U}{\partial U_j}\frac{\partial U_j}{\partial C_0}=\sum_{j=0}^{n}P_j\frac{\partial U_j}{\partial C_0}$$

$$\frac{\partial U}{\partial D_t}=\sum_{j=0}^{n}\frac{\partial U}{\partial P_j}\frac{\partial P_j}{\partial D_t}$$

$$=\sum_{j=t}^{n}U_j\frac{\partial P_j}{\partial D_t}\left(\text{because }\frac{\partial P_j}{\partial D_t}=0\text{ if }j<t\right)$$

$$=U_t\frac{P_t}{D_t}-\sum_{j=t+1}^{n}\frac{P_j}{(1-D_t)}U_j$$

$$=\sum_{j=t}^{n}\frac{P_j}{(1-D_j)}(U_t-U_j).$$

The final step in this derivation follows from the fact that

$$\frac{P_t}{D_t}-\sum_{j=t+1}^{n}\frac{P_j}{1-D_t}=S_t-S_t\left[\sum_{j=t+1}^{n}D_j\prod_{i=t+1}^{j-1}(1-D_i)\right]=0.$$

The proof in note 6 can be extended to show that the expression in square brackets is equal to 1.

[10] At least one attempt has been made to derive by questionnaire a utility function encompassing income, risks of death, and various states of ill health. See G. Torrance, *A Generalized Cost-Effectiveness Model for the Evaluation of Health Programs*, Faculty of Business, McMaster University, Research Series No. 101, 1970.

subjective feelings about, the value of life. Assume that the contributions of each C_i to the function U_t are separable and that all utility functions U_t take the special form

$$U_t = \sum_{i=0}^{t-1} \frac{C_i^\beta}{(1+r)^i}, \tag{3'}$$

where r is a rate of discount connecting "annual utility" accruing at different periods of time and β is the elasticity of annual utility with respect to consumption.

Given this assumption, the price of a reduction in the mortality rate at time t becomes[11]

$$\frac{-\partial C_0}{\partial D_t} = \frac{1}{\beta} C_0 \left[\sum_{j=t}^{n} \frac{\left(\frac{C_j}{C_0}\right)^\beta S_j}{(1+r)^j} \right] \frac{1}{(1-D_0)(1-D_t)}. \tag{10}$$

If we make the additional assumption, an assumption which is reasonable in the context of national accounting, that $C_i = C_j = C$ for all i and j, then the price of an instantaneous reduction in today's mortality rate becomes

$$\frac{-\partial C_0}{\partial D_0} = \frac{1}{\beta} C \sum_{j=0}^{n} \frac{S_j}{(1+r)^j} \frac{1}{(1-D_0)^2}. \tag{11}$$

[11] Equation (10) is derived by substituting equation (3′) into equation (9). The numerator of equation (9) becomes

$$\begin{aligned}\sum_{j=t}^{n} \frac{P_j}{(1-D_t)} (U_j - U_t) &= \sum_{j=t}^{n} \frac{P_j}{(1-D_t)} \left[\sum_{i=0}^{j-1} \frac{C_i^\beta}{(1+r)^i} - \sum_{i=0}^{t-1} \frac{C_i^\beta}{(1+r)^i} \right] \\ &= \sum_{j=t}^{n} \frac{P_j}{(1-D_t)} \left[\sum_{i=t}^{j-1} \frac{C_i^\beta}{(1+r)^i} \right] \\ &= \frac{1}{(1-D_t)} \sum_{j=t}^{n-1} \left[\frac{C_j^\beta}{(1+r)^j} \left(\sum_{i=j+1}^{n} P_i \right) \right] \\ &= \frac{1}{(1-D_t)} \sum_{j=t}^{n-1} \frac{C_j^\beta S_{j+1}}{(1+r)^j}.\end{aligned}$$

The denominator becomes

$$\sum_{j=0}^{n} P_j \frac{\partial U_j}{\partial C_0} = \sum_{j=1}^{n} \beta P_j C_0^{\beta-1} = (1-D_0)\beta C_0^{\beta-1}.$$

Consequently,

$$\frac{-\partial C_0}{\partial D_t} = \frac{1}{\beta} C_0 \left[\sum_{j=t}^{n} \frac{\left(\frac{C_j}{C_0}\right)^\beta S_j}{(1+r)^j} \right] \frac{1}{(1-D_0)(1-D_t)}.$$

The term $1/(1 - D_0)^2$ enters equation (11) as a consequence of our assumption that consumption and risk of death enter the utility function as discrete units instead of as flows over time. The term could be eliminated from equation (11) by shortening the time periods enough that the probability of dying in any period is effectively zero. Instead of graduating time in years, we might graduate it in weeks, days, or seconds.

The parameter r in equations (3′) and (11) is different from and as a rule less than the real rate of interest on riskless assets. A lender of money faces two types of risk. The first is that the borrower does not repay the loan. The second is that the lender himself dies before the date of repayment. Normally, when we speak of a loan as being riskless we are referring to the absence of only the first type of risk whereas r is a rate of discount riskless in both respects. An individual in a competitive market arranges his time pattern of work and consumption to equate his rate of substitution in use between present and future consumption to the discount factor in the market. To be precise,

$$\left.\frac{-\partial C_0}{\partial C_t}\right|_U = \frac{1}{(1 + i_t)^t}, \tag{12}$$

where i_t is the market's real rate of interest on riskless t year loans. On the other hand, it is a consequence of equation (3′) that for any $j > t$,

$$-\left.\frac{\partial C_0}{\partial C_t}\right|_{U_j} = \frac{1}{(1 + r)^t}. \tag{13}$$

It is easily shown that

$$\frac{1}{(1 + i_t)^t} = -\left.\frac{\partial C_0}{\partial C_t}\right|_U = \frac{S_t}{S_1}\left(\frac{C_0}{C_t}\right)^{1\beta} \frac{1}{(1 + r)^t}, \tag{14}$$

which implies that $r < i_t$ as long as $C_0 \leq C_t$. The term S_t/S_1 in equation (14) is like a second discount factor, for it is the product of annual components, all of which are less than 1.

The separability assumption (3′) is a much stronger assumption and a much less theoretically acceptable one than the expected utility hypothesis (1′). It is a discrete version of an assumption used widely in the theory of economic growth, and its advantages and disadvantages in that context are well-known.[12] The advantage of equation (3′) in our context is that it can accommodate any observed market price of life through an appropriate choice of r and β. If, for instance, a man of age 30 pays \$100 to

[12] See H. Wan, *Economic Growth*, Harcourt Brace Jovanovich, 1971, pp. 267–285.

avoid a 1 in 1,000 chance of losing his life, his value of $-\frac{\partial C_0}{\partial D_0}$ is $100,000 and values of the parameters of r and β can be chosen to equate the two sides of equation (11). The principal disadvantage of equation (3′) is that no value is placed on longevity itself independently of the level of consumption. Instead of assuming that U_t takes the form (3′), we might have assumed that

$$U_t = t^{\alpha} \sum_{j=0}^{t-1} \frac{C_j{}^{\beta}}{(1+r)^j}, \tag{3''}$$

which would imply, if $\alpha > 1$, that a man would accept a reduction in the present value of the timestream of $C_j{}^{\beta}$ in order to prolong his life. The consequences of assumptions like (3″) will not be investigated.

GROWTH OF WHAT?

Economic growth is usually defined as the rate of appreciation of real income per head. Though the customary measure of income in this context is gross national product, we recognize that net national product is the more appropriate concept and would use it as the measure of income but for certain difficulties in measuring depreciation. Our problem is to expand the concept of real income per head to impute for the fall in mortality rates.

One's first instinct is to go back to Hicks's definition of income as the amount that a man may consume in a year without impoverishing himself. This is usually interpreted by the formula,

$$Y(t) = C(t) + W(t+1) - W(t), \tag{15}$$

where $Y(t)$ is income in the year t, $C(t)$ is consumption in the year t, and $W(t)$ is wealth at the outset of the year t.[13] Presumably anticipated improvement in mortality rates would be incorporated in wealth which in turn is closely related to utility as defined by equations (1), (2), and (3) above. If during the course of a year, a man comes to believe that the mortality rates facing him in the rest of his life will be lower than he had anticipated at the beginning of the year, then $W(t+1)$ will be that much greater than $W(t)$ and income will have increased accordingly.

There are several reasons why this framework is not appropriate for imputing a value for the fall in mortality rates. First, a national account-

[13] We shall use a term of the form $X(t)$ to refer to the value of the variable X in the year t. This usage should be distinguished from X_t, which refers to an event that may or may not occur t years in the future.

ant measuring growth cannot be expected to predict future mortality rates, any more than he can be expected to predict future consumption. The most the national accountant can be expected to observe is current consumption, current age-specific mortality rates, current investment, and that part of current wealth that is actually evaluated in the market. Second, anticipated reductions in age-specific mortality rates appear to individuals as windfall gains that accrue not in the present year but in the future. Such windfall gains could play havoc with measures of growth of income as defined by equation (15), for they could cause income to decline steadily from the base year even though people are becoming steadily better off. Suppose C is constant forever and mortality rates are improving at a decreasing rate, so that $W(t+1) > W(t)$ for all t, but $[W(2) - W(1)] > [W(3) - W(2)] > [W(4) - W(3)]$ and so on. Clearly, Y is declining over time and economic growth is negative. Whatever it is to which we impute a value for increased life expectancy, it cannot be income as defined by equation (15).

I suggest that what we are seeking to observe is the growth rate of a surrogate for U as defined in equation (1). We wish to record the improvement in well-being inclusive of current consumption and prospects for the future. This statement must be qualified in an important respect. As has already been said, the national accountant cannot presume to know what people expect for the future. He designs measures to reflect, not welfare given current expectations for the future, but welfare as it would be if current conditions persisted indefinitely into the future. Measures of economic growth should be designed to reflect the growth of U of equation (1), as it would be if all C_j were equal to current income per head and all D_j were equal to age-specific mortality rates in the current year. The C_j are measured by current income rather than by current consumption on the assumption that income is the maximum consumption that can be sustained indefinitely with present technology and resources.[14]

Our statistics of economic growth are to reflect the improvement in U, but they cannot record the growth of U itself because, at best, U is only defined up to a linear transformation and the growth rate of U is not defined at all. We must find a variable which is a surrogate for U and for which a growth rate is well-defined. Fortunately this problem is fundamentally the same as that of measuring real consumption in circum-

[14] This interpretation of real income is compared with other interpretations in Dan Usher, "The Concept of Real Income," Queen's Discussion Papers, No. 99, 1973.

stances where prices are changing over time. In that case, we choose a base year and define real consumption in any other year to be the amount of money needed to make one as well off in the base year as one was in the other year.

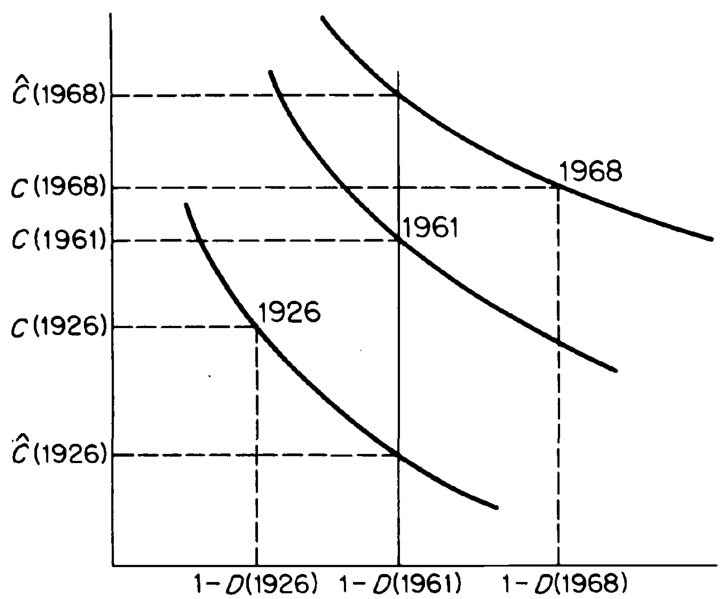
By analogy, we define a term $\hat{C}(t)$ to be the value of net national product at which one would be as well off with mortality rates of the base year as one was in the year t with actual net national product, $C(t)$, and actual mortality rates, $D_j(t)$, of that year. If the base year is 1961, $\hat{C}(t)$ is defined by the equation

$$U[\hat{C}(t), D(1961)] = U[C(t), D(t)], \tag{16}$$

where $D(t)$ is a vector of age-specific mortality rates in the year t. As conventionally measured, economic growth is the growth of $C(t)$. When an imputation is made for increased life expectancy, economic growth becomes the growth of $\hat{C}(t)$. The effect of the improvement in mortality rates on growth is the difference between the growth rate of $\hat{C}(t)$ and the growth rate of $C(t)$.

These measures are illustrated in Figure 1. Imagine three men, one living in 1926, one living in 1961, and one living in 1968. They can

FIGURE 1



live for at most two periods, they face probabilities $D(t)$ of dying at the start of the second period, their consumption, $C(t)$, is the same in both periods, and their utility functions are identical.

$$U(t) = U[C(t), D(t)]. \tag{17}$$

Three indifference curves, one containing the C and D of 1926, another containing the C and D of 1961, and a third containing the C and D of 1968 are shown in Figure 1. Points representing values of C and D in the years 1926, 1961, and 1968 are labeled accordingly. Consumption as conventionally measured is indicated by the points $C(1926)$, $C(1961)$, and $C(1968)$ on the vertical axis. Consumption inclusive of a premium for the improvement in mortality rates is indicated by the points $\hat{C}(1926)$, $\hat{C}(1961)$, and $\hat{C}(1968)$ where each $\hat{C}(t)$ is defined in accordance with equation (16) as the amount of consumption one would need in 1961 to be as well off as a man living in the year t.

Finally there is the question of whose utility we are considering in estimating values of U or its surrogate $\hat{C}$. In accordance with accounting conventions, we would want to measure the average value of $\hat{C}$ in the population as a whole, taking young and old into account. Other things being equal, the $\hat{C}$ of a young man would be greater than the $\hat{C}$ of an old man, and these would have to be averaged according to the proportions of young men and old men in the population. This averaging procedure would have to be conducted with respect to a standard age distribution (for instance, the age distribution in the base year), for we would not want our statistics to imply that people are becoming better off over time if all that is happening is that the proportion of young people in the population is increasing.

MEASURING ECONOMIC GROWTH WITH AN IMPUTATION FOR THE INCREASE IN LIFE EXPECTANCY

The development of the argument so far is that economic growth inclusive of an imputation for increased life expectancy is the growth of a variable $\hat{C}(t)$ where

$$U[\hat{C}(t), D(1961)] = U[C(t), D(t)] \tag{16}$$

where the utility function in equation (16) is of the form

$$U = \sum_{j=0}^{n} P_j \left(\sum_{i=0}^{j-1} \frac{C_i^{\beta}}{(1+r)^i} \right) = \sum_{j=0}^{n} \frac{C_j^{\beta} S_j}{(1+r)^j}, \tag{18}$$

and U is measured as if all C_i were equal to the current net national product, and all D_i were current age-specific mortality rates. Designate the common value of C_j by $C(t)$ and the value in the year t of

$$\sum_{j=0}^{n} \frac{S_{j+1}}{(1+r)^j}$$

by $L(t)$. Hence, equations (18) and (16) become

$$U(t) = C(t)^{\beta} L(t) \tag{19}$$

and

$$\hat{C}(t) = C(t)[L(t)/L(1961)]^{1/\beta}. \tag{20}$$

The significant feature of equation (20) is that the terms on the right-hand side of the equation representing conventional income, $C(t)$, and increased life expectancy, $[L(t)/L(1961)]^{1/\beta}$, are multiplicative; so the rates of growth of the two terms cumulate rather than average out in the formation of the final rate.

$$G_{\hat{C}} = G_C + (G_L/\beta). \tag{21}$$

Normally imputations to the accounts are added in rather than multiplied in, so that the effect of an imputation is to reduce the rate of growth whenever the growth of the imputed item is less than the growth of the rest of the accounts. It follows from the assumptions we have made about the form of utility function and the concept of income that the effect of the imputation for increased life expectancy is necessarily to increase the rate of growth, and that the increase is normally greater than the rate of growth of life expectancy itself.

If we ignore the term $1/(1 - D_0)^2$ in equation (11), the value of life becomes

$$\frac{-\partial C_0}{\partial D_0} = \frac{1}{\beta} CL. \tag{22}$$

Equations (21) and (22) are the basis for all of the estimates which we will derive.

Time series of $\hat{C}(t)$ can be computed from observed values of income and mortality rates for given values of the parameters r and β. Recall that the parameter r is defined in equation (3′) as a rate of discount on annual utility for a given length of life. It is different from and as a rule less than the market rate of interest. It seems reasonable to suppose that this rate lies between zero and 5 per cent.

The choice of a value for β is more critical and we have less a priori information to guide us in our judgment. A case can be made for supposing that $\beta = 1$. This would imply that in all decisions affecting values of C_j and D_j, people act to maximize their wealth, W, defined as

$$W = \sum_{j=0}^{n} P_j \sum_{i=0}^{j-1} \frac{C_i}{(1 + r)^i}. \tag{23}$$

A man would pay a $1/_{1,000}$ part of the present value of his expected lifetime consumption. He would be indifferent to whether he lives a long life or a short life if consumption per year in the short life is sufficiently higher than consumption per year in the long life that the present values of consumption are the same. It is possible for taste to have this form but there is no good reason to suppose that it does, and a man might well be willing to exchange some present value for a longer life. Nevertheless, the maximization of wealth assumption has the right qualitative implications: the value of life is an increasing function of consumption and of the expected length of life, but the marginal valuation of an extra year of life at any given value of consumption is a decreasing function of life expectancy. One might argue that the growth over time of the expected present value of lifetime consumption as it would be if current income and current mortality rates persisted indefinitely is a useful statistic to observe even though it is a poor surrogate for utility.

The alternative to supposing that $\beta = 1$ is to estimate β from equation (22). For this purpose we need an observation on the value of the life of a man of whom we know his age, his expected consumption, and his mortality rates in every future year because all of these characteristics affect the value of $-\partial C_0/\partial D_0$. In principle, one could get this information from questionnaires. One might ask, "Suppose there is a 1 in 1,000 chance that the cup in front of you contains hemlock rather than coffee. What would you pay to avoid having to drink the contents of the cup?" The answer, multiplied by 1,000, would be the value the respondent places on his life, and, by questioning people of different ages and with different incomes, one could obtain some notion of how the response is affected by these variables. Of course, no serious statistician would ever pose this question because the respondent cannot be expected to answer it truthfully. The reason for mentioning it in this context is to keep in mind the sort of information we would like to obtain if we could.

There are situations where this question has to be answered. Decisions have to be made in circumstances where lives are at stake, and where valuations of changes in mortality rates are implicit in public and private decisions.

a. We place values on life-saving in our decisions to engage or not to engage in medical expenditures. If the cost per patient of a kidney transplant is $72,000, and if we decide that those who need kidney transplants will get them, and if the expected life of a person with a kidney transplant is 17 years, we are deciding that a 17-year extension of life is worth at least $72,000.

b. Similarly, a valuation of life-saving is implicit in expenditures to prevent road accidents.

c. A valuation of changes of mortality rates reflecting private as opposed to public decisionmaking is implicit in rates of hazard pay. If a carpenter who works at the top of a high building runs a 1 in 1,000 risk per year of falling off, and if he accepts a premium of $100 for taking that risk, he values his life at $100,000.

d. If the amount of armor on an airplane affects the chances of its being shot down, a valuation of life is implicit in decisions as to how much armor the plane should have.

Though the pricing of life is implicit in many public and private decisions, it is difficult to find prices and to extricate valuation of life from other considerations. I have only been able to find a few prices and these are shown in Table 1. In interpreting these prices an in using them to impute values of decreases in mortality rates, several considerations should be kept in mind.

First, by value of life, I mean nothing more than $\partial C_0/\partial D_0$, the amount one would pay per unit for a decrease in one's mortality rate in the current year. The statement that the price of life is $20,000 in this sense does not mean that a man would sacrifice his life for $20,000, any more than the statement that the price of butter is $0.25 per pound means that a man would pay $20,000 for the pleasure of consuming 40 tons of butter.

Second, the valuation of life implicit in decisions affecting mortality rates is different from the valuation society puts on saving the lives of identifiable people. Thedie and Abraham [15] have expressed this point as follows: "If a miner is imprisoned at the bottom of a pit, if a mountaineer is in danger up in the mountains, if a vessel is in danger of shipwreck on

[15] J. Thedie and C. Abraham, "Economic Aspect of Road Accidents," *Traffic Engineering and Control,* 1961, p. 590.

TABLE 1

Scraps of Evidence on the Value of Life
(implicit or explicit value of the life of a man about 30 years old)

	Dollars (thousands)
1. Hazard pay	
premium miners accept for working underground	34–159
test pilot	161
2. Medical expenditure	
kidney transplant	72
dialysis in hospital	270
dialysis at home	99
3. Valuation of the cost of disease	75
4. Valuation of the cost of airplane accidents	472
5. Traffic safety	
recommended for cost-benefit analysis by the National Safety Council	37.5
value of life in a cost-benefit study of highways	100
6. Military decision-making	
instructions to pilots on when to crash-land airplanes	270
decision to produce a special ejector seat in a jet plane	4,500

SOURCE: Line 1. Hazard pay: Three collective bargaining agreements in the mining industry contain premiums for working underground of 14, 5, and 3 cents per hour. These were respectively: Opemiska Copper Mines (Quebec) Ltd., and Le Syndicates Travailleurs des Mines de Chibougamou-Chapais (1965), Lake Shore Mines Ltd. and International Union of Mine, Mill, and Smelter Workers Local 240 (1958), and Hollinger Consolidated Gold Mines Ltd. and United Steelworkers of America Local 4305 (1961). In the United States, the risk of a fatal accident is 0.49 per million man-hours in coal mining and is 0.05 in all industries combined (*Accident Facts 1970*, the National Safety Council, Chicago). Suppose that half of the premium for working underground is compensation for the risk of a fatal accident and the other half is compensation for the risk of nonfatal accidents and for inconvenience, and that, in the mines to which the agreements refer, the risk of a fatal accident above ground is 0.05 per million hours and the risk of an accident underground, in mining proper, is 0.49 per million hours, so that the extra risk of working underground is 0.44. The value of life implicit in the three agreements is therefore $159,000, $57,000 and $34,000, respectively. The questionable aspects of this calculation need neither emphasis nor elaboration. Note however that in principle hazard pay yields a true value of life in that, like all wage rates, it reflects valuations at the margin. If the hazard pay were set too low, the miners would be disinclined to work underground and if hazard pay were set too high they would be disinclined to work above ground. A United States air force pilot whose basic salary was $12,012 was paid a premium of $2,280 for engaging in especially dangerous test flights that raised his chance of losing his life from 0.1348 to 1.695 per cent per year. The

(Notes continued on next page)

Notes to Table 1 (continued)
value of life implicit in that contract was $167,000 [$2,280 ÷ (.01695 − .001348)]. (J. W. Carlson, "Valuation of Life-Saving," Ph.D. dissertation, Harvard University, 1963.)

Line 2. Medical expenditure: These figures are based on data from H. E. Klarman, J. O'S. Francis, and G. D. Rosenthal, "Cost Effectiveness Analysis Applied to the Treatment of Chronic Renal Disease," *Medical Care*, 1968, pp. 48–54. Discounting at 6 per cent, they find the present values of the costs of hospital dialysis, home dialysis, and transplantation to be $104,000, $38,000 and $44,500, respectively, and that the years gained in the three treatments are 9, 9, and 17. The figures in our table are not the costs of the treatments but the implications of these numbers about the value of the life of an average man of 30 years of age whose life expectancy is 45 years. The value of life of a 30-year-old man that would make hospital dialysis, for instance, a marginal life-saving expenditure is $104,000 × (18/7), where 18 and 7 are the approximate discounted life expectancies at 5 per cent of 45 and 9 years of life. The discounted life expectancy of 17 years is 11 years. In principle, all of these medical estimates may reflect intramarginal situations in that many people who have to pay their full share of the extra taxes required to finance these treatments would willingly vote to have these treatments made available for everyone even if the treatments were more expensive than they are now. Nevertheless, one gets the impression from the literature that the cost of hospital dialysis is, if anything, extramarginal in that the expenditure on hospital dialysis is often said to be more than society "can afford."

Line 3. The source of this estimate is Dorothy P. Rice, *Estimating the Cost of Illness*, Health Economics Series 6, U.S. Department of Health, Education, and Welfare, 1966, p. 93. The figure in Table 1 is an average of the discounted earnings of a man and a woman of age 25–29 when the discount rate is 6 per cent. For reasons discussed at the outset of this paper, I believe that this type of calculation is inappropriate in principle for determining the value of life. I include it together with the valuation of loss of life in airplane accidents because endorsement of this calculation by the U.S. government puts a certain weight on the estimate of the value of life independently of the validity of the method by which the estimate was arrived at, and signifies that the estimate itself is deemed reasonable.

Line 4. Gary Fromm measures the cost of a fatality in an air crash as the present value of the lifetime earnings of the typical passenger ("Civil Aviation Expenditures," in R. Dorfman, ed., *Measuring Benefits of Government Investments*). Assuming the average age of a passenger to be 40 years, and setting the discount rate at 6 per cent, he estimates the cost per fatality in 1960 to be $373,000. I increase this number to $472,000 in Table 1 to approximate the present value of the earnings of an airline passenger whose income is typical of incomes of all airline passengers but who is only 30 years old. Fromm thinks of his calculation as representing a lower limit to the true value of life. Leaving aside the question of the suitability of the present value of earnings calculation for evaluating the cost of loss of life, the contrast between Fromm's estimate of the value of life of an airline passenger who tends to be rich and Rice's estimate of the value of life of an average American raises the interesting issue of whether a public decision-maker ought to accept private valuations in cost-benefit analysis where life-saving is one of the benefits or costs. This would seem to be a case in which each dollar of benefit ought not to be counted as equal to every other dollar of benefit "to whomsoever the benefits may accrue."

Line 5. Traffic safety: A figure of $37,500 was recommended as the value of life for cost-benefit analysis of traffic safety by J. L. Recht, *How to Do a Cost-Benefit Analysis of Motor Vehicle Accidents*, National Safety Council, September 1966. This figure also seems to have been arrived at by discounting somebody's lifetime earnings. The figure

(Notes continued on next page)

Notes to Table 1 (concluded)
of $100,000 is presented, without justification or explanation other than that it is alleged to be customary, in a study conducted for the National Highway Safety Bureau of the U.S. Department of Highways, No. FH-11-6495.

Line 6. Military decision-making: The pilot of a F-86L jet fighter plane occasionally finds himself in a position where he might either eject himself from the plane, allowing it to crash, or attempt a landing. Instructions to the pilot as to when to eject himself from the airplane imply a value of life of at least $270,000, when consideration is given to his probability of survival if he abandons the plane, to his probability of survival if he tries to land the plane, to the cost of the plane, to the probability of losing it in the event of an attempted landing, and to the damage that might be caused by a crashing plane. This figure is not very instructive because the cost of training a pilot for a F-86L jet is $300,000 (Carlson, *op. cit.*). Carlson also cited a case in which the Air Force spent $9 million designing and producing an ejector seat which would save between one and three lives.

Table 1 is a collection of numbers which are not obviously intramarginal. In my cursory examination of cost-benefit analysis in circumstances where the lengthening of lives is one of the benefits, I encountered many examples of projects which had to be intramarginal in the sense that no rational decision-maker could refuse to undertake such projects when the possibility of doing so is recognized. For instance, G. Torrance (*A Generalized Cost-Effectiveness Model for the Evaluation of Health Programs*, Faculty of Business, McMaster University, Research Series No. 101) found that the cost per newborn child saved in a program of preventing hemolytic disease was $932.00. I would hope that this fact conveys no information about the value of life.

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the high seas, it would be criminal to reckon efforts and money according to the number of human lives to be saved. It would be vain to inquire whether the sum spent on saving these few lives if invested elsewhere (on roads for instance) might not have enabled more lives to be saved. It is impossible to weigh in the balance certain deaths and probable deaths, even if the latter are in greater number."

Thirdly, the price of life is different from the price of butter in that the price of butter is the same to everyone who buys butter while the price of reductions in mortality rates may vary from one man to the next within the same market. Mortality rates are private commodities, by which I mean that they are not and cannot be traded in the market because they are produced in the household from ordinary commodities. Other private commodities are risk and capital as components of stocks and bonds, the consumption activities in Lancaster's formulation of the theory of demand,[16] leisure, and the components of a hedonic price index. Ordinary commodities like pounds of butter or hours of the services of a carpenter cost the same to a rich man and a poor man alike. The price of a private commodity like leisure is different to a rich man than to a poor man, for each man values leisure as the marginal product

[16] K. Lancaster, "A New Approach to Consumer Theory," *Journal of Political Economy*, 1966, pp. 132–157.

of an hour of work, and the marginal product of a poor man is different from the marginal product of a rich man insofar as productivity of labor is the source of the difference in their incomes. If the price of butter were lower to the poor man than to the rich man, the poor man in a competitive economy would sell butter to the rich man and cause prices to equalize. No comparable mechanism equalizes the price of leisure. Leisure cannot be detached from its owner in the way that butter can be detached from its owner, and arbitrage fails to equalize prices in this market.

Precisely the same is true of the price of a reduction in mortality rates. Suppose, as illustrated in Figure 2, that a man is confronted with a number of ways of reducing his mortality rate, listed here in order of cost; wearing a safety belt in his car, visiting his doctor for an annual check-up, fire-proofing his house, having a special test for cancer, installing a radio transmitter in his yacht, reinforcing his automobile, keeping a co-pilot at all times in his private jet plane. These options constitute a supply curve to the individual of reductions in his mortality rate, and corresponding to this supply curve is a demand curve for reductions in mortality rates which could be derived in the usual way as the locus of all combinations of $\partial C_0/\partial D_0$ and D_0 consistent with the utility function of equation (1) when other parameters are held constant or varied in some systematic way with D_0. The position of the demand curve would depend on the tastes of the individual and on his income, and the wealthier he is, the more he would pay to reduce mortality rates and the higher would be his demand curve. Each man's supply curve of reduction of mortality rates is also unique as it depends on the circumstances of his life, in particular, on the nature of his work. In Figure 3 the supply curves facing a rich man and a poor man are presumed to be identical. Their demand curves differ, and the value of life of a rich man (in our special sense of the term "value of life") is higher in equilibrium than the value of life of a poor man.

Evidence on shadow prices of mortality rates is of limited use in constructing an imputation to economic growth, because mortality rates are private commodities. Even in perfect markets, values of reductions in mortality rates differ from one man to the next so that prices implicit in given transactions are relevant only to people who actually engage in those transactions and not to the population as a whole. Furthermore, private commodities are typically indivisible; so their costs need not be shadow prices at all. The value of a reduction of the mortality rate implicit in the decision to have an annual medical check-up need not

FIGURE 2

Supply Curve of Mortality Rate Reduction to a Rich Man

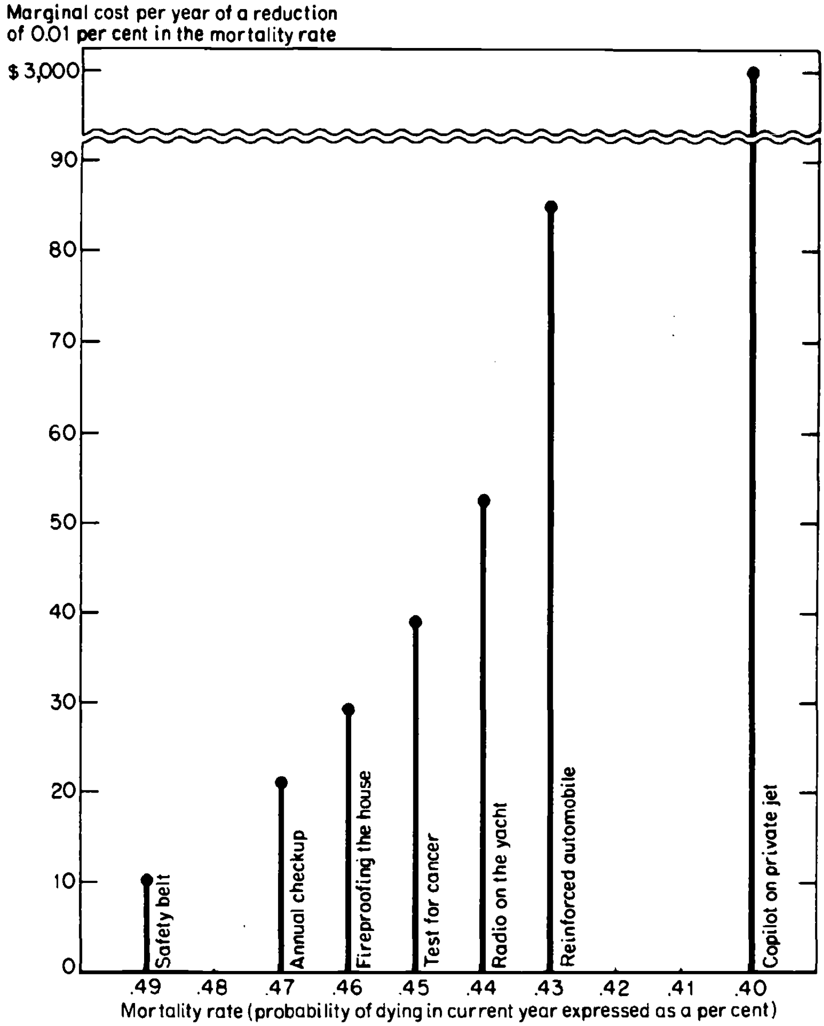
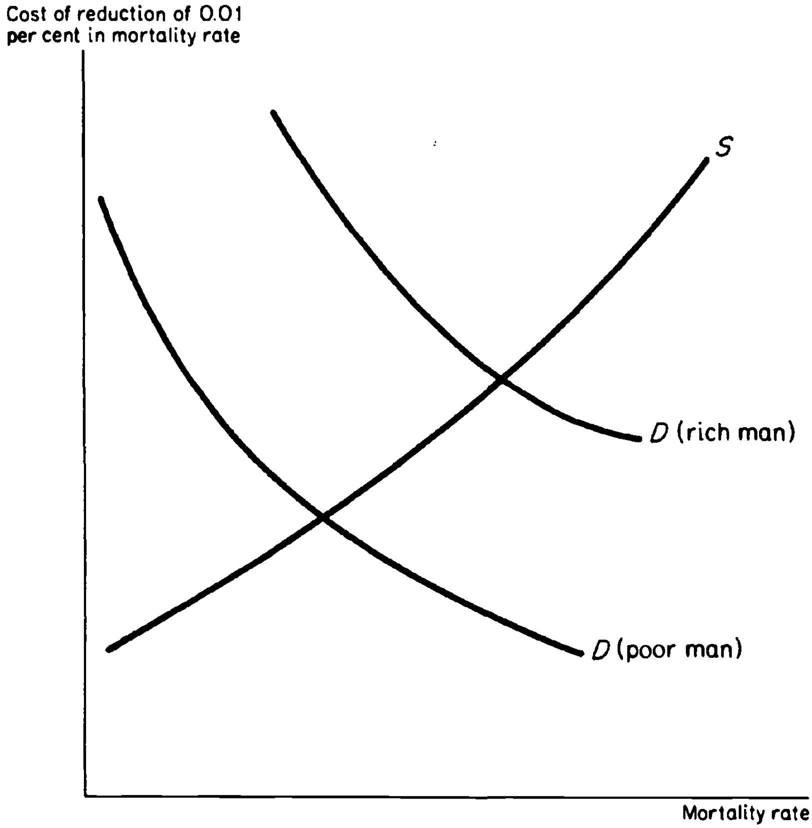


FIGURE 3

Choice of Mortality Rates of a Rich Man and a Poor Man, Assuming Their Supply Curves Are the Same



reflect a man's valuation of his life if his demand curve cuts his supply curve at a higher value.

The issue is complicated still further by the fact that reductions in mortality rates have externalities. We are prepared to sacrifice to prolong our neighbor's life even though we are relatively unconcerned about the size of our neighbor's income. Evidence of public and private behavior in circumstances where decreases in mortality rates can be bought conveys some useful information and gives hints of what might be a reasonable valuation of life in cost-benefit analysis and in our imputation for increased life expectancy. This evidence does not point to a unique price or to a unique range of prices depending on a man's age and his mortality rates in each future year. Reductions in mortality rates differ from ordinary commodities in that unique prices do not exist.

Having said this, we shall suppose that there is a unique price $\partial C_0/\partial D_0$ corresponding to a set of mortality rates D_j and a level of permanent consumption C, as there would be if society were one individual writ large, and we shall use this information to impute a value for the increase in life expectancy in the national accounts.

AN IMPUTATION TO THE CANADIAN ACCOUNTS

Both the value of life and the corresponding growth rate of income inclusive of an imputation for the increase in life expectancy are computed in accordance with equations (21) and (22) with several values of the parameters r and β and with Canadian data for the years 1926 to 1968. The data required are time series of real net national product per head to measure $C(t)$ and age-specific mortality rates to measure $D_j(t)$. In each year, the value of L for the population as a whole was taken to be a weighted average value of L in that year for all ages, with weights reflecting the age distribution of the population in 1961. The rate of interest, r, was given values of 1, 3, and 5 per cent, and β, which is the more critical variable, was given all values between .05 and 1.0 in steps of .05. The growth rate of real net national product per head over the years 1926 to 1968 was 2.25 per cent. For all combinations of r and β, the computed values of life and growth rates of net national product inclusive of the imputation for increased life expectancy are presented in Table 2. The effect of the imputation for increased life expectancy depends very much on the values chosen for the parameters β and r. For $r = 1$ per cent, the rate of economic growth inclusive of the imputation for increased life expectancy varies from 2.48 per cent when $\beta = 1$ up to 6.98 per cent when $\beta = 0.05$. From among these growth rates, we choose the one corresponding to a computed value of life that approximates values of life recorded in Table 1.

If one sets a value of life at, say, \$150,000, the effect of the imputation for increased life expectancy is to raise the growth rate by about one-half of 1 per cent a year, from 2.25 per cent without the imputation to about 2.8 per cent. This result holds for all three interest rates; if $r = 1$ per cent, then, to the nearest 0.05, $\beta = 0.45$ and the growth rate is 2.77 per cent; if $r = 3$ per cent, then $\beta = 0.30$ and the growth rate is 2.84 per cent; if $r = 5$ per cent, then $\beta = 0.25$ and the growth rate is 2.80 per cent.

TABLE 2

Growth Rates, 1926–68, and the Value of Life

	$r = 1$ Per Cent		$r = 3$ Per Cent		$r = 5$ Per Cent	
β	Av. Value of Life, 1961 [a] (000 omitted)	Growth Rate of Income [b]	Av. Value of Life, 1961 [a] (000 omitted)	Growth Rate of Income [b]	Av. Value of Life, 1961 [a] (000 omitted)	Growth Rate of Income [b]
5%	$1,331	6.98%	$910	5.78%	$671	5.00%
10	666	4.61	455	4.01	336	3.63
15	444	3.83	303	3.42	224	3.17
20	333	3.43	228	3.13	168	2.94
25	226	3.19	182	2.95	134	2.80
30	222	3.04	152	2.84	112	2.71
35	190	2.92	130	2.75	96	2.64
40	166	2.84	114	2.69	84	2.59
45	147	2.77	101	2.64	75	2.55
50	133	2.72	91	2.60	67	2.52
55	121	2.68	83	2.57	61	2.50
60	111	2.64	76	2.54	56	2.48
65	102	2.61	70	2.52	52	2.46
70	95	2.59	65	2.50	48	2.45
75	89	2.56	61	2.48	44	2.43
80	83	2.54	57	2.47	42	2.42
85	78	2.53	54	2.46	40	2.41
90	74	2.51	51	2.44	37	2.40
95	70	2.50	48	2.43	35	2.39
100	67	2.48	46	2.42	33	2.39

NOTE: The growth rate of income without the imputation for increased life expectancy is 2.25 per cent. Values of the variable $C(t)$ from 1926 to 1968 are taken from the national accounts. The appropriate concept is net national product in 1961 dollars which is not provided directly by the accounts but which may be estimated as [gross national expenditure in constant (1961) dollars × (gross national expenditure − capital consumption allowance)] ÷ (gross national expenditure), all the terms of which are contained in *National Income and Expenditure Accounts, 1926–1968*, Dominion Bureau of Statistics, August 1968.

Time series of age-specific mortality rates for the first year of life, for the next four years, and for five-year intervals thereafter up to age 84, and with a final category of age 85 and above, were obtained from various issues of *Vital Statistics*, Dominion Bureau of

(Notes continued on next page)

Notes to Table 2 (concluded)
Statistics, pp. 84–101. Annual mortality rates were constructed on the assumptions that the rate for any grouping of ages applies equally to all ages within that group and that ninety years is the maximum length of life. These annual mortality rates do not correspond exactly to the terms D_j because D_j is the probability of dying on the first day of the year j on the special assumption that all deaths occurring in any year are concentrated on the first day. Consequently the estimate of L differs slightly from that implied by equations (16) and (19). In the calculations leading to Table 2, the discounted life expectancy of a man who is now j years is measured as

$$L_j = \sum_{i=j}^{90-j} \frac{\left[\prod_{k=j}^{i-1} (1 - \bar{D}_k)(1 - \bar{D}_i/2)\right]}{(1 + r)^{i-j}},$$

where the $\bar{D}_j$ are age-specific mortality rates obtained from vital statistics data. The term in square brackets is the sum of the probability of a man of age j completing at least $i - j$ man years of life

$$\left[\prod_{k=j}^{i} (1 - \bar{D}_k)\right]$$

and half the probability of his dying $i - j$ years from now

$$\left[\prod_{k=j}^{i-1} (1 - \bar{D}_k)(\bar{D}_i/2)\right].$$

The factor 2 is included in the expression above because a man who will die i years from now has an expectation of remaining alive for half of that year.

The term $L(t)$ in equation (23) is estimated as

$$L(t) = \left[\sum_{j=0}^{89} P_j(1961)L_j(t)\right] \div \left[\sum_{j=0}^{89} P_j(1961)\right]$$

where $L_j(t)$ is the value of L_j in the year t and $P_j(1961)$ is the Canadian population of age j in the year 1961.

[a] Defined as $(1/\beta)C(1961)L(1961)$.

[b] Inclusive of an imputation for increased life expectancy: growth rate of $C(t)[L(t)/L(1961)]^{\beta}$.

The estimated increase of one-half of 1 per cent in the growth rate attributable to the improvement in life expectancy is by no means insignificant but seems to me to be rather low. The reason may be that I have underemphasized the importance of the fall in mortality rates in infants and children. The first hypothesis in the calculation is that each man is concerned with his own mortality rate exclusively, and since the great majority of people have passed infancy, the decline in the infant mortality rates cannot have a great effect on the final estimate. The decline in the infant mortality rate would have had a greater impact on the imputation if the interest of parents and prospective parents had been taken into account explicitly.

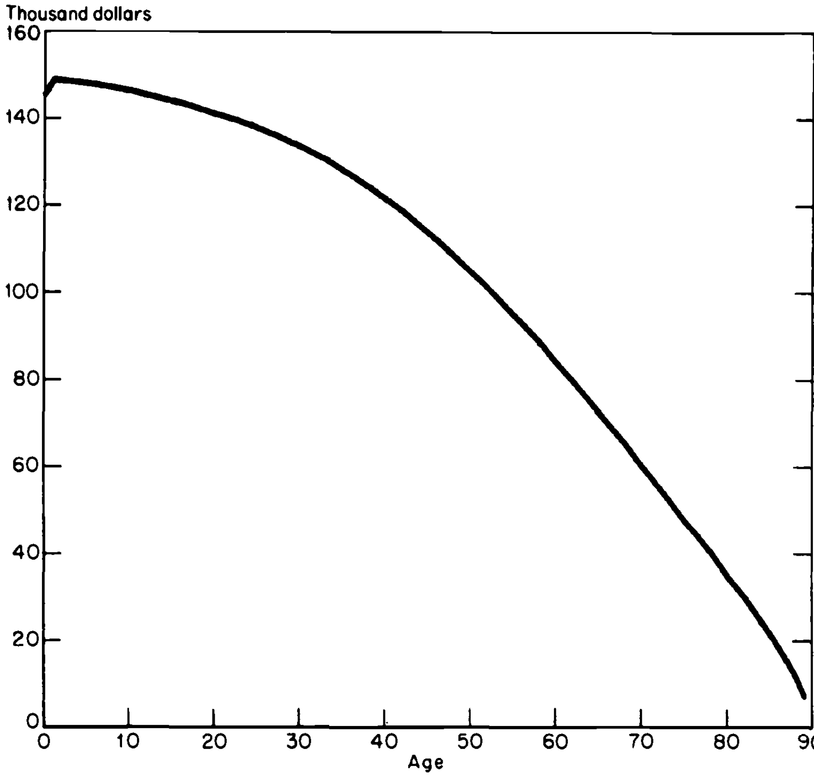
I have criticized the use of present value of earnings as a measure of the value of life, arguing that the present value of earnings does not reflect what a government responsive to the preferences of its citizens would pay to reduce mortality rates. However, the alternative concept of the value of life gives rise to measurements that have a good deal in common with the present value of earnings measurements they are intended to replace, for both are variants of expected discounted income. An important empirical difference between the two measures is in the age distribution of the value of life, illustrated in Charts 1 and 2. Chart 1 is based on our calculations and Chart 2 shows present values of earnings as estimated by Rice [17] in a study under the auspices of the U.S. Department of Health, Education, and Welfare. It turns out that both calculations put a value of about $130,000 on the life of a 30-year-old man, but the graph of the present value of earnings is an inverted *U* that peaks sharply at about age 30, while the value of life attains its maximum at about age 2, implying that society would spend more to preserve the life of a child than it would spend to preserve the life of an adult. Disease occurs chiefly in infancy and in old age when the present value of earnings is quite low relative to our calculation of the value of life. Rice assessed the cost per death from tuberculosis to be $31,000 and the cost per death from diseases of infancy and early childhood to be only $25,000, despite the fact that she valued the life of an adult at prime earning capacity at over $100,000. An implication of the calculation in this paper is that the value of the life of a child is on the order of $150,000: a government representing people whose preferences are described by equations (1′) and (3′) with $r = 5$ per cent and $\beta = 0.25$ would be prepared to spend up to $150,000 to save the life of a randomly selected child in 1961. Another difference between the present value of earnings calculation and the value of life calculation in this paper is that the former values men more than women while the latter puts the same value on the lives of men and women.

The final test of these two contrasting age distributions of the value of life is whether they reflect preferences in the community at large. I have no hesitation in saying that my preferences as to the comparative values of children and adults, and of men and women, are more nearly represented by the calculation in this paper than by the present value of earnings calculation. Unfortunately, the very plausible age distribution of the value of life in Chart 1 emerges in part for the wrong reasons. The value of a child's life is high not because concern of parents for children is

[17] Dorothy P. Rice, *Estimating the Cost of Illness,* Health Economics Series 6, U.S. Dept. of Health, Education, and Welfare, 1966.

CHART 1

Value of Life by Age in 1961, r = 5 Per Cent, β = 0.25
(Canadian dollars)

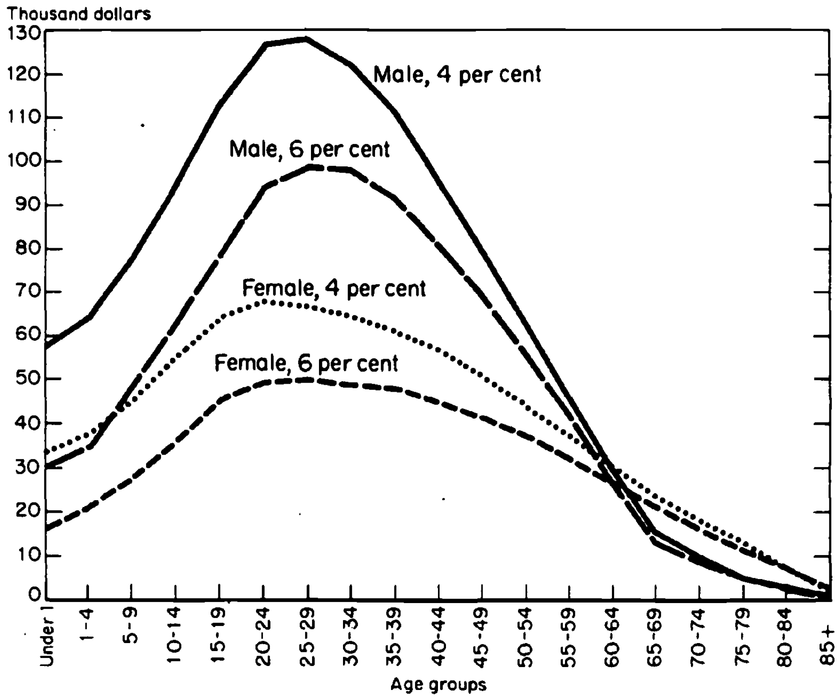


built into the utility function but because the expected discounted consumption is higher for children than for adults. The year to year change in discounted life expectancy, L, is shown in Chart 3.

As mentioned briefly at the outset of this paper, the addition of an imputation to the accounts for the improvement in life expectancy involves an element of double-counting if the rest of the accounts are left unchanged because the maintenance or increase of life expectancy is part of the benefit of medical and other expenditures already included in the accounts. I have chosen to ignore this issue and to add, or rather multiply, the improvement in life expectancy to the conventional measure of income without additional adjustments. My reasons for doing so are these: First, a substantial part of medical expenditure must surely be attributable to the attainment of comfort rather than increased life expectancy. Second, medical expenditures are not the only ones that increase life expectancy. If the expenditures that increase life expectancy are scattered among the major categories in the accounts, and if these expenditures grow at about the same rate as the rest of the accounts, it makes no difference to the final estimate of the rate of growth whether the mix of expenditures that increase life expectancy is included or not. Third, in strict logic there is really no end to the list of expenditures that may affect life expectancy. Food, clothing, and housing are all on the list in the sense that without any of these our lives would be shortened con-

CHART 2

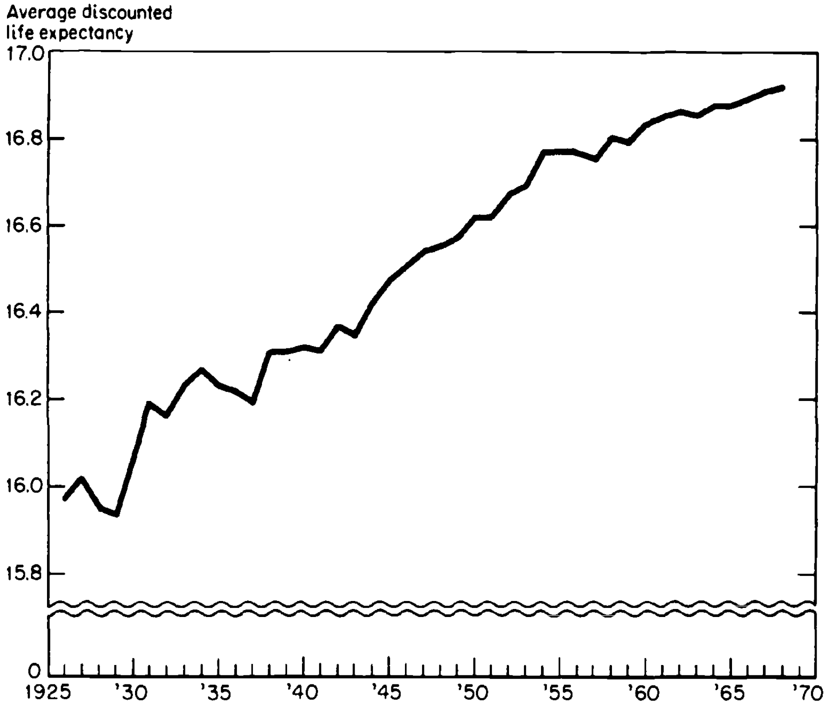
Present Value of Lifetime Earnings: Amount by Sex and Discount Rate



NOTE: The chart is based on data for the year 1963.
SOURCE: D. P. Rice, *Estimating the Cost of Illness,* U.S. Department of Health, Education and Welfare, 1966, p. 94.

CHART 3

Average Discounted Life Expectancy, 5 Per Cent, All Ages, 1961 Weights



siderably. But as a rule, the marginal dollar of expenditure in these categories has little to do with life expectancy and what connection there is had best be overlooked.

Closely related to the problem of double-counting is the fact that most of the change in mortality rates from one period of time to another appears to the individual as a free good. The imputation we have been discussing is to the expenditure side of the accounts exclusively—to the list of goods and services we obtain from the economy in any year—and there do not appear to be comparable items that may be attached to the income side of the accounts to restore the balance.

IMPUTATIONS FOR OTHER COUNTRIES

I have no direct intuition about the value of life in countries outside of North America, and no information with which to determine reasonable values of r and β. What can be done is to suppose that their tastes are the same as ours. In that case combinations of r and β which are plausible for Canada are plausible for other countries as well. Calculations on these lines are set out in Table 3. The numbers in the table are derived in exactly the same way as the Canadian numbers were derived, and the table should be self-explanatory. The reader who is uncomfortable with the assumption that shapes of indifference curves and values of β and r are the same elsewhere as in Canada may interpret the statistics in Table 3 as indicating the growth of income of Ceylon, for instance, as it would be assessed by a Canadian in the circumstances of the Ceylonese economy.

The interesting feature of Table 3 is the magnitude of some of the imputations for some of the underdeveloped countries. The growth rate of Ceylon is more than doubled, and the growth rate of Chile is almost doubled. If one may generalize from these scanty bits of information, it seems that in the period since World War II the underdeveloped countries, alleged by Pearson and many other authors to have prospered less on average than the rich countries, have in fact done no such thing. It was in this period that many poor countries enjoyed an improvement in life expectancy greater than that enjoyed by rich countries in this or any other period of time, an improvement that more than compensates for the difference between rich and poor countries in growth rates of GNP as conventionally measured.

COMMENTS

Though the coverage of the national accounts may be satisfactory for the purpose of designing and evaluating short-run economic policy, it is generally believed to be too narrow for the purpose of monitoring the progress of the economy as a whole. In the last few years there has developed an interest in social indicators, which are time series of significant aspects of life—justice, health, progress in the arts—outside the normal coverage of the national accounts. (Expenditures on these items are included in the national accounts, but it is input to these items rather than outputs that is reflected in measures of real income.)

An imporant constraint on the use of social indicators is that there does not seem to be a natural and appealing way of aggregating them into a single measure of the progress of the economy. Of course, weights can always be chosen, but there is normally no basis for preferring one set of weights to another, no way of finding weights that reflect common rates of trade-off in use between social indicators, and no assurance that

TABLE 3

Imputations for Increased Life Expectancy in Other Countries

		Growth Rate of GNP [a]			
Country	Period	Without Imputation for Life-Expectancy Increase	$r = 1\%$, $\beta = .45$	$r = 3\%$, $\beta = .30$	$r = 5\%$, $\beta = .25$
Ceylon	1946–63	1.65%	3.81%	4.22%	4.14%
Chile	1931–65	1.57	2.77	2.94	2.89
France	1911–64	1.82	2.47	2.56	2.53
Japan	1930–60	3.13	4.49	4.67	4.58
Taiwan	1952–66	4.15	5.09	5.25	5.22

SOURCE: The principal sources of data were various issues of the U.N. *Yearbook of National Accounts Statistics* and the U.N. *Demographic Yearbook.* These sources were supplemented by (a) for France, *Annuaire Statistique de la France*, 1966; C. Kindelberger, *Economic Growth in France and Britain, 1851–1950*, and *Long-Term Economic Growth, 1860–1965*, U.S. Department of Commerce, 1966; (b) for Japan, *Japan Statistical Yearbook*, 1964; (c) for Taiwan, *National Accounts of the Less-Developed Countries, 1950–1966*, Organization for Economic Cooperation and Development, and *China Yearbook, 1966–1967*, China Publishing Company, Taiwan; (d) for Ceylon, *Statistical Abstract of Ceylon*, various issues; (e) for Chile, M. Mamalakis and C. W. Reynolds, *Essays on the Chilean Economy*, Irwin, 1965, statistical appendix, p. 384.

Gross national product was used instead of net national product to represent $C(t)$ because the information needed to estimate the latter is frequently unavailable. Quite a bit of crude estimating was required to derive annual mortality rates from the available data. As with the Canadian data, mortality rates in five-year intervals had to be attributed to each year separately, but in addition some even larger time intervals had to be dealt with, and sometimes the time intervals differed from one year to the next. The higher age-groups were particularly troublesome. Two methods were used to derive mortality rates in five-year intervals from data on mortality rates in ten- or fifteen-year intervals. If data were available for five-year intervals in another year, I would normally assume proportionality between mortality rates in the five-year intervals in the two years. Otherwise mortality rates in intervals longer than five years would be attributed to each year in the interval. The maximum age was assumed to be 90. Sometimes when the final open-ended time interval, intervals such as "mortality rates for people over 70 years of age," began well short of age 85, mortality rates in five-year intervals were estimated by postulating that they rose in a systematic manner consistent with available data on population and mortality rates in the larger time intervals. For each country, data on income and mortality rates were collected for the first year, the last year, and selected years in between.

[a] Inclusive of an imputation for increased life expectancy.

the coverage of the different series is mutually exclusive. Confronted with a set of social indicators, one finds oneself in a position such as one would be in if faced with innumerable time series of ordinary quantities —chicken soup, can openers, light bulbs, ties, spark plugs, telephones— without prices and with no way of aggregating the series into a single index. The emergence of social indicators gives rise to a search for a way of combining them with each other and with the economic information in the national accounts.

The task of this paper has been to find a natural way of combining two social indicators, the GNP and mortality rates, into a single, comprehensive index. Weights were constructed from information about the value of life, from assumptions about the form of utility functions, and on the strength of a somewhat unfamiliar concept of real income. The resulting system of weights for comparing the conventional measure of income and mortality rates on the same scale, while not wholly arbitrary, is less well-grounded in observed behavior in the market than the price weights used to combine quantities in the national income; there is every reason to believe that people differ in their assessments of the relative importance of growth of national income and the decline in mortality rates, for arbitrage does not equalize values of life among people in the way it equalizes prices of butter. In the final analysis, the weighting of the growth of conventional income and decline of mortality rates for cost-benefit analysis or in a unified measure of economic growth is a political problem.

Despite this intrinsic lack of precision, the imputation for the decline in mortality rates is worth making because of its magnitude. A large part of the answer to the question "How are we doing?" depends on whether life expectancy is increasing or not. An imputation of an extra half per cent to the rate of economic growth in Canada is too large to be ignored. To exclude the imputation for increased life expectancy in measuring the rate of economic growth of certain poor countries is to overlook half of the economic growth and to misrepresent economic history on a very large scale.

The imputation of a value to the accounts for the increase in life expectancy casts a wider net among the social indicators than may be evident at first glance. The worst effects of pollution are eventually manifest in mortality rates. Admittedly there are aspects of pollution, such as noise and congestion, that probably do not affect mortality rates significantly. But the major concern with pollution is with its lethal aspects, and these are accounted for in the imputation. Any attempt to impute a negative value to the national accounts for the ill effects of pollution will have to be done in the context of the complete matrix of causes of changes in mortality rates. One might well want to show that pollution causes income, in some sense of the term, to be less than it might otherwise be, but one would not want to show a reduction of income as a consequence of the lethal aspects of pollution unless one also shows that the potential decline is overbalanced by the over-all rise in life expectancy. The general rule is that one ought not to impute for a part of any category, such as life expectancy or leisure, if the trend of growth of the part is opposite to the trend of growth of the category as a whole.

The aspect of the analysis in this paper that I find least satisfactory is the mechanical and arbitrary nature of the separability assumption (3′) used in deriving the utility assumption. The main point made in the introduction is that value of life is essentially a matter of taste. The inclusion in the utility function of the parameter β, which may be set in accordance with real or imagined evidence about behavior, gives considerably more scope for taste than is incorporated into the present value of earnings calculation. The relation between a person's age and the value of his life seems reasonable in that high values are placed on the lives of children. Unfortunately, this very plausible result emerges from the wrong reason. It ought to reflect externalities in the utility function, particularly the concern of parents for children. Instead it is based on the fiction that children, who have longer to live than adults, place higher values on their lives. Though the implications of our utility function are plausible, we really have no assurance that anybody's tastes are actually reflected in it.

COMMENT

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Perhaps no single factor has so altered the prospects of the individual as the historically unprecedented decline of mortality which began in the mid-nineteenth century in the West and in this century in the less developed countries. In northern Europe, the expectation of life at birth, which averaged about 40 years in 1850, rose to about 70 years by 1950. Even more dramatic is the estimate that one-fourth of a cohort of births in the 1840's would be dead by age 2.5 while in the 1940's the first quarter of a cohort would not be dead until age

62.5. As Stolnitz [3, p. 28] put it, "the number that could expect to survive the childhood years a century ago was substantially smaller than the number reaching old age today." The decline of mortality, facilitated by the transfer of Western medical and public health technology, has been even more rapid in the less developed countries although, of course, their mortality rates remain well above those in the advanced countries.

Common sense would suggest that such changes in longevity should be a major source of increased individual welfare; yet the national income accounts which provide the main statistical basis for judging changes in welfare omit altogether any direct consideration of changes in mortality rates. At the very least, Dan Usher in his attempt to remedy this difficulty has provided us with an imaginative, tightly argued and intriguing way of looking at the problem of imputing value to changes in longevity and has, as well, illustrated a number of ways in which it should not be done. If this method is accepted, the paper also takes on major substantive importance because of the magnitude of the adjustment to conventionally computed growth rates when imputations for the value of changes in age-specific mortality rates are made. For instance, he finds that under certain assumptions the growth rate of Canadian per capita income from 1926 to 1968 was increased by one-half of 1 per cent—from 2.25 to 2.8 per cent—by the imputation while the growth rates of some less developed countries which have recently experienced very rapid declines in mortality were doubled, becoming higher than growth rates in more developed countries rather than lower, as the conventional measure would have it. I believe that Usher's work points in the right direction and that this direction is important to explore further, but, for theoretical reasons I shall elaborate shortly, I think his imputations overstate the contribution of increases in life expectancy to the growth in welfare.

The need for a new approach to the economic valuation of human life has been amply illustrated, sometimes in grisly fashion, from examples drawn from existing approaches in a recent paper by Mishan [2] and by Usher in this paper. For example, using per capita income or consumption as a standard, most neoclassical growth models imply that a decrease in mortality rates would generally imply a reduction in economic welfare. In these models, the impact of declining mortality on national economies is usually considered, following the Malthusian tradition, to be exerted mainly through its impact on the rate of population growth which, in turn, determines the rate of growth of the labor force and, sometimes, the savings rate. It is almost always concluded that in steady state growth, the level of per capita income or consumption at any moment in time will be inversely related to the rate of population growth. Furthermore, in some models excessive rates of population growth induced by income growth (or transfer of medical technology) may prevent an economy from escaping a "low level equilibrium trap" to reach a higher level of living in which population growth is smaller. These implications are frequently invoked to support policies to reduce birth rates but, in logic, they may equally well be used to support policies to raise death rates.

The question being answered by such models, which Usher terms the "birth control question," is: "How much better or worse off would the community at large be if I ceased to exist or if I had never been born?" The thrust of this question is that, because of the law of variable proportions, a marginal increase in the labor force caused by population growth will reduce the average income of others. This will cause a decrease in welfare if we concentrate on the welfare of the "others" and ignore the welfare of the one who ceased to exist or of persons interested in his existence. Apparently this is more easily done when contemplating a potential birth than a potential death for reasons not apparent from logic of the argument itself (see [2, p. 690] for a similar point).

In any event, Usher argues that the "birth control question" is not the true "valuation-of-life question" which he says is: "How much would I pay to avoid a small probability of my death?" As an example, he states that a man who will pay $500 to avoid a 1 in 1,000 chance of death may be said to place a $500,000 value on his life. It should be emphasized that this is not the "insurance question" criticized by Mishan [2, p. 691] in which the answer to the question "What is my life worth to my wife and children?" will determine the premium the man would be willing to pay for life insurance against a 1 in 1,000 chance of his death. The $500 expenditure given in answer to the "valuation of life question" represents $500 of real resources because the man expects to avoid the 1 in 1,000 chance of death by his expenditure while a "mathematically fair" life insurance premium merely covers the risk entailed in passive acceptance of the chance of death and uses no real resources. There would be no imputation problem if all changes in mortality were the result of expenditures by individuals to change their own rates, assuming each such expenditure to be the maximum amount the individual was willing to pay for the reduction. Obviously, this is not the case; so imputation is necessary even at the risk of a fair amount of double-counting entailed by a failure to adjust conventionally measured income for expenditures designed to reduce mortality. At the end of the section "An Imputation to the Canadian Accounts," Usher gives several plausible reasons for doubting the seriousness of double-counting problems, especially when the emphasis is on measuring the growth rather than the level of income.

Usher approaches the evaluation of life question formally by assuming that an individual's utility for the rest of his life, U, can be expressed as a function of the lifetime utility, U_j, that he would receive from his current and future consumption stream if he should live exactly j years and the probability, P_j, that he lives exactly j years for all possible values of j from zero to n, the maximum length of the remaining proportion of the individual's life. In order to make this approach operational, Usher specializes this general utility function by making two assumptions. The first, which he calls the "expected utility hypothesis," is that the utility function takes the form,

$$U = \sum_{t=0}^{n} P_t U_t, \tag{1'}$$

and the second, which he calls the "separability assumption" is that

$$U_t = \sum_{i=0}^{t-1} \frac{C_1{}^{\beta}}{(1+r)^i}, \tag{3'}$$

where U_t is the individual's lifetime utility should he live exactly t years, β is the elasticity of annual utility with respect to consumption, and r is a discount factor which Usher argues is "different from and as a rule less than the real rate of interest on riskless assets." Given these assumptions and recognizing that the P_t are functions of the age-specific mortality rates, it is possible to find the increase in current consumption C_0 necessary to compensate the individual for a small increase in his current mortality D_0 by evaluating

$$-\left.\frac{\partial C_0}{\partial D_0}\right|_U .$$

This marginal rate of substitution is considered by Usher to be the value of life, and given the schedules of future consumption and age-specific mortality rates, it will be determined by the parameters r and β.

Usher argues that national income accounts should be based upon statistics reflecting current conditions rather than forecasts of the future.

Accordingly, he assumes that $C_i = C_j = C(t)$, where $C(t)$ is the current level of NNP and that current age-specific mortality rates will continue into the future. Combining (18) and (19), these equations imply

$$U = \sum_{j=0}^{n} \frac{C_j^{\beta} S_j}{(1 + r)^j} = C(t)^{\beta} L(t), \tag{18–19}$$

where the S_j are survival rates and $L(t)$ is the "discounted expectation of life." Equation (19), in turn, implies that

$$\hat{C}(t) = C(t)\, L(t)/L(1961)(1/\beta), \tag{20}$$

where $\hat{C}(t)$ is "the value of net national product at which one would be as well off with mortality rates of the base year as one was in year t with actual net national product, $C(t)$, and actual mortality rates, $D_j(t)$, of that year." The difference between the growth of $\hat{C}(t)$ and $C(t)$ represents the imputation to national income for improvements in mortality.

The most remarkable implication of Usher's approach as embodied in (19) and (20) is that the growth rates of discounted life expectancy $L(t)$ and of conventionally measured income $C(t)$ cumulate rather than average out so that

$$\hat{G}_{\hat{C}} = G_C + (G_L/\beta), \tag{21}$$

where β is assumed to be less than or equal to one. As Usher points out, "It is a consequence of the assumptions we have made about the form of the utility function and the concept of income that the effect of the imputation for increased life expectancy is necessarily to increase the rate of growth, and the increase is normally greater than the rate of growth of life expectancy itself." Since it is this implication that mainly accounts for the large empirical magnitude of the imputation, it is important to examine just what concept of income Usher is employing and how it compares to the conventional concept before we know how to react to his estimates.

I believe that it can be demonstrated that Usher's concept of income is, in one sense, the polar opposite of the conventional concept and that the meaning of the conventional concept can be greatly clarified by the use of Usher's formulation. If, to take an extreme case, an individual lived forever, we could express his "lifetime" utility in Usher's terms by suitably rewriting (18–19) to read as follows:

$$U = \sum_{i=0}^{\infty} \frac{C_j^{\beta} S_j}{(1 + r)^j} = \frac{C(t)^{\beta}}{r}. \tag{18′–19′}$$

If β is set equal to 1, the right hand side of (18′–19′) is equal to the present value of a perpetual continuation of consumption at its current level $C(t)$. In conventional terms, of course, this is equal to society's wealth defined as the present value of the stream of output that could be produced if the society's current stock of resources remained intact forever. Included in the stock of resources is the population from which the labor force is drawn.

It is a fact of sometimes deep significance that a population composed of mortal men may itself be immortal. In order to carry out his computations, Usher assumes "that there is a unique price $\partial C_0/\partial P_0$ corresponding to a set of mortality rates D_j and a level of permanent consumption C, as there would be if society were one individual writ large." It is now apparent that the conventional view of permanent consumption as the return from a fixed stock of resources is as it would be if the individual were immortal society writ small. In this sense, Usher's concept of income and the conventional concept are polar opposites.

It now becomes clear that Usher's rejection of Hicks's definition of income,

$$Y(t) = C(t) + W(t+1) = W(t), \tag{15}$$

was based on an erroneous supposition that a decrease in mortality rates would cause wealth to increase (see the section "Growth of What?"). If the individual is society writ small, he is immortal by definition and changes in actual mortality rates are immaterial.

It would appear that our reaction to Usher's imputations must depend on our philosophical position as to whether national income should measure the permanent output obtainable from a fixed social stock of resources or the level of a surrogate for the lifetime utility of an average individual in the population. If I were forced to make such a choice, I would find much to recommend Usher's position as against the conventional position. It seems to me, however, that the choice need not be so severe. Usher began his theoretical model with the injunction, "Ignore the fact that men live in families and that families are imbedded in communities of people who are concerned with each other's well-being." In the sense of welfare, this is an injunction to ignore sources of longevity other than one's own physical existence, especially the expectation of the existence and well-being of one's children and other heirs. In a sense, the conventional view of income implies that an individual is indifferent, after discounting, between his own and his heir's consumption; his "rate of benevolence," to use Boulding's term [1], is equal to unity. Surely, the truth is that the rate of benevolence is somewhere between zero and one. Thus, Usher's imputation—on this score, at least—probably gives us an upper bound on the value of increased life expectancy.

Following the line I have been arguing, it is parents who reveal their preference for decreasing the risk of death faced by their offspring and to whom a change in welfare should be imputed when infant and child mortality rates change. Since parents have the power to create a new life to replace one lost while an adult cannot replace his own life, the value of a decrease in infant or child mortality using this approach would probably differ substantially from that found using Usher's approach. The magnitude of the imputation for changes in life expectancy is likely, empirically, to be quite sensitive to changes in the treatment of the mortality rates faced by the young because it is these rates that have changed the most, especially in the less developed countries.

In this paper, Usher has raised a set of issues of which many economists, including myself, were only dimly aware and he has succeeded in demonstrating that the resolution of these issues is of vast importance for our understanding of past economic growth and our evaluation of policy alternatives before us. Now that we are aware of them, I am confident that the issues raised here will be pursued much further, both empirically and conceptually.

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