Irving Fisher and the Contribution of Improved Longevity to Living Standards

By WILLIAM D. NORDHAUS*

ABSTRACT. It is not widely recognized that conventional measures of national income and output exclude the value of improvements in the health status of the population. The present study discusses the theory of the measurement of national income, proposes a new concept called "health income" that can be used to incorporate improvements in health status, and applies the theory to data for the United States over the 20th century. It concludes that accounting for improvements in the health status would, over the twentieth century in the United States, make a substantial difference to our measures of economic welfare.

I

Introduction

AMONG IRVING FISHER'S many contributions to economics, one that is little noted and scarcely remembered is his emphasis on the economic importance of health. For the most part, his concern was in promoting healthy lifestyles. In addition, he made an early (perhaps the earliest) estimate of the impact of mortality and morbidity on national output.

This essay considers the question of how measures of economic welfare might change if they included measures of health status as well as of conventional consumption. The surprising finding is that

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inclusion of improvements in health status would, over the 20th century in the United States, make a substantial difference to our measures of economic welfare. While Fisher thought and cared deeply about index numbers, measurement of income, utility theory, and health, he never connected these different concepts. On the other hand, he must have had an intuitive understanding of the importance, as suggested by the following passage:

> A large part of our subjective income is due to our conditions of health or disease. . . . [A] healthy body is absolutely essential for receiving and enjoying the income from external wealth. . . . Economists, by fixing attention exclusively on physical phenomena, leave out the most essential element of all, the vigor of human life. The true "wealth of nations" is the health of its individuals. (Barber 1997, Vol. 2: 204)

In the sections that follow, I begin with a brief discussion of Fisher's writings on health. I then provide an analysis of how traditional measures of income might be modified to incorporate changes in mortality and life expectancy. Finally, I make preliminary estimates of the quantitative impact of adjusting national-income measures for mortality.

II

Fisher on Health

FISHER'S CAMPAIGN FOR healthful living today seems quirky. Its origins came when he contracted tuberculosis in the summer of 1898, shortly after having been promoted to full Professor of Political Economy at Yale at the age of 31. As Fisher explained in 1917, it was this experience that opened his eyes to the importance of health:

> I feel a little ashamed to admit that as an economist and as a student of society I had been blind, as the average man or woman of today is blind, to what heath conservation means. Suddenly I discovered I had tuberculosis and took a long enforced vacation. When after three years I went back to Yale, I was unable for two years to do even half a man's work. . . . At length by dint of conscientious application of a dozen or more specific points of hygiene, not only did I succeed in winning back my previous working power, but acquired more than I had ever dreamed of acquiring. (Barber 1997, Vol. 13: 83)

As with all Fisher's passions, he set about studying and proselytizing with enormous vigor. Among his most notable contributions were the establishment of the Life Extension Institute and a book, jointly written with Dr. Eugene Fisk, which stressed rules on individual hygiene (Fisher and Fisk 1915). In this field, as in so many others, Fisher was decades ahead of his time, emphasizing the importance of individual lifestyles. He laid out the Fifteen Rules of Health (see Table 1). Fisher was open—some might say, too open—to every new nostrum, and it is easy to poke fun at them. Among more entertaining rules were "Ventilate your clothes while they are on you," "Eat slowly," and "Eat some hard foods." However, he also emphasized the importance of weight, abstinence from tobacco, alcohol, and drugs, and vigorous exercise. All these sound commonsensical today, but it is striking that the Fisher-Fisk volume was the first important pamphlet emphasizing the importance of lifestyles in addition to antimicrobial health care.

III

Including Health Status in Measures National Income

A. Current Approaches to Measuring the Contribution of Health in the National Accounts

While the GDP and the rest of the National Income and Product Accounts (NIPA) may seem to be arcane concepts, they are truly among the great inventions of the 20th century. Nevertheless, since the beginning, there have been concerns that the accounts are incomplete and misleading because they omit most nonmarket activity. To meet this criticism, private scholars as well as official statistical agencies have begun extending the national accounts to include several nonmarket sectors, including national resources, the environment, transportation, leisure time, and unpaid work.[1]

One question that has been virtually ignored in attempts to extend the national accounts is the need to account adequately for improvements in human health. It is little understood outside the priesthood of national accountants that there is no serious attempt to measure the "real output" of the health care industry. The techniques used to measure the price and quantity of health care are highly defective, and there are *no* attempts to account for improvements in the length of life into current national accounts.

Table 1

Fisher's Fifteen Rules of Health*

The book summarizes in fifteen rules the ways in which the individual has it within his own power to add to his efficiency. These rules are under four heads: Air, Food, Poisons, Activity.

Under Air There Are Five Rules:

1. Ventilate every room you occupy.
2. Ventilate your own clothes while they are on you. In other words, select light, and loose, and porous materials for your clothing. The skin needs the air contact.
3. Live out of doors as much as you can. Seek outdoor avocations and recreations. . . .
4. Sleep out of doors, if it is possible. We do not yet understand what that great sense of well-being is which comes after sleeping out-of-doors, but it is very real.
5. Breathe deeply. Take some long breaths every day systematically. One doctor advises his patients to take 100 long breaths every day. In India, rhythmic deep breathing is a part of the religious system.

Under Food the Four Rules Are:

6. Avoid overeating and overweight. This rule becomes especially important soon after you graduate from college, and therefore it is important before you graduate. It is the rich, overfed sedentary man or woman who later becomes the prey of the wear-and-tear diseases.
7. Avoid overeating of nitrogenous or protein foods. Consequently this rule practically means to avoid overeating of meat and eggs. Such indulgence is really the great dietetic sin of Americans, and one of the chief reasons, I believe, for the fact that in America certain degenerative diseases are more common than in other countries. We eat so excessively of meat, partly because we can afford it, party because of an abnormal appetite coming from the hurry habit. Therefore we who hurry

Table 1 *Continued*

so are heavier meat eaters than the people of Europe and other countries and we pay for that indulgence in high blood pressure and diseases of the kidney.

8. Eat some hard foods, some raw foods and some bulky foods every day. Hard foods exercise the teeth.
9. Eat slowly. The hurry habit is responsible for many evils.

Under Poisons the Four Rules Are:

10. Evacuate thoroughly, regularly and frequently, to avoid "auto intoxication."
11. Stand, sit and walk erect for the same purpose; for bad posture is largely responsible for constipation.
12. Do not allow poisons and infections to enter the body. Among other things this rule means total abstinence from alcoholic beverages and from the use of tobacco.
13. Keep the teeth, gums and tongue clean. Primitive people have perfect sets of teeth without the use of the toothbrush.

Under Activity, There Are Two Rules:

14. Work, play, rest and sleep in moderation and in due relation to each other.
15. Keep a healthful mental attitude, for it is worry rather than work which kills.

*From Barber 1997, Vol. 13. They have been renumbered for this table.

It might be thought that including health status is some radical, far-out, and woolly-headed attempt to incorporate intangible, non-economic, and sociological measures into our social accounts. This argument is wrong; health care expenditures are already included in measures of national income and output. Indeed, they are a growing fraction of GDP—the fraction of personal consumption expenditures devoted to medical care rose from 5.1% in 1959 to 16.7% in 2003. While inclusion of health care is not radical, it is radical to suggest that we should make a serious attempt to measure the *output* of the health care sector and to *value* this output correctly.

Recent economic studies suggest that there is little connection between medical spending and the measured economic value of health-status improvements. At a commonsense level, the lack of connection comes because "real" medical care spending in fact measures spending on inputs rather than on health outcomes. The current approach is to measure health output primarily by the number of physician-visits, the number of hospital days, and similar measures, rather than the actual delivery of services or changes in health status. It may come as a surprise to most non-economists that improvements coming from new products, such as the discovery of antibiotics or the substitution of drugs for invasive surgery, are completely omitted in current measures of real output.

Attempts to measure improvements in the health status of the population—including everything from vaccinations, microsurgery, and new drugs to airbags, exercise, and anti-cigarette advertising—pose a new and difficult challenge to measuring national income. Recently, economists have begun providing better outcome-oriented estimates of the prices and outputs in the health-care sector. One of the most striking findings comes from a study by Cutler, McClellan, Newhouse, and Remler (1998), who estimated that a true price index for the treatment of heart attacks would rise about 5.5% per year more slowly than the corresponding component of the CPI. Similar results were found in studies of treatment for glaucoma by Shapiro and Wilcox and for cataract surgery by Shapiro, Shapiro, and Wilcox.[2]

Given the likelihood that we are dramatically mismeasuring, and almost certainly underestimating, the contribution of improvements in health care to economic welfare, this raises the question of how to proceed to obtain better estimates. One approach would be to continue the approach just described, of constructing better measures of output and prices. This approach was adopted by the Boskin Commission and is the thrust of much current research on health economics.[3]

Another quite different approach, which is used in the present study, is to obtain direct measures of health status, weight them with appropriate prices, and then estimate the value of improvements in health status. This approach is actually much simpler than "fixing" price and output indexes because measures of health status are generally much better than data on the impacts of particular technologies on health status. We will see that following this path has radical impacts on our measures of real income and output.

B. Alternative Measures of National Income

Before proposing alternative concepts, it will be useful to describe different approaches to measuring national income. The concepts of social income and national income go back centuries. They are largely based on the analogous definitions of individual income with appropriate adjustments for aggregation and national boundaries. We can distinguish two fundamentally different approaches to measuring income—one based on production and one based on utility. The former is the basis of modern national-income accounting while the latter is more appropriate when considering sustainable income and the contribution of improvement in health status.

1. *Production-Based Measures (Hicksian Income)*

The modern treatment of social income dates from the writings of J. R. Hicks. When economists and accountants measure national income, they have almost universally relied upon the Hicksian definition. The discussion of social income in *Value and Capital* states: "The purpose of income calculations in practical affairs is to give people an indication of the amount which they can consume without impoverishing themselves" (Hicks 1939: 172). Hicks then goes on to provide his first definition of social income:

> *Income No. 1* is thus the maximum amount which can be spent during a period if there is to be an expectation of maintaining intact the capital value of prospective returns; it equals Consumption plus Capital accumulation. (Hicks 1939: 173, 178, emphasis added) [4]

This definition is what is called "Hicksian income"—the maximum amount that can be consumed while leaving capital intact. In practice, income equals consumption plus a generalized measure of capital accumulation.

The Hicksian concept is the standard definition of net national or domestic product used in the national-income accounts of virtually all nations today. It is *production based* in the sense that it attempts to measure the rate of production at a given time. Such measures are not concerned with the health status of the population or whether people are enjoying that production for a longer lifespan.

2. *Utility-Based Measures (Fisherian Income)*

While standard concepts of income are useful tools for measuring current production, they are not equivalent to economic welfare. The shortcoming of the traditional approach is clear when we consider situations in which technologies are improving or people are living longer. An economy in which people have a per capita income of $20,000 with lives that are nasty, brutish, and short would be ranked as equivalent to one with the same per capita income and lives that are healthy, civilized, and long. In the context of health, the key point is that the same *annual* income with a long and healthy life has a higher living standard than that income with a short and diseased life. Including health status in income is particularly important when a large and growing fraction of our economy is devoted to health care.

An alternative approach is to define income as utility-equivalent consumption.[5] I denote this "Fisherian income" after Irving Fisher, who defined income as the flow of consumption that could be harvested from the nation's capital stock.[6] Under this approach, income is defined as the level of consumption that would give the equivalent level of utility from consumption and other determinants of utility in different situations. This definition has been used to define the level of "sustainable income" in situations in which there is a tug of war between resource exhaustion and technological change.[7] In cases in which lifetimes are fixed, this is equivalent to defining income as the maximum that can be consumed with current assets and current and future incomes.

For concreteness, call this "utility national income" and define it as follows:

> *Definition. Utility national income* is the maximum amount that a nation can consume while ensuring that members of all future generations can have lifetime utility that is at least as high as that of the current generation.

If life expectancy is unchanging, income is the maximum real consumption annuity that a nation can spend out of its resource endowment. The major difference in analyzing living standards with variable lifetimes is to recognize that people are better off when they live longer, and that this fact should be reflected in measures of their incomes and living standards. This approach measures the increased income from longer life expectancies by the consumption equivalent of the utility or value of the health or longevity improvements.

IV

Integrating Health Status into Income Measures

CONSUMPTION AND INCOME are traditionally measured as flows of goods and services (or utilities) during a given period of time. Changes in an individual's health status pose no terribly deep issues of measurement, for we can treat these as new or improved "goods and services" that can be appropriately priced and included in the consumption basket.

Incorporating changes in lifetimes, by contrast, poses qualitatively different problems of measurement. I begin this section by considering a simple life-cycle model of consumption in which there are tradeoffs between life and consumption. I then show how this approach might be used to construct a framework for measuring income.

A. A Life-Cycle Model with Variable Lifetime

We want to examine the gain in "real income" from improved health and life expectancy. We do this in the context of the life-cycle model of consumption. An individual is assumed to value consumption and health according to a lifetime utility function:[8]

$$V[c_t; \theta, \rho, \mu_t] = \int_{\theta}^{\infty} u(c_t) e^{-\rho(t-\theta)} S[\mu_t] dt, \qquad (1)$$

where $V[c_t; \theta, \rho, \mu_t]$ is the value at time t of the consumption stream now and in the future faced by an individual of age θ; $u(c_t)$ is the stream of instantaneous utility or felicity of consumption; ρ is the pure rate of individual time preference; $S[u_t]$ is the set of survival probabilities; and μ_t is the set of mortality rates. The key assumption here is that utility is a function of the utility of consumption weighted by the probability of survival. As we will see, the utility function has a natural semi-cardinal interpretation as the value of life extension.

We begin with a simple and tractable assumption about mortality to show the basic relationships; when developing the empirical estimates in later sections we will use more realistic life tables. Consider the simple case in which the survival function is exponential. Equation (1) then becomes:

$$V[c_t; \theta, \rho, \mu_t] = \int_{\theta}^{\infty} u(c_t) e^{-(\rho-\mu)(t-\theta)} dt. \tag{2}$$

We assume that each individual has a given endowment of expected labor income and can buy full-value real annuities with any desired trajectory. We can further simplify for computational purposes (to be relaxed later) by assuming that the real interest rate faced by the individual is equal to the mortality adjusted rate of time preference, $(\rho + \mu)$. Given these assumptions, the individual will choose a consumption annuity that yields constant consumption during the individual's lifetime, $c_t = c^*$. Integrating Equation (2) yields a particularly simple outcome:

$$V[c_t; \theta, \rho, \mu] = u(c^*)/(\rho + \mu). \tag{3}$$

Equation (3) shows that the total utility value of consumption is the utility of the flow of constant consumption discounted by a discount rate that equals the sum of the force of impatience and the force of mortality.

An individual will often face a tradeoff between "health and wealth." What would be the tradeoff given by Equation (3)? At age θ, changes in consumption and health yield:

$$\begin{cases} dV/dc^* = u'(c^*)/(\rho + \mu) \\ dV/d\mu = -u(c^*)/(\rho + \mu)^2. \end{cases} \tag{4}$$

Hence the relative value of consumption and mortality is:

$$dc^*/d\mu = -u(c^*)/[u'(c^*)(\rho + \mu)]. \tag{5}$$

We make two normalizations that will simplify the discussion without loss of generality. First, we simplify by selecting a goods-metric utility function. This gives us a metric in which utility is measured in terms of goods at the equilibrium, which implies that $u'(c^*) = 1$. Second, we chose the units so that zero is the utility at which the individual is indifferent between life and death. This implies that there is zero utility after death.

Given these assumptions, Equation (5) reduces to:

$$dc^*/d\mu = -u(c^*)/(\rho + \mu) \tag{6}$$

or, without discounting:

$$dc^*/d\mu = -Tu(c^*) \tag{7}$$

where T is life expectancy and equal to $1/\mu$ in the exponential case. The interpretation here is that a uniform change in mortality rates at every age will produce a welfare change equal to the number of years of life (T) times the goods value of life, given by $u(c^*)$.

The major difficulty in applying this approach is determining the value of life. We can consider this question in the simple model sketched above. Suppose that the mortality rate declines by an amount Δ for one period. Then the survival rate is higher by e^{Δ} at the end of the period. Discounted utility evaluated at age $\theta \geq K$ is then

$$V(\theta) = e^{\Delta}u(c^*)/(\rho + \mu) \tag{8}$$

Hence, using this simple mortality assumption, the tradeoff between current risk and current consumption is approximately $dc/d\mu(\theta) = u(c^*)$.

From this discussion we see that it is generally not correct to adjust for changes in health status by calculating lifetime consumption, which would be c^*T in the present example. This approach is only correct when $u(c) = 1$. Our numerical estimates below indicate that this approach will generally undervalue improvements in life expectancy.

B. Valuation of Life

Measuring utility income with health improvement requires finding appropriate "prices" to use to value health status. There is a voluminous literature on the value of fatalities prevented.[9] It is generally accepted that the "willingness to pay" to reduce risk is the appropriate approach for valuing risk reductions. Studies of this fall into three general categories: labor market studies, which examine the risk-wage tradeoff; consumer purchase decisions (such as for smoke detectors), which examine the price-risk tradeoff; and contingent valuation studies, which attempt to determine preferences from a systematic examination of an individual's stated preferences.

The most weight is generally put on labor market studies because these reflect actual behavior, because labor force decisions are repeated, and because there are dozens of studies from different periods, countries, occupations, and samples. It is important to note that the tradeoff examined is a *current risk-current income* ($dc/d\mu$) choice between current occupational risks and current wages. From these tradeoffs (which involve comparing income per year against mortality risk per year) we derive an implicit dollar cost per unit mortality risk. Because the risks are relatively small (around between 1/100,000 per year to 50/100,000 per year), we interpret these prices as the marginal valuation of risk changes.

Not surprisingly, there is great variation in the implicit price of risk (or price of a statistical life). The serious estimates from a recent survey range from $0.6 million to $13.5 million per fatality prevented. The U.S. Environmental Protection Agency uses the relatively high figure of $4.8 million per fatality prevented in its cost-benefit study of the value of clear air.[10] Tolley, Kenkel, and Fabian (1994) recommend a value of $2.0 million per fatality prevented for use in health care decisions. In this study, I settle on $3.0 million per fatality prevented in 2000 prices and 1990 income levels as a reasonable choice, but the figures are easily modified to reflect different assumptions.

In our analysis above, we calculated the increment to sustainable consumption of an additional life-year, LY. There is some confusion but little solid evidence on how to measure the value of an added life-year. Most studies derive LY values from the studies of the value of reduced mortality.

To convert the value of mortality reduction to the value of a life-year requires further assumptions about timing and discounting. Many of the studies underlying the value of mortality reduction concern labor market decisions of working men. Assume for simplicity that the representative worker is aged 40 and that the mortality rate is a constant 2.5% per year. To convert these into value per life-year requires assuming a utility discount rate, which we alternatively take to be 0, 1, and 2.5% per year. With no discounting and the $3 million life value, the population-weighted value of a life-year is $210,000 and the annuity value of an additional life-year is about $5,000 per year. Again using the simplified mortality assumption and a discount rate of 2.5% per year, a life-year has value of $625,000 and the annuity value is $31,000 per year. These numbers appear somewhat high relative to other estimates. Tolley et al. (1994) recommend a central present value of $100,000 per LY from their studies (see also the discussion in Viscusi 1993).

In the estimates presented below, we use actual survival functions rather than the theoretical ones analyzed above. Using the equilibrium 1950 population distribution and 1980 mortality rates, the value of a LY varies from $152,000 at a zero discount rate to $376,000 at a 2.5% discount rate. The associated consumption annuities are $2,200 per year and $11,400 per year per additional LY, respectively (all scaled to 1990 income levels in 2000 prices).

C. Measuring Income with Variable Lifetimes

Next we turn to the issue of measuring income or consumption. For this purpose, we take the utility-based measure of income. We begin with the simplest case of utility-based income with fixed and certain lifetime. Assume that the consumption discount rate is a constant, *r*. Once we know the entire path of consumption, given by C(s) for s ≥ t, we can easily calculate utility income at time *t*, denoted by **C**(t), as

$$\mathbf{C}(t) = r\left[\int_t^{\infty} C(s)\exp[-r(s-t)]ds\right].$$

Note that **C**(t) measures the *constant* consumption annuity available at time *t*. This definition shows that measures of utility income or sustainable income are inherently wealthlike measures, as was emphasized by Irving Fisher and Paul Samuelson.[11]

The utility definition of income is a natural springboard for considering the measurement of income with varying lifetimes. Begin by extending the definition of income and consumption to uncertain, variable, and endogenous lifetimes. To begin with, consider the traditional definition of income. For example, say that in lifetime situation "Short" individuals consume 100 units per year each and live for 50 years, while in situation "Long" individuals consume 100 units per year and live for 60 years. Under the standard flow definition of consumption, there would be no difference in economic welfare or living standards between Short and Long. This is clearly defective to the extent that people prefer to live longer.

An alternative and preferable approach is to convert the consumption trajectory and survival function into the equivalent utility with a benchmark survival function and consumption. Take the Short lifetime situation as the benchmark. Using the example of the last paragraph, we ask what consumption annuity using the life expectancy of situation Short would give individuals the same utility as the consumption and life expectancy of situation Long. An individual might consider situation Long (with a constant consumption of 100 and a lifetime of 60 years) to be equivalent to, or have equivalent utility with, a constant consumption annuity of 110 units per year with the life expectancy of situation Short. We would then say that (using situation Short as the benchmark) the income in situation Long was 110 compared to that of 100 in situation Short.

Using the notation of the last section, define S = Short and L = Long. Then let $V[c_t^S; \theta, \rho, \mu_t^S]$ be the utility of consumption stream c_t^S and age-specific mortality rate μ_t^S while $V[c_t^L; \theta, \rho, \mu_t^L]$ is the utility of consumption stream c_t^L and age-specific mortality rate μ_t^L. We define income $c^*(L, \mu^S)$ as the constant consumption stream that would go with mortality rates in Short, which yields the equivalent utility as the consumption stream and mortality rates in situation Long. That is, $V[c^*(L, \mu^S); \theta, \rho, \mu_t^S] = V[c_t^L; \theta, \rho, \mu_t^L]$.

We then compare incomes in different situations by estimating the constant equivalent consumption annuity with a benchmark mortality function. Say we use mortality rates from situation S as the benchmark. We can then compare situations S and L by comparing $c^*(S, \mu^S)$ and $c^*(L, \mu^S)$, such that $V[c^*(S, \mu^S); \theta, \rho, \mu_t^S] = V[c_t^S; \theta, \rho, \mu_t^S]$

and $c^*(L, \mu^S)$ such that $V[c^*(L, \mu^S); \theta, \rho, \mu_t^S] = V[c_t^L; \theta, \rho, \mu_t^L]$. There will be the usual index-number problems involved in these comparisons because the definitions will differ depending on whether we use the mortality rates of situation S or L.

Because this tangle of algebra is somewhat forbidding, it will be useful to summarize the major points. Traditional income accounting looks at the flows of consumption and income in measuring living standards—consumption of food, purchases of electricity and apparel, airline travel, and so forth. These measures do not consider the length of life or the quality of the population's health. The alternative proposed here corrects for mortality by asking how much consumption the individual would be willing to pay to trade off for health. If, for example, an individual would pay 2% of consumption each year to gain an additional life-year, then we use that number to say that an additional life-year is equivalent to a 2% increase in annual income. In the estimates below, we use this technique only to adjust for changes in life expectancy, although they could also be used to adjust for changes in morbidity.

V

The Impact of Improved Life Expectancy on Economic Welfare in the United States, 1900–1995

A. Previous Studies

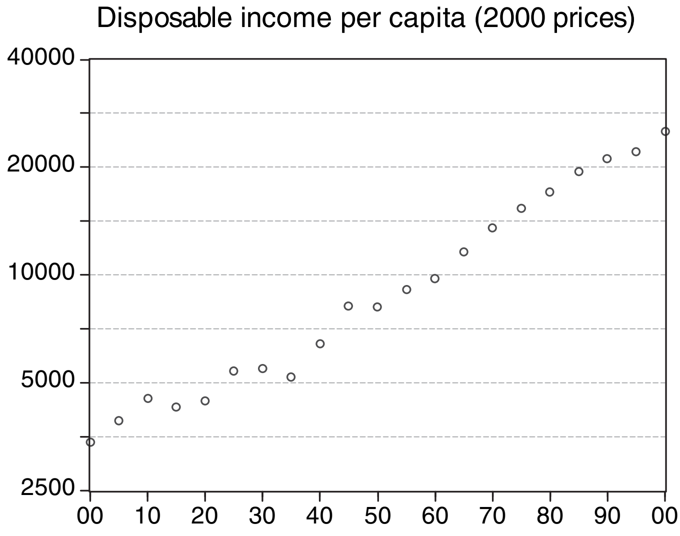
The literature on estimating the economic value of improved health is surprisingly sparse. Dan Usher (1973, 1980) considered the issue as part of a more general study of the adequacy of conventional national output measures, but his approach was highly stylized. A number of indexes incorporate life expectancy, particularly the United Nations Development Program's Human Development Index (HDI).[12] The technique for incorporating health in the HDI is, however, completely arbitrary. Economic historians have begun to compile systematic indicators on various health-related measures, such as height and the body-mass index, and these tend to move with other measures of health status, but it is difficult to put a price tag on these indexes.[13] Important additions to the literature are studies by David Cutler and Elizabeth Richardson (1997), which are discussed below, and the contribution of Kevin Murphy and Robert Topel (2002).

B. Methods

We now implement the ideas in earlier sections using data for the United States. The calculations here estimate the value of the health component of utility income, or the value of improvements in health status, which we call "health income." The fundamental data for the United States are shown in Figures 1 through 4. Figure 1 shows per capita disposable income for the United States from 1900 to 2000. The data are from the Commerce Department for the period 1929–2000 and from various private scholars for 1900–1929. The Commerce Department figures are in chained indexes converted to 2000 price levels. Earlier estimates are in constant prices.

Figure 1

Disposable income per capita, 2000 prices.



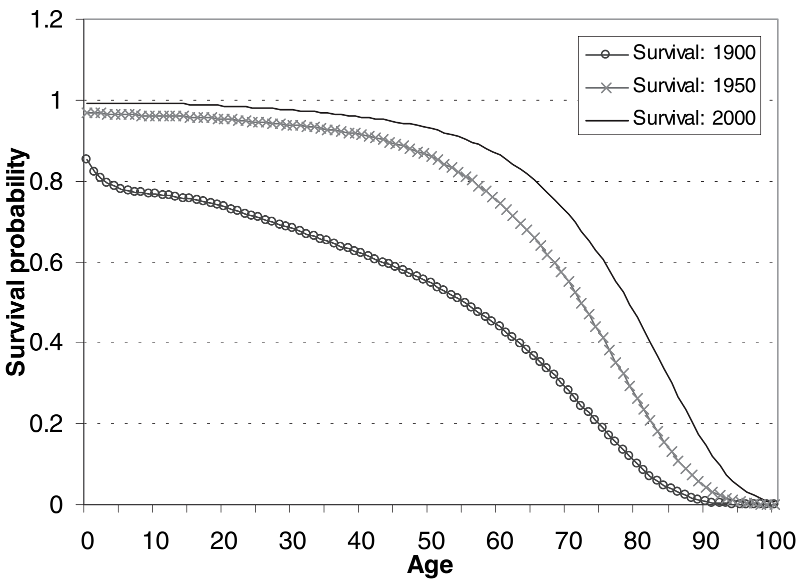
Source: Bureau of Economic Analysis.

Figure 2 shows the survival rates for three years: 1900, 1950, and 2000. The most dramatic change came in the early part of this century—the probability of surviving the first year rose from 85% in 1900 to 97% in 1950. Figure 3 shows life expectancy at different ages. Figure 4 shows the change in life expectancy at different ages over the last century. Gains in life expectancy have been substantial throughout the entire century.

To calculate the value of improved health status, we use the *life-years approach* outlined above (an alternative, using the mortality approach, can also be done and gives similar answers). Under the life-years approach, the economic value of improved health is equal to the increase in life expectancy times the value of an additional life-year. The estimates are weighted by the share of the population that

Figure 2

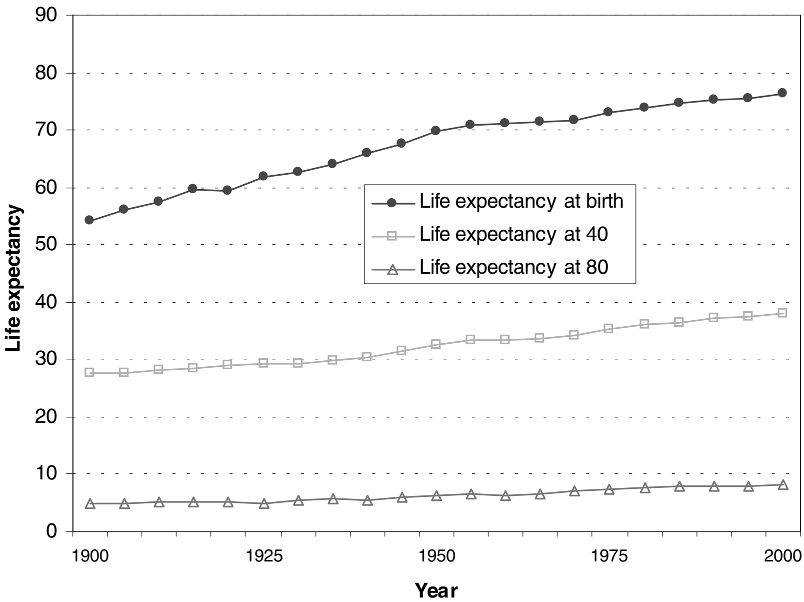
Survival probabilities by age, 1900, 1950, 2000.



Source: Department of the Census and Social Security Administration.

Figure 3

Life expectancy at different ages, 1900–2000.



Source: Constructed from data in Figure 2.

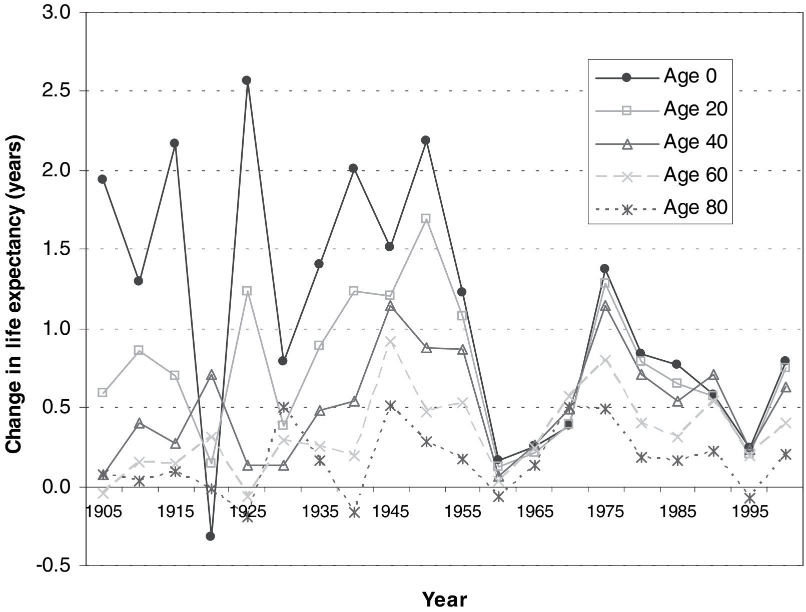
is experiencing the greater life expectancy, where we use the 1950 equilibrium population weights for all years.

C. Simple Calculations

It may be helpful to work through a simple example to illustrate the methodology. For the period 1975 through 2000, the undiscounted increase in weighted life-years was 2.53 years. Raising life expectancy by one LY is estimated to be the equivalent of raising the consumption annuity at each age by 10.3% of income. Therefore, the gains over that quarter-century were equal to $2.53 \times 10.3 = 26.1\%$, or 1.05% per year. Per capita real income grew by 1.98% per year over that

Figure 4

Change in life expectancy at different ages, 1900–2000.



period, so the value of health increases was 53% as the growth in conventional measured per capita real income.

D. Actual Calculations

The central results of this paper, showing calculations on the economic contribution of health and nonhealth consumption, are shown in Table 2 and Figure 5. For these estimates, we use only estimates based on changes in life expectancy. These estimates differ from the simple calculations in the last section because they use actual survival rates and population distributions rather than the simplified ones assumed above.

The major result that comes through using all techniques is that the value of improvements in life expectancy improvements is about as

Table 2

Health Income Improvements and Growth in Per Capita Income

	Growth Rates (Percent per Year)				
	1900–1925	1925–1950	1950–1975	1975–2000	1900–2000
Health improvements (as fraction of income)					
Discount rate					
0.0%	1.0%	1.6%	1.1%	1.0%	1.2%
1.0%	1.4%	2.3%	1.5%	1.4%	1.6%
2.5%	2.2%	3.6%	2.3%	2.1%	2.5%
Per capita disposable income					
	1.8%	1.7%	2.5%	2.0%	2.0%

Gains in consumption from improvements in health have been the same order of magnitude as conventionally measured income. Results are sensitive to the discount rate. *Source*: See discussion in text.

large as the value of all other consumption goods and services put together. For example, over the two decades from 1975 to 2000, conventionally measured per capita income grew at an average rate of 2.0% per year. Over this period, the annual average improvements in life expectancy had an economic value between 1.0 and 2.1% of income, depending upon the discount rate.[14] Over the entire period from 1900 to 2000, the value of improved health or health income grew at between 1.2 and 2.5% of consumption, whereas income grew at a rate of about 2.0% of consumption.

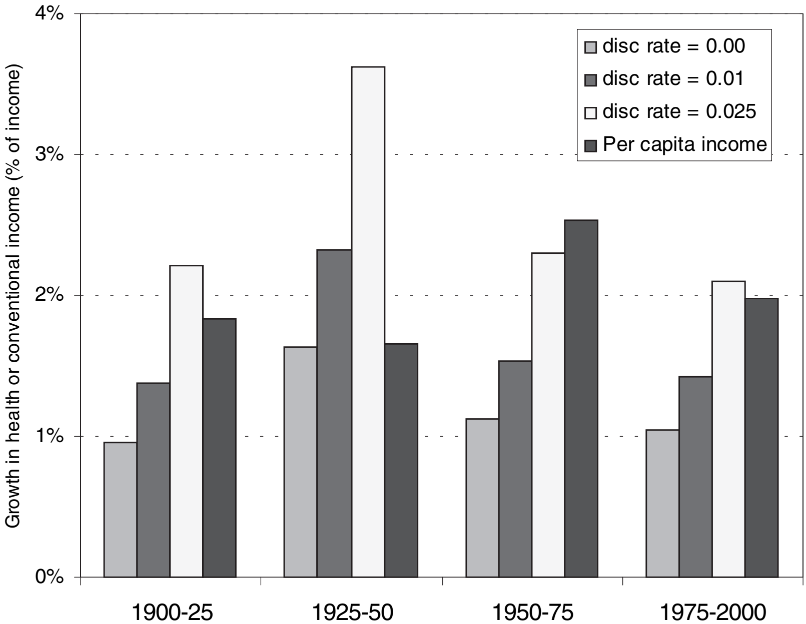
Looking at the entire 20th century, the contribution of the increase in life expectancy was between 59% and 126% of the contribution of income from all sources combined.

E. Qualifications

How robust are the estimates provided here? The underlying mortality data are among the most reliable of our social statistics. The most

Figure 5

Growth in health income and conventional income, 1900–2000.



Growth in health income is change in health income divided by income and is shown for three different discount rates. See text for discussion.

fragile estimates concern mortality and life-year valuation, as discussed above. One assumption on which there is little evidence is that the premium on reduced mortality is a constant fraction of per capita consumption over the entire period. More precisely, we assume that the value of a reduction in the mortality rate of 0.001 per year is $3,000 at 1990 income levels and in 2000 prices, and we scale that value over time to the ratio of the given year's per capita income to 1990 per capita income. There are no comprehensive studies of the mortality premium over time, although movements in the wage of risky occupations (such as coal mining) are consistent with this assumption. I suspect, however, that the premium has risen over time. This would be consistent with the rising share of health care expenditures in total consumption. If the premium were indeed increasing over time, then the contribution of health to economic welfare would be relatively smaller in the earlier period and relatively larger in the later period.

A few other assumptions are significant but will not affect the major results. One important issue is whether people should be weighted the same at every age. Many health care professionals and some survey evidence suggest that the value of a life-year is higher in the middle of the life span (between 20 and 40 years) than at either end.[15] Most surveys indicate, for example, that infant mortality would receive a lower weight than adult mortality.

Another major omission from this study is the value of reduced morbidity. The data on morbidity is less comprehensive and more difficult to value. One study indicates that including morbidity might add another 5% or so to the value of health improvements estimates here, although that number seems suspiciously low.[16]

VI

Discussion and Conclusion

THIS PAPER CONTRIBUTES to a new view of the economics of health. This new view is that improvements in health status have been a major contributor to economic welfare over the 20th century. To a first approximation, the economic value of increases in longevity in the last 100 years is about as large as the value of measured growth in nonhealth goods and services. This conclusion validates the view of Irving Fisher in 1906:

> [T]he devices of modern hygiene, sanitation, and preventive medicine . . . are of greater economic import than many of the luxurious and enervating devices commonly connoted by "wealth." (Barber 1997, Vol. 2: 204)

The first question one should ask is whether this finding is plausible. One way of considering the question is to consider the health equivalent of the Sears-catalogue question:

> Consider the improvements to both health and nonhealth technologies over the last half century (say from 1950 to 2000). Health technologies include a variety of changes such as the Salk polio vaccine, new pharmaceuticals, joint replacement, improved sanitation, improved automobile

> safety, smoke-free workplaces, etc. Over this period, life expectancy at birth increased from a little under 70 years to a little more than 76 years. Nonhealth technologies were wide-ranging and include the jet plane, television, superhighways, VCRs, and computers.
>
> Now consider the following choice. You must forgo either the health improvements over the last half-century or the nonhealth improvements. That is, you must choose either (a) 1950 health conditions and 2000 nonhealth living standards or (b) 2000 health conditions and 1950 nonhealth living standards. Which would you choose?

If you would either choose (b) or find it a difficult choice, then you would agree with the results of this paper.

There are many questions left open by the present findings. It is important to note that we cannot attribute the growth in health income to particular investments or expenditures. Such a task, which would apply the techniques of growth accounting to health improvements, is especially challenging.[17] It is also necessary if we are to recognize not only the historical sources of improved health but also those investments that may best contribute to future improvements.

Another particularly important question is the extent to which improvements arise from improved basic knowledge (such as the germ theory of disease, the discovery of antibiotics, or the DNA revolution) or investments in improved health capital and infrastructure (such as larger investments in health education or improvements in emergency response services). A second issue, particularly relevant for the contribution of basic knowledge, is the extent to which improvements in knowledge were domestically generated or imported. It seems likely, for example, that most of the major medical discoveries in the first part of the period covered here arose in Europe, while America was increasingly the source of increases in medical knowledge in the last few decades.[18] To the extent that improvements in health income are due to imported technologies, this emphasizes one of the gains from trade that is largely overlooked in traditional measures of the economic impacts of international trade.

Of course, health is more than doctors and hospitals. It encompasses other parts of national output, such as pollution control and highway safety spending, and reflects individual lifestyles, such as decisions about smoking, drinking, driving, drugs, and exercise.

Moreover, medical knowledge is a global public good, which is increased by efforts in many countries. Because we cannot tally the totality of costs on health care, we cannot say for sure whether we are getting one-half or twice or thrice the return on health dollars that we are on nonhealth dollars. And it is surely the case that health care expenditures are often misallocated and wasteful. However, notwithstanding the complexity and bureaucracy, improvements in health status in the United States have yielded major increases in economic welfare, and those are not captured in our present national accounting systems.

Notes

1. See Eisner (1989). A recent review of environmental and other aspects of nonmarket accounting is contained in National Research Council (1999).

2. See Shapiro and Wilcox (1997) and Shapiro, Shapiro, and Wilcox (1999).

3. See Advisory Commission (1996) and Murray and Lopez (1996).

4. This discussion ignores the subtlety of Hicks's discussion of price changes, interest rate effects, the difference between *ex ante* and *ex post* capital, and a number of other factors.

5. This approach is used in an analogous manner in the theory of measuring the cost of living.

6. See Nordhaus (1994, 2000) for a discussion.

7. See Nordhaus (1994).

8. An early treatment of this issue is contained in Shepard and Zeckhauser (1984). A detailed treatment of the value of life with extensions is contained in Rosen in Tolley et al. (1994).

9. See Viscusi (1993) and Unsworth, Neumann, and Browne (1992) for a comprehensive review of the economics literature. The monumental study edited by Murray and Lopez (1996) is a particularly useful analysis of the issue in the context of health care.

10. This was based on the survey by Unsworth, Neumann, and Browne (1992).

11. Irving Fisher's discussion dates from 1910–1914 and is contained in Fisher (1997). Paul Samuelson's approach is contained in Samuelson (1961).

12. See UNDP (1997) for a discussion and the numbers.

13. A useful review of the economic history literature is contained in Costa and Steckel (1995).

14. Because there is no natural denominator for measuring improvements in health care, we use the same denominator for calculating growth as we

do for income. This allows us to compare the relative importance of income and improvements in health status, whereas there is no obvious way to measure the value of the level of health status.

15. A particularly interesting discussion is contained in Murray and Lopez (1996).

16. See Cutler and Richardson (1997), discussed below.

17. One of the most comprehensive studies of growth accounting is Denison (1961).

18. A nontechnical history is contained in Porter (1997).

References

Advisory Commission. (1996). *Toward a More Accurate Measure of the Cost of Living: The Final Report of the Advisory Commission to Study the Consumer Price Index*. December 4 (updated version).

Barber, William J. Ed. (1997). *The Works of Irving Fisher*. London: Pickering and Chatto.

Costa, Dora L., and Richard H. Steckel. (1995). *Long-Term Health Trends in Health, Welfare, and Economic Growth in the United States*. NBER Historical Working Paper 76. Cambridge, MA: National Bureau of Economic Research.

Cutler, David, Mark B. McClellan, Joseph Newhouse, and Dahlia Remler. (1998). "Are Medical Care Prices Declining?" *Quarterly Journal of Economics*, vol. 113, no. 4, 991–1024.

Cutler, David, and Elizabeth Richardson. (1997). "Measuring the Health of the U.S. Population." *Brookings Papers on Economic Activity: Microeconomics* 217–271.

Denison, Edward. (1961). *The Sources of Economic Growth in the United States*. New York: Committee for Economic Development.

Eisner, Robert. (1989). *The Total Incomes System of Accounts*. Chicago: University of Chicago Press.

Hicks, J. R. (1939). *Value and Capital*. 2nd ed. Oxford: Clarendon Press.

Murphy, Kevin M., and Robert H. Topel. (2002). "The Economic Value of Medical Research." In *Measuring the Gains from Medical Research: An Economic Approach*. Eds. Kevin M. Murphy and Robert H. Topel. Chicago: University of Chicago Press.

Murray, Christopher, J. L. Murray, and Alan D. Lopez. Eds. (1996). *The Global Burden of Disease*. Cambridge, MA: Harvard School of Public Health.

National Research Council. (1999). *Nature's Numbers: Expanding the National Economic Accounts to Include the Environment*. Eds. William D. Nordhaus and Edward Kokkelenberg. Washington, DC: National Academy Press.

Nordhaus, William D. (1994). "Reflections on the Concept of Sustainable

Economic Growth." In *Economic Growth and the Structure of Long-Term Development*. Eds. Luigi L. Pasinetti and Robert M. Solow. Oxford: Oxford University Press.

——. (2000). "New Directions in National Economic Accounting." *AEA Papers and Proceedings* vol. 90, no. 2, May: 259–63.

Samuelson, Paul A. (1961). "The Evaluation of 'Social Income.'" In *The Theory of Capital*. Eds. F. A. Lutz and D. C. Haig. London: Macmillan.

Shapiro, Irving, Matthew Shapiro, and David Wilcox. (1998). "Measuring the Value of Cataract Surgery." In *Medical Care, Output, and Productivity*. Eds. E. Berndt and D. Cutler. NBER/CRIW conference.

Shapiro, Matthew, and David Wilcox. (1997). "Mismeasurement in Consumer Price Index: An Evaluation." NBER *Macroeconomics Annual* 11: 93–142.

Shepard, Donald S., and Richard J. Zeckhauser. (1984). "Survival Versus Consumption." *Management Science* 30(4): 423–39.

Tolley, George S., Donald Scott Kenkel, and Robert Fabian. Eds. (1994). *Valuing Health for Policy*. Chicago: University of Chicago Press.

United Nations Development Programme. (1997). *Human Development Report, 1997*. New York: Oxford University Press.

Unsworth, Robert, James Neumann, and W. Eric Browne. (1992). *Review of Existing Value of Life Estimates: Valuation Document*. Background document prepared for Section 812 Analysis, Industrial Economics Incorporated, Cambridge, MA, November 6.

Usher, Dan. (1973). "An Imputation to the Measurement of Economic Growth for Changes in Life Expectancy." In *The Measurement of Economic and Social Performance*. Ed. Milton Moss. New York: Columbia University Press.

——. (1980). *The Measurement of Economic Growth*. New York: Columbia University Press.

Viscusi, W. Kip. (1993). "The Value of Risks to Health and Life." *Journal of Economic Literature* 31: 1912–1946.