ABSTRACT In this paper, we develop and apply an economic framework for valuing improvements in health, based on Murphy and Topel (2002). Past improvements in health and longevity have had enormous social value. By our estimation, the contributions to the economic well-being of longer lifetimes have been worth about $73 trillion since 1970, or about $2.6 trillion per year. The average 50-year-old man gained additional life-years worth roughly $350,000, while a 50-year-old woman gained about $180,000. Looking ahead, prospective benefits from further progress are also large: a 10 percent reduction in mortality from heart disease would be worth over $4 trillion, and even a 1 percent reduction in cancer deaths would be worth over $400 billion. These values suggest that public investments in basic medical research may yield huge social returns, but distortions in the allocation of medical care and in research incentives may yield future benefits that are smaller than the costs of achieving them. While the average net health benefits of increased medical expenditures are large, costs may have greatly exceeded benefits in certain periods and age groups.
In earlier research, we developed and applied an economic framework for valuing improvements in health and longevity (Murphy and Topel 2002). The foundation for that analysis was individuals’ “willingness to pay” for life-extending improvements in health. This framework allowed us to value the substantial gains in life expectancy that occurred between 1970 and 1998—a period during which the benefits of medical progress have been huge—as well as to calibrate the value of potential future progress against a variety of diseases. For example, we concluded that the even a 1 percent permanent reduction in mortality from cancer would have a current value of about over $400 billion to current and future generations of Americans, or roughly 5 percent of current national output. Progress against other major mortality-causing ailments would produce concomitant benefits, with the implication that investments in medical progress may yield unusually large social returns.

Against these gross benefits of improvements in health, one must deduct two types of cost. The first is the cost of medical research and development—the production of new ideas and techniques—that would make such medical progress possible. If recent history is a guide, these costs likely would pale in comparison to the potential benefits. For example, between 1986 and 1995, average annual public and private expenditures for medical R&D were about $28 billion, while reduced mortality from a range of diseases yielded benefits worth roughly $2.5 trillion per year. In other words, the benefits of increasing health over this period were roughly 100 times the public and private research expenditures directed toward producing those gains. If even a small fraction of the historic gross benefits of improving health can be attributed to medical research, then these benefits have greatly outweighed the costs of producing them. Looking forward, our estimate that a 1 percent reduction in mortality from cancer would yield additional life-years worth roughly $500 billion means that a $100 billion investment in cancer research would be worthwhile if it had even a one-in-five chance of reducing mortality by 1 percent (and a four-in-five chance of doing nothing at all).

But these calculations ignore the cost of actually implementing the medical advances that are the outcome of medical R&D. Empirically, these costs take the form of increases in medical expenditures—public and private spending on medical treatments and care. Because much, perhaps most, of medical expenditures involve third-party payers (public and private insurance) with imperfect monitoring and incentives, we are less sanguine about the notion that the value received by consumers of new medical technologies knowledge will outweigh these costs. Many observers believe these distortions in providing and paying for medical care cause the costs of treatment to exceed benefits, at least on the margin (e.g., Fuchs 1972, p. 19). Stepping back one stage, these “you invent it and we will pay for it” distortions in the post-research provision of medical care imply concomitant distortions in medical research: research incentives are distorted toward cost-intensive, output-increasing methods of care, which further increase...
long-run medical costs. Research into new methods that would be economically worthwhile if they were efficiently implemented in the post-development (treatment) stage may be a waste under methods of allocating medical resources. Ex ante, it may be socially rational to forgo the development of new lifesaving methods of treatment simply because those methods will be used inefficiently ex post.

While this cautionary tale applies to future investments in medical knowledge and technique, evidence to suggest that it is important must come from the past. And though the average social returns from increased longevity in the latter decades of the 20th century were quite large, they were not so large as to rule out that even some past gains have been inefficient from a cost-benefit perspective. Deducting increases in medical expenditure from the $70 trillion gross gain described above produces a net social increase in the value of life-years of about $43 trillion since 1970, so benefits greatly exceeded costs on average. Using data on health expenditures by age and sex drawn from the Medical Expenditure Surveys (MES), we allocate rising medical expenditures to men and women across the age distribution. Valuing the life-years of men and women equally at each age, we find uniformly positive net gains for men, but rising medical expenditures exceed the value of life extension among women after 1980. These estimated net social losses for women hold for all age groups except newborns, and they increase sharply with age. In effect, we find that among older women medical expenditures have risen sharply, but older women don’t live sufficiently longer than they did before to offset those increased costs based on our estimates of willingness to pay. While there are many caveats to this pattern of estimates, which we discuss below, our point is not that health expenditures on women have been inefficient. Instead, it is that even in a world of apparently large benefits from health improvements, the costs of achieving those benefits can be large, or even economically prohibitive.

In the next section, we outline our economic framework, building on but simplifying the analysis in Murphy and Topel (2002). We show how to value additional life-years that are the result of life-extending improvements in health, how to account for attendant changes in medical expenditures, and how to aggregate individual valuations of health improvements to obtain social (aggregate) values. In the following sections, we first apply the framework to mortality and health expenditure data, yielding estimates of willingness to pay for past health improvements, both overall and for specific life-threatening ailments. We then apply the model prospectively, showing potential gains from progress against a variety of diseases.

**Framework: Measuring the Value of Increased Longevity**

Our approach provides a simple yet flexible framework for measuring what individuals are willing to pay for mortality-reducing improvements in health. It can
be extended to incorporate other health advances that improve the “quality” of life, but we do not take up those issues here (see Murphy and Topel 2002 for a technical analysis). In a nutshell, we draw upon existing economic evidence for the value of life, and apply that evidence to the valuation of life-extending medical advances.

Many public and private cost-benefit calculations require evidence on the economic value of a “statistical life”: what people would be willing to pay for a reduction in the risk of dying that would save, on average, one life in a given period of time. For example, suppose that automobile airbags reduce the probability that the representative driver dies in an accident by 1/10,000 per year. If drivers are willing to pay $500 per year for this safety enhancement, then the value of a statistical life is $500 × 10,000 = $5 million: the cumulative willingness to pay for one expected life saved. Empirical studies to establish this magnitude have been conducted for a variety of such tradeoffs, such as the wage premiums that workers require to accept more risky jobs or what consumers are willing to pay for safer products (see Viscusi 1993 for a survey). For our purposes, the results of this research put the value of a statistical life in the range of $3 million to $7 million, which is consistent with the values used by government agencies for policy evaluation. For example, the Environmental Protection Agency uses a value of $4.5 million in evaluating the potential gains from environmental improvements. We will use the midpoint of this range, $5 million, as our benchmark for evaluating gains in longevity. For prime-aged individuals, this puts the value of life-year—what a person would pay for to have an additional year of life in one’s prime—at $250,000 to $300,000 (see Figure 1). The reader who finds this estimate to be either high or low can adjust the following empirical magnitudes accordingly.

Calibrations of the value of a statistical life are silent on how the value of additional life-years might change over the course of life, and we have found no related medical research on the subject. Is an additional year at age 80 worth as much as an additional year at age 35? Both economic theory and common sense tell us that this is unlikely: the value of being alive for another year is likely to decline, after a point, as people age. For our calculations, we assume that the shape of the age-value profile conforms to empirically estimated age-earnings profiles from age 20 to 65, and then depreciates at 5 percent per year thereafter. As shown in Figure 1, this means that the peak value of “living” is just under $300,000 around age 50, but declines to about $100,000 by age 80. Some might find this assumed depreciation of values at older ages to be aggressive, others may not. As the reader will see, some of our conclusions can be sensitive to this calibration.

Our approach is as significant for what it does not do as for what it does. To economists, the value of improving longevity derives from what individuals gain from the enjoyment of consumption and time during additional life-years—the amenities of life. This value is not related to the increased number of “jobs” that might be associated with a population that lives longer, or the increase in mea-
sured national output. These are costs, not benefits. To make the point rather starkly, consider a medical advance that reduces mortality rates only among older, retired individuals. Such an advance has no impact on employment, productivity, or national output. Yet the beneficiaries of this advance clearly gain from remaining alive longer—the advance has social value because it contributes to the well-being of individuals—and that is what our framework measures.

Given any current age, changes in mortality from any source affect the probabilities of being alive (the survivor probability) at future ages. For example, consider changes in treatment of heart disease that reduce death rates (increase survivor probabilities) at ages 50 and above. A 50-year-old male now has greater probabilities of enjoying life-years at ages 51, 52, and so on. The value of these gains to the 50-year-old is the present discounted value, measured from age 50, of each of the future life-year values in Figure 1, weighted by the increase in the probability of surviving to that age. Generally, for a person of current age \( A \), the present discounted value of remaining life can be written:

\[
V(A) = \sum_{a=A}^{\infty} [v(a) - c(a)] S(a | A) \beta^{a-A}
\]

In (1), \( v(a) \) is the value of consumption and leisure at age \( a \); \( c(a) \) is health care expenditure at age \( a \) (treated as a cost of living); \( S(a | A) \) is the probability of being alive at age \( a \); and \( \beta < 1 \) is a discount rate. Using (1), advances in health technology and care can affect: (a) \( S(a | A) \), the probability of surviving to future age \( a \); (b) \( v(a) \), the overall quality of life at age \( a \); or (c) \( c(a) \), the cost of health care. So think of a change in health that raises survivorship by \( \Delta S(a | A) = S_1(a | A) - S_0(a | A) \) at each age \( a \). This change in health may also raise the value

\[
\Delta v(a) = [v_1(a) - v_0(a)] S_1(a | A) - [v_0(a) - v_0(a)] S_0(a | A)
\]

Figure 1

*Estimated value of life-years by age.*
of quality of life ($\Delta v(a) \geq 0$) and it may either raise or reduce expenditures on health care ($\Delta c(a)$). The change in (1), which measures willingness to pay for the health improvement, is

$$\Delta V(A) = \sum_{a=0}^{\infty} [v_0(a) - c_0(a)] \Delta S(a | A) \beta^{a-A}$$

(2)

$$- \sum_{a=0}^{\infty} \Delta c(a) S_1(a | A) \beta^{a-A}$$

$$+ \sum_{a=0}^{\infty} \Delta v(a) S_1(a | A) \beta^{a-A}$$

The first term in (2), $[v_0(a) - c_0(a)] \Delta S(a | A)$, reflects willingness to pay for a change in future probabilities of remaining alive, holding constant the net value of a life year at each age. As we point out below, these values conform to the economic literature on the value of a “statistical life,” which seeks to estimate willingness to pay for small changes in the probability of dying from various events. Using this literature to calibrate the value of a “life-year,” $v_0(a) - c_0(a)$, we combine these estimates with changes in mortality rates at each age, $\Delta S(a | A)$, to obtain changes in the value of life driven by changes in survivor probabilities alone.

The second term in (2), $- \Delta c(a) S_1(a | A)$, is the change in the expected cost of health care at age $a$. We use data on the distribution of health expenditures across age groups from the MES, together with aggregate data on health expenditures, to estimate this component. Finally, $\Delta v(a) S_1(a | A)$ is the change in the value of a life-year at age $a$ caused by health improvements. It is, in effect, the change in the “quality” of life, as when medical advances make living with arthritis less painful. Evidence on this component is much harder to come by, and in our application of the theory we will ignore it, focusing solely on valuing the gains from increased longevity.

Simple as it is, equation (2) is a powerful tool for valuing both past and prospective progress against mortality in general and against specific life-shortening diseases. For past changes in mortality, age-specific mortality tables are published both for total death rates and for death rates from particular diseases, while data from the MES provide evidence on costs, at the individual level, over an extended period. These data allow a direct calculation of changes in individual valuations $\Delta V(A)$ over time. The social value of such changes at any date is the aggregate of individual values for both current and future generations, again discounted to present value. The same method applies to future prospective progress against mortality-causing diseases, except the changes in survivor rates in (1) are hypothetical future values instead of empirically observed ones.1

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1Given that life tables reflect the mortality experience across cohorts at a point in time, our esti-
gregating (2) over the current and future populations to which such gains apply, the social value of improved health is

\[
\Delta W = \sum_A N(A) \Delta V(A) + N_f(0) \Delta V(0)
\]

where \(N(A)\) is the population of age \(A\), and \(N_f(0)\) is the present discounted value of the number of future births.

This framework has several important implications for assessing the value of medical progress. We merely outline these here (the interested reader is referred to Murphy and Topel 2002 for further details):

1. The social value of medical progress increases with both per-capita income and with the size of the current and future populations to which new medical knowledge applies. Thus economic growth raises willingness to pay for medical advances, and the public good nature of new medical knowledge means that a given amount of progress is more valuable when it can be applied to a larger population.

2. The value of progress against particular ailments is greater when the age structure of the population is concentrated near, but before, the ages where progress actually occurs. Progress against heart disease or Alzheimer’s may be of little value to a society consisting of 20-year-olds, because mortality from these diseases occurs far in the future and such gains are discounted. But for a society of 50-year-olds, such progress is of more immediate interest and value.

3. Progress against particular ailments exhibits an important sense of complementarity. Progress against heart disease, say, raises future values of \(S(a,A)\), the probability of being alive at future ages. In turn, this raises the value of progress against cancer because individuals are now more likely to survive to the ages where cancer is likely to kill. To put it more vividly, a cure for Alzheimer’s is of little value if you are likely to die of a heart attack before reaching the ages where Alzheimer’s is a risk, but it is much more valuable when surviving to those ages is likely.

To be economically worthwhile, the benefits of improved health must offset the costs of producing them. These costs have two basic components. The first is the up-front cost of developing new methods to cure and treat life-shortening diseases, which takes the form of medical research and development expenditures, broadly defined.\(^2\) The second is the cost of actually implementing new

\(^2\)For our purposes, investments in public health knowledge and infrastructure fit within the defi-
procedures, represented by $\Delta c(a)$ in (2), which takes the form of direct medical expenditures by individuals and institutions. These expenditures can either rise or fall as a consequence of technical advances, depending on the nature of the advance and the nature of demand for medical services.

For most private goods, once developed, the balance of benefits against costs is surely positive. If the value received from consuming the good or service is smaller than the cost of obtaining it, people won’t buy it. Then costs are properly internalized in private decisions to consume. But the presence of third-party payers for medical services distorts this decision, so that the true benefits of medical services consumed may be smaller than their costs. The resulting over-consumption of medical services can then, in turn, distort medical R&D incentives. For one thing, consumption is artificially price-insensitive, which encourages the development of high-cost, output-expanding technologies over cost-reducing ones. Perhaps more importantly, it may be inefficient ex ante to develop new, life-saving technologies because the technology will be used inefficiently ex post, even if development would be socially beneficial with efficient ex post decision-making. This second best result can occur because when we cannot commit to use the technology efficiently, it may better not to have the technology at all.

Empirically, past and potential future gains in the value of life—driven by the first component of (2)—are quite large, much larger than reasonable costs of R&D that might underlie them. This fact suggests that past social returns on medical R&D have been extraordinary. Yet growth in medical expenditures, $\Delta c$, is also quite large, which leaves us with two empirical questions. First, have past increases in the cost of medical treatment been offset by gains in the value of life? Second, for reasonable magnitudes of medical R&D investment, are potential future gains in the value of life from progress against life-threatening diseases large enough to warrant both the costs of medical R&D and the costs of implementing new medical technologies?

**Empirical Evidence:**

**Valuing Past Reductions in Mortality**

Our empirical approach has four main components. First, we measure the dollar value of life-years gained from reductions in mortality, both past and prospective. Second, we attribute past gains to progress against various diseases. Third, we assess the prospective value of progress against various diseases. Fourth, we compare the value of past life-years gained against increases in total medical expenditure, both in the aggregate and at different ages.

Figures 2 and 3 break down the per-individual gains in the value of remaining life for the period 1970 to 1998, based on the values of life-years shown in Figure 1. For men (Figure 2), the largest gains occurred at middle age—around age 50—where gains over the 28-year period totaled roughly $350,000 per person. This peak at middle age is driven by the fact, documented more fully

Some might object that, with average household incomes of about $60,000, few men or women could pay the value we assign to increasing life-spans. This objection is misplaced. Our method values units of additional life-years (increases in the probability of living) at the prices that people currently pay for those units, and then sums them up. As an analogy, think of a household that inher-
below, that gains in life-expectancy at the end of the 20th century were concentrated among older individuals. Indeed, more than half of the gains shown in Figure 2 are due to reduced mortality from heart disease. The largest gains occurred in the 1970s, though progress in the ’80s and ’90s was only slightly slower.

For those who think these estimates are too large, consider the following conceptual experiment. In 1970, a representative 50-year-old American male could expect to live 21.8 more years. By 1998, the expected remaining life of a 50-year-old male had risen to 26.6 years, for a gain of 4.8 years. Now put yourself in the position of a 50-year-old male in 1998, who is offered the following trade. You can have your current standard of living and health, or you can have $350,000 and the health of a 50-year-old in 1970, when expected lifetimes were nearly five years shorter. If you think that 50-year-olds will certainly take the offer, then you think our estimates of the gains from longevity are too high. But if you think the decision is a close call, then you must find our estimates reasonable.

The gains for women over this period, shown in Figure 3, are substantially lower than for men. Their peak gain, also around age 50, is only $180,000. This is an aspect of convergence between men and women, as women’s expected lifetimes were longer in 1970, and they remain so today. Figure 4 shows that this convergence is largely due to progress against heart disease, which kills more men than women (and at earlier ages). Gains among women are also more concentrated in the 1970s, a fact that will prove important when we deduct rising expenditures for medical care.

![Figure 4](image-url)


---

4Expected remaining life for a 50-year-old woman increased by 2.8 years between 1970 and 1998.
Table 1 aggregates these gains over current and expected future populations, using equation (3). The numbers are simply huge, because the population to which per-person gains are applied is large. Between 1970 and 1980, American men gained additional life-years with an aggregate value of $21 trillion. Progress for men slowed somewhat over the next 18 years, but even so, the cumulative post-1970 gain for men totals $46 trillion. Women’s gains, which total “only” $26 trillion over the full period, slow much more dramatically than men’s. As women’s life-spans were longer, and remain so, this is evidence of convergence in female-male mortality. Combining the gains for men and women, reductions in mortality between 1970 and 1998 yielded additional life-years with a capital value of nearly $73 trillion. Putting these values in a slightly different context, the annual average flow of increased value of life was roughly $2.6 trillion per year, compared to an average value of U.S. GDP over this period of about $5.8 trillion per year. In other words, mortality-reducing progress yielded unmeasured annual benefits worth about 45 percent of average measured GDP over this period. These are gains in welfare that are not counted in national income statistics.

Long-Term Changes: Valuing Increasing Life-Spans over the 20th Century

The improvements documented in Table 1 are a continuation of longer-term health gains that go back for over a century. Using age- and gender-specific mortality tables that begin in 1900, Figures 5 and 6 show the distribution of gains by age and decade in the 20th century, valuing additional life-years in each decade at current willingness to pay. In other words, the figures show the value received by individuals today from health improvements that were produced in the past. Vertical differences between two curves at any age represent gains at that age for a particular decade, so the top curve (1998) represents cumulative gains from 1900 to 1998.

The figures document several important facts. For men, the largest gains in the value of life are at birth and at young ages, representing large declines in infant and child mortality. We estimate that improved health over the 20th cen-

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Table 1: Aggregate Gains from Increased Longevity, 1970–1998

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>$21,215</td>
<td>$12,139</td>
<td>$13,223</td>
<td>$46,577</td>
</tr>
<tr>
<td>Females</td>
<td>$15,863</td>
<td>$6,979</td>
<td>$3,461</td>
<td>$26,303</td>
</tr>
<tr>
<td>Total</td>
<td>$37,078</td>
<td>$19,117</td>
<td>$16,685</td>
<td>$72,880</td>
</tr>
</tbody>
</table>

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5Gains for future cohorts (i.e., the currently unborn) account for roughly 33 percent of the total gain of $73 trillion from 1970 to 1998.
The same conceptual experiment mentioned above applies. From 1900 to 1998, the remaining life expectancy of a representative 30-year-old male increased by 11.3 years. We estimate that these life-years have a current value of about $800,000. So if a representative current 30-year-old male is offered less than $800,000 to accept the health of a representative 30-year-old in 1900, we predict that he would refuse the deal.

Figure 5
Cumulative gains from increases in longevity for males, 1900–1998.

Figure 6
Cumulative gains from increases in longevity for females, 1900–1998.

The same conceptual experiment mentioned above applies. From 1900 to 1998, the remaining life expectancy of a representative 30-year-old male increased by 11.3 years. We estimate that these life-years have a current value of about $800,000. So if a representative current 30-year-old male is offered less than $800,000 to accept the health of a representative 30-year-old in 1900, we predict that he would refuse the deal.

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of the $800,000 gain enjoyed by 20-year-olds occurred by 1960, but the con-
formable proportion for 40-year-olds is about half, and among 60-year-olds it is
substantially less than half. In other words, progress in the first half of the 20th
century disproportionately benefited the young, as infant mortality and the inci-
dence of a number of diseases affecting younger individuals were reduced. But
progress at the end of the century disproportionately benefited older individu-
als, reflecting progress (as we will see) against heart disease, stroke, and other ails-
ments. It is worth noting the comparative lack of progress, across nearly all age
groups, in the 1960s.

The gains for women, shown in Figure 6, differ from men’s gains in both tim-
ing and magnitude. Cumulative gains for prime-aged adult women are slightly
less than $1 million, indicating that expected remaining durations of life in-
creased more for women. Importantly for what follows, Figure 6 shows little
progress for women after 1980, reflecting the female-male convergence men-
tioned above, but very substantial gains in the middle decades of the century. Just
as men gained little in the 1950s, female progress slowed in the 1960s and again
in the 1990s.

The difference in timing between men’s and women’s cumulative gains is
shown in Figure 7, which graphs the age-weighted average gain for men and
women over the entire century. Notice that men gain virtually nothing between
the early 1950s and late 1960s, which caused the female-male difference in
cumulative gains to exceed $150,000 by 1970. But most of that gap had vanished
by 1998.

Adjustments for Increasing Health Expenditures

As we noted earlier, calculations such as those discussed above do not account
for the costs of implementing new medical technologies, or for the costs of ex-
panding medical care generally. And it is well known that medical expenditures have risen sharply in the United States—faster than in any other developed economy—so it bears asking whether the benefits of increasing longevity justify the costs.

Our calculations of changing health care costs are based on survey data from MES, collected in 1977, 1987, and then as a panel starting in 1996. As is the case with virtually all survey estimates of household consumption, predicted nationwide medical expenditure from these surveys vastly underestimates actual national expenditure for medical services. So we use the age profile of relative expenditures from the survey data in these years to allocate total medical expenditures in 1970, 1980, 1990, and 1998. As the relative expenditure profiles are nearly constant over time, we use the 1977 survey to assign shares for both 1970 and 1980; we use the 1987 survey to allocate 1990 aggregate expenditures; and we use the 1998 survey to allocate 1998 aggregate expenditures. This procedure gives us estimates of aggregate health care expenditure by age and gender from 1970 to 1998.7

Table 2 shows the evolution of medical expenditures in the United States over the period we study. Medical expenditures grew from 11.3 percent of total con-

<table>
<thead>
<tr>
<th>Table 2</th>
<th>U.S. Health Expenditures, 1970–1998</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal expenditures (billions)</td>
<td>$73</td>
</tr>
<tr>
<td>% of total consumption expenditures</td>
<td>11.3</td>
</tr>
<tr>
<td>Real expenditures (billions of $1996)</td>
<td></td>
</tr>
<tr>
<td>Current year population</td>
<td>$261</td>
</tr>
<tr>
<td>Fixed 1996 population</td>
<td>$369</td>
</tr>
<tr>
<td>Per capita expenditures</td>
<td></td>
</tr>
<tr>
<td>Current year population</td>
<td>$1,286</td>
</tr>
<tr>
<td>Fixed 1996 population</td>
<td>$1,816</td>
</tr>
<tr>
<td>Present value of total expenditures (billions of $1996)</td>
<td>$13,556</td>
</tr>
</tbody>
</table>

7Our allocations of medical spending by age and gender are based on the Medical Expenditure Survey (MES) and its successor, the Medical Expenditure Panel Survey (MEPS). As we note in the text, population estimates of medical spending from these micro data understate actual medical spending. If the understatement varies by age, then our allocations will be biased. Based on data from national health care systems in Canada and the United Kingdom, the age profile of expenditures in the MES and MEPS is flatter than in these systems, suggesting that we might understate spending at older ages. However, MES and MEPS projections account for about 62 percent of total medical spending, but only 68 percent of actual Medicare expenditures, for which virtually all Americans over age 65 qualify. These data suggest that the actual age profile of medical spending is flatter in the United States.
Sumption in 1970, to 19.6 percent in 1998. Adjusting real per-capita expenditures for the changing age composition of the population, per-person expenditure on medical services grew from $1,816 in 1970, to $3,994 in 1998, or by 120 percent. Calculating the present value of aggregate medical expenditures using 1998 population weights and survivor probabilities, as in equation (2), and assuming that the same level of expenditure applies to future years and birth cohorts, the capital value of medical expenditures grew $13.5 trillion in 1970, to over $40 trillion by 1998.

Table 3 calculates net social gains by combining the estimates from Tables 1 and 2. Before discussing these estimates, it is important to note that this method of allocating benefits and costs is only a rough analogue of equation (2), so several caveats are in order. Recall that in (2) the term $\sum \Delta c(a) S_t(a|A)$ represents the change in cost of medical care that are the direct consequence of implementing medical advances, with gross value $\sum [v_0(a) - c_0(a)] \Delta S(a|A)$. What we actually measure is the value of increased longevity and changes in medical expenditures from all sources. This can cause us to either over- or underestimate the true social value of health care advances, for several reasons. First, changes in medical expenditures clearly include expenditures that raise the “quality” of life, $\langle \Delta v(a) > 0 \rangle$, which we ignore, so that we may underestimate true social gains from medical advances. Second, however, we attribute all of increased longevity to medical and health care advances whose costs are reflected in medical expenditure. Some of these gains may be attributed to advances in public health knowledge and infrastructure—for example, cleaner water or air. We don’t count the costs of implementing these, which leads us to overstate net benefits of improvements in broadly defined health care. Third, some advances in health may simply be an outcome of economic growth and rising incomes—people would be living longer anyway—which would also lead us to overstate gains. Finally, many medical expenditures are investments in health that would produce future...
benefits, so costs incurred in one period may yield measurable benefits at some other time. Thus an increase in medical expenditures in, say, the 1990s may be socially valuable, but the benefits are yet to be seen. This bias is less important the longer the period over which we measure costs and benefits.

With these caveats in mind, Table 3 shows our estimates of net social gains. Over the full 28-year period, increased longevity yielded a gross social value of $73 trillion, while the capitalized value of medical expenditures grew by $27 trillion, leaving a net gain $46 trillion—still a large gain by almost any standard. Notice that almost two-thirds ($30 trillion) of this gain occurs in the 1970s, where both gross benefits are highest and costs are lowest. Overall, rising medical expenditures absorb only 37 percent of the value of increased longevity.

The estimates in Table 3 represent a sort of average gain over the population as a whole. Yet many critiques of the efficacy of rising medical expenditures focus on marginal decisions to expend resources when benefits are smaller than costs. One margin where these distortions allegedly operate is on life-extending procedures for individuals who are near death, where benefits are allegedly small but costs are large; for example, over a quarter of all Medicare expenditures are spent in the last year of life, a proportion that has remained remarkably stable since the 1970s. Table 4 provides some evidence on how our estimates of average net gains vary with age. For men, net gains are positive overall and in each sub-period for all but the oldest (85+) age category. Our estimate of incremental costs as a proportion of gross benefits is fairly constant until we reach older age categories (55 and older), when the cost share rises sharply. Keep in mind, however, that this is exactly the age range over which we assume a 5 percent annual depreciation in the value of a life-year (see Figure 1), so our results can be sensitive to that assumption. Interestingly, the largest allocated net losses for the oldest men occurred in the 1970s, when net gains for younger groups were the largest.

For women the story is rather different. Compared to the results for men, women’s incremental costs are a larger proportion of benefits in every age group, and we estimate negative average net benefits for women over age 65. For the three sub-periods we study, we estimate average net losses for women in almost every age group in the 1980s and 1990s. In other words, even on average for these periods, the value of women’s longevity gains has not offset the rising costs of medical care.

Prospective Gains from Reductions in Disease

The preceding estimates are retrospective, asking what was gained from past reductions in mortality. We now turn to estimates of what can be gained from future progress against mortality-causing diseases. Our estimates are of the gross gain from increased longevity—the value of \( \sum [v(a) - c(a)]\Delta S(a|A) \) in our previous notation—so we make no attempt to deduct prospective costs. Our estimates should be interpreted as the value of life-years that could be gained from...
a given reduction in mortality from a disease; this value must be large enough to cover the costs of developing and implementing new medical advances that would save lives. In other words, we measure potential gross values, and the costs of achieving these values must be lower in order to make such progress economically worthwhile.
Our benchmark calibration of the potential value of medical progress is a 10 percent reduction in mortality from a life-threatening disease; from past experience, such progress—or greater progress—seems within the realm of possibility. Our estimates can be scaled up or down at the reader’s whim; for example, a cure for cancer would be worth 10 times the estimates that we produce here, and so on.

Figures 8 and 9 show our estimates of the age profiles of individual values resulting from a 10 percent reduction in mortality from five major causes of death. For both men and women, the largest gain in value would be for cardiovascular diseases, with peak gains occurring in late middle age. Potential gains from progress against cancer are nearly as large, and they have an earlier peak for women, which reflects the earlier incidence of breast cancer. Progress against infectious diseases—which include AIDS—has lower average value, because of
the much lower incidence of the disease, but its value also peaks earlier, which also reflects the age profile of incidence.

The profiles in Figures 8 and 9 give values of progress at different ages. To get the current social value of such progress, we aggregate over the age distribution of the current population and add the present value of gains measured at birth for forecasted future birth cohorts. These social values for the United States are shown in Table 5. A 10 percent reduction in all-cause mortality would have a present discounted social value of about $17 trillion. About 30 percent of this total ($5.1 trillion) is due to potential progress against cardiovascular diseases, where much progress has already been made. But progress against cancer is a close second at $4.3 trillion, with roughly equal benefits for men and women, though breast cancer is obviously a more important component of this total for women. At a more disaggregated level, progress against infectious diseases—of which AIDS is a major component—is of roughly the same value to men ($498 billion) as progress against breast cancer would be for women ($421 billion). But these values, important though they are, are dwarfed by the potential for progress

<table>
<thead>
<tr>
<th>Major Cause of Death</th>
<th>Males</th>
<th>Females</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Causes</td>
<td>$10,016</td>
<td>$7,147</td>
<td>$17,163</td>
</tr>
<tr>
<td>Major Cardiovascular Diseases</td>
<td>$2,994</td>
<td>$2,149</td>
<td>$5,142</td>
</tr>
<tr>
<td>diseases of heart</td>
<td>$2,471</td>
<td>$1,614</td>
<td>$4,085</td>
</tr>
<tr>
<td>cerebrovascular diseases</td>
<td>$356</td>
<td>$399</td>
<td>$755</td>
</tr>
<tr>
<td>Malignant Neoplasms</td>
<td>$2,258</td>
<td>$2,101</td>
<td>$4,359</td>
</tr>
<tr>
<td>respiratory and related organs</td>
<td>$793</td>
<td>$516</td>
<td>$1,309</td>
</tr>
<tr>
<td>breast</td>
<td>$3</td>
<td>$421</td>
<td>$424</td>
</tr>
<tr>
<td>genital organs and urinary organs</td>
<td>$271</td>
<td>$282</td>
<td>$553</td>
</tr>
<tr>
<td>digestive organs</td>
<td>$538</td>
<td>$393</td>
<td>$931</td>
</tr>
<tr>
<td>Infectious Diseases (including AIDS)</td>
<td>$498</td>
<td>$146</td>
<td>$644</td>
</tr>
<tr>
<td>Chronic Obstructive Pulmonary Disease</td>
<td>$309</td>
<td>$295</td>
<td>$605</td>
</tr>
<tr>
<td>Pneumonia and Influenza</td>
<td>$192</td>
<td>$166</td>
<td>$358</td>
</tr>
<tr>
<td>Diabetes</td>
<td>$222</td>
<td>$227</td>
<td>$449</td>
</tr>
<tr>
<td>Chronic Liver Disease and Cirrhosis</td>
<td>$212</td>
<td>$98</td>
<td>$310</td>
</tr>
<tr>
<td>Accidents and Adverse Effects</td>
<td>$962</td>
<td>$407</td>
<td>$1,369</td>
</tr>
<tr>
<td>motor vehicle accidents</td>
<td>$514</td>
<td>$244</td>
<td>$757</td>
</tr>
<tr>
<td>Homicide and Legal Intervention</td>
<td>$323</td>
<td>$90</td>
<td>$413</td>
</tr>
<tr>
<td>Suicide</td>
<td>$407</td>
<td>$101</td>
<td>$508</td>
</tr>
</tbody>
</table>
against heart disease, which would be worth $2.4 trillion to men and $1.6 trillion to women.

These calculations of the value of potential progress are admittedly rough, and one may properly quibble with some of our assumptions and imputations. As just one example, we have valued women’s and men’s life-years equally at all ages, but one might argue that we should value them differently, especially at older ages where women’s survivor probabilities are substantially higher than men’s. If the risk of dying indexes the quality of life more broadly defined, then an 80-year-old woman may value a life-year more highly than an 80-year-old man. But we think our willingness-to-pay framework is basically correct, and far superior to other approaches that value mortality reductions based on productivity or foregone earnings. To an economist, people do not live to work; they live to enjoy the valuable things of life.

Conclusion

Past improvements in health and longevity have had enormous social value. By our estimation, the contributions to economic well-being of longer lifetimes have been worth about $73 trillion since 1970 alone. Since medical costs are already counted in national income accounts, all of this value is uncounted surplus that has accrued to the American population. Valuing life-years at their implicit prices, the annual flow of such uncounted benefits comes to about $2.6 trillion per year, or over 40 percent of counted national income. The average 50-year-old man—in the age range that benefited the most—gained additional life-years worth roughly $350,000, while a 50-year-old woman gained about $180,000. A rough allocation of costs of medical treatment reduces these average benefits, but does not nearly eliminate them. Net benefits of the growth in medical expenditures totaled $46 trillion ($1.6 trillion per year), though there is some evidence, especially for older women after 1980, that the balance of costs and benefits was negative for certain age groups. This is an issue that surely deserves more research attention.

These benefits dwarf expenditures on medical research, which averaged less than $20 billion per year. In a nutshell, this gap between benefits and costs is the argument for greater public investments in medical R&D: if even a small portion of past benefits can be attributed to basic medical research, then returns have (at least on average) been colossal. Looking ahead, potential future gains are also large: a 10 percent reduction deaths from heart disease alone would be worth over $4 trillion, and even a 1 percent reduction in mortality from cancer would be worth over $430 billion. The open question, it seems to us as economists, is

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Some of these benefits are the result of medical expenditures, public health infrastructure, and development costs that occurred before 1970, and some of the benefits of current expenditures will occur in the future. So our allocation of costs and benefits is a sort of “steady state” estimate.
not whether research could deliver such gains, but whether new procedures and techniques would be so costly to implement that the net gains from further improvements in longevity would not be worthwhile. Distortions in decisions that allocate medical care—which also distort research incentives in the development of new methods of care—mean that the balance of future benefits and costs need not be positive, even in an expected value sense. Our estimates that the value of increased longevity fell below the costs of medical treatment for some age groups and periods of time—especially after 1980—should be viewed as cautionary evidence in this regard.

References
Figure 1. Estimated Value of Lifeyears by Age
Figure 2. Gains from Increased Longevity for Males 1970-1998

- $50,000
- $0
- $50,000
- $100,000
- $150,000
- $200,000
- $250,000
- $300,000
- $350,000
- $400,000

- 0 10 20 30 40 50 60 70 80 90 100
- Males90-98
- Males80-90
- Males70-80

Age

Gains from increased longevity for males from 1970 to 1998, showing different age groups and their respective gains.
Figure 3. Gains from Increased Longevity for Females 1970-1998
Figure 4. Gains from Reductions in Heart Disease 1970-1998

- **Males**
- **Females**
Figure 5. Cumulative Gains From Increases in Longevity for Males 1900-1998
Figure 6. Cumulative Gains From Increases in Longevity for Females 1900-1998
Figure 7. Cumulative Gains for Males and Females 1900-1998
Figure 8. Value of a 10% Reduction in Death Rates from Selected Disease by Age for Males
Figure 9. Value of a 10% Reduction in Death Rates from Selected Disease by Age for Females

- Cardiovascular
- Cancer
- Cerebrovascular
- Infectious Disease (Incl. AIDS)
- Accidents