

The following are excerpted remarks made by Kevin M. Murphy and Robert H. Topel at a Milken Institute Forum on Aug. 31, 1999. Murphy is the George Pratt Shultz Professor of Business Economics and Industrial Relations at the University of Chicago. Topel is the Isidore Brown and Gladys J. Brown Professor in Urban and Labor Economics at the University of Chicago.

They were introduced by Michael Milken, Chairman of the Institute, and Donald Straszheim, President.

MICHAEL MILKEN: I just wanted to point out my own particular feelings of how important this topic is today, in attempting to quantify an investment in medical research and also what form that medical research should take.

To date, very little economic analysis has been done in this area. And for many of us who spend a considerable amount of our time trying to convince our federal government, state governments, and for-profit institutions to invest more money in medical research, work in this area is of paramount importance to drive home the message.

Today, you'll see that some of this work is talking about benefits in trillions of dollars. So, 1 percent benefit more than covers what is projected to be the federal government's entire investment in research for an entire decade.

The numbers are so large that when one thinks about them, it's surprising how little we've invested in this area, how little the general public really knows of the amount that's invested in medical research, and what the potential benefits to society are from these investments.

I obviously have a personal interest, in that I was diagnosed with cancer back in 1993, and have lost 10 members of my family to cancer. And we would have liked to have had a solution.

We have lost 12 million Americans to cancer since the war on cancer was declared. And, subject to some value you're going to hear today, we're talking about some large number, which is probably measured in \$50 trillion.

So, the cost is high, but the potential benefits are high. And today's technology affords us the opportunity to do things on a much faster basis, such as the ability to store the data of all human beings in not only the United States, but the entire world; and the ability to store your grandparents' DNA, parents' DNA — so when the solutions to the problems are around, we have these data banks that can be accessed that might help our own descendants.

What's been missing in this debate is a strong economic argument to show what are the benefits of an investment in medical research. One would be hard-pressed to find higher returns than are afforded to us — particularly in the United States of America, at the close of the 20th century — from investments in medical research.

The outcome of this work, and the putting forth of these ideas, can have a significant impact, not only on the people in America, but the entire human race.

There was a fundamental shift that occurred in 1993 in this country that has caused the delay of much medical research. And that was the proposal of a new health care plan — which was misinterpreted by the marketplace, I believe — but caused the reduction in market value by almost 50 percent of all large pharmaceutical companies.

The response to that was to focus on acquisitions of other companies, which has resulted in a dramatic reduction in research by those companies. And maximizing the value of those enterprises has turned them, in many cases, to organizations whose greatest benefit is the status quo.

So, there is less change and a small group today has significant control over a large percentage of our products.

The biotech industry — 1,500 of them out there — keeps everyone honest in the marketplace out of fear that there's some new product coming down that would cause a dramatic change in anyone's product line.

But the change in '93 moved from valuations on just research. In the case of Merck, it lost \$30 billion in value in 14 months, which was equal to the entire value of the entire biotech industry in the whole country.

By cutting research, those numbers go straight to the bottom line. So this process has not been a smooth one in the 1990s for many of our large companies, as they've focused on creating shareholder value and maximizing the breadth of their product line, not necessarily the depth of their product line in any one particular area.

So this is an important topic, and a topic which, considering its importance, has had, really, a dearth of research, relative to the potential benefits.

Thank you.

DONALD STRASZHEIM: Thanks, Michael.

Robert Topel and Kevin Murphy are both going to make some comments and will accept questions right in the middle of the presentation. So when you've got a question, just get yourself recognized, break in, and they'll be happy to answer them.

First, Robert Topel, on my immediate left, is the Isidore and Gladys Brown Professor in Urban and Labor Economics at the University of Chicago Graduate School of Business, where he's been since 1983. He has been on the faculty there for almost 20 years, but had a one-year break, during which he taught at UCLA.

He's been a resident consultant to the RAND Corporation in his past. He is a long-time National Bureau of Economic Research research associate, editor of *The Journal of Political Economy*, and an editorial board member of the *International Journal of The Economics of Business* since 1993.

Kevin Murphy is the George Schultz Professor of Business Economics and Industrial Relations at the Graduate School of Business, also, at Chicago, where he's been since 1982, and previously spent two years at the Unicon Research Corp. here in Santa Monica.

Kevin was the winner of the Johns Bates Clark Medal given from the American Economics Association to the country's leading economist under the age of 40.

“The Social Value of Medical Research”

ROBERT TOPEL: Thanks, Don.

Our topic today is the economic value of increased longevity and medical research. More generally, we want to have something to say about the social value of health and longevity and its relation to medical research.

So, we have several goals. One is to provide an economic framework for valuing the improvements in health and, more generally, longevity. Another is to provide evidence on the uncounted social surplus that's occurred in the United States because of increased health of its citizens — and, in particular, increased life spans, where we'll have some hard and direct evidence. And finally, we want to develop some evidence relating increased life spans and improved health to basic medical research.

Those are the three goals. We've made the most progress on the first one. We've made substantial progress, but we're by no means done, with the second one. And our progress on the third one, of developing the connection between research and improved health, is still on our research agenda.

Our basic framework is decidedly economic. So, in valuing people's lives, or in valuing what the social gains are to changes in longevity and health, we ask: how much are people willing to pay for improvements in the quality of their lives? It's very much like thinking about the value of any good or service in a market economy: how much are people willing to pay?

Our underlying theme is that medical research and other basic research is a public good. It's one where the social returns — for those of you who are familiar with arguments about public goods — where the social returns may greatly exceed the private returns. And we're going to try to provide evidence on that kind of issue today.

To begin the discussion, let us tell you something about the magnitudes of medical spending in the United States. And everything we have to say today will apply to the United States.

When we talk about benefits, you might want to keep in mind that, since we're mainly talking about the production of ideas that generate benefits in terms of improved health to the citizenry, the broader context of those benefits is that people in other countries are going to benefit as well. So the social surplus spread over other countries is going to be larger than what we talk about here today. But, as you have already heard, we're going to be in the trillions of dollars when we start talking about these benefits.

In 1995, roughly \$35 billion was spent on medical research in the United States. Of that, \$13 billion came from the federal government, which came to 21 percent of federal research and development funding.

There was a 46 percent increase in R&D spending between 1968 and 1995, while percapita spending on health care roughly doubled.

Health care as a percentage of personal consumption has been increasing over time. It was 10 percent of personal consumption in 1980; it had risen to 16 percent — or a 60 percent increase — by 1995.

The value of increased life expectancy alone, which ignores improvements in just health or the quality of life that people enjoy while they're alive, added \$2.8 trillion per year to national wealth from 1970 to 1990. That's expressed in 1990 dollars.

If we think of that in terms of the flow of goods and services that we got over that period, that comes to roughly half of average annual GDP over that period. So the type of surplus that we're talking about that's largely uncounted is very large indeed.

Of that \$2.8 trillion, about one-and-a-half trillion is due to reduced mortality from heart disease alone. And that's an area where the extant literature indicates that there may have been some important effect of research, or an important connection between research and the treatments and changes in lifestyles that were keeping people alive.

Future potential gains are as large or larger than the ones that we've experienced over the last 20 years. So, we've estimated the present value of eliminating various diseases or making progress against various diseases.

Eliminating heart disease — that means eliminating all deaths from heart disease — would be worth, in terms of willingness to pay, roughly \$48 trillion.

Eliminating cancer is of the same magnitude — \$47 trillion.

But even in terms of more reasonable outcomes that could occur, just a 20 percent reduction in mortality from cancer would generate value that's worth roughly \$10 trillion in present-value terms.

So the potential benefits are very large. And they're large enough that higher expenditures on research may be justified, even if they yield only small returns. Simply a 1 percent reduction in mortality from cancer would have a value of roughly \$500 billion, according to our calculations.

KEVIN MURPHY: One way to put that in perspective is to think about the numbers we're putting here are \$48 trillion, \$47 trillion, and the numbers we were putting down for research expenditures are \$10 billion, \$35 billion. So the potential benefit are roughly a thousand times the cost numbers. One percent progress would be worth, on either heart disease or cancer, \$500 billion, which would be very large relative to the kind of expenditure numbers that we're talking about.

And that's going to be an important theme for what we're going to say.

AUDIENCE MEMBER: Could you just say a little more specifically how you estimated how much people were willing to pay for the improvements?

MURPHY: We're going to get to that.

MILKEN: When you were speaking of the figure for medical research, you were talking about total medical research.

TOPEL: Exactly.

MILKEN: I think that's an important clarification.

The entire investment in cancer research in the past 28 years is around \$30 billion. So, cumulative investment for 28 years is \$30 billion versus a potential benefit of \$47 trillion. You were talking about mortality related to any specific disease category.

TOPEL: Exactly.

MILKEN: So your number would be...

MURPHY: It's important not to forget the billion versus trillion distinction. That's the important one to keep in mind.

TOPEL: Right. The ratios here are indeed large.

Let me say something about our general approach. Keep in mind, we're a pair of economists. We wrote a paper. It's got lots of equations, and it has to have that in order to earn the respect of our peers.

We won't be discussing what that looks like here today.

The basic approach that we take is that we wanted to first develop a theoretical framework for expressing the value of changes in mortality, or health. And then, using that, to estimate economic values for changes in mortality, for both historical and potential future changes. And we've already given you some indication of the magnitudes of those, historically, and for potential future changes. And then, third, to make an empirical connection between medical research, the stock of knowledge, and observed changes in mortality or health.

So, here's our economic framework.

What are changes in mortality or lives saved, or changes in health — what are those worth? Only by answering this can we make useful public-policy decisions. So our economic approach asks: How much are people willing to pay to live a little longer or be a little healthier or live a little better?

So that concept of willingness to pay for life extension and improved health is reflected in many kinds of decisionmaking that people undertake all the time.

In the area of health, we can think of changes in diet and exercise that have occurred in light of medical evidence, such as reduced smoking, especially among segments of the population that are best-informed, or choices regarding safety equipment — the way people decide whether they are going to have airbags in their cars, or how safe their cars are going to be.

Another example is occupational choices. Individuals choose occupations that may be more or less risky, and offer, therefore, greater or lesser chances of dying on the job.

So, our basic idea is that increases in medical knowledge raise the probability of being alive at any future age. So the expected duration of life increases.

Our approach is going to yield a specific but flexible form for the amount that a person would be willing to pay. And, for those of you who are interested in the technical stuff, yes, there is an equation, and

it's got lots of interesting stuff in it. But you're not going to see it today.

So, what are people willing to pay for life-extending innovations or for improvements in their health? Our methodology allows us to incorporate both of those.

The approach has several important implications. One is that the value of increased life expectancy is proportional to the levels of income and consumption. So, the wealthier we are, the more we're willing to pay for additional years or expected years of life.

The value of increased life expectancy depends on the value of non-market time. It isn't sufficient just to think, as many do in valuing people's lives — especially in what's sometimes called “forensic economics” — about what foregone earnings are, or lost productivity. You also have to take into account the value of people's non-market time — how much they value being around.

And that's particularly important for the kinds of advances we're talking about here, where much of the reduction in mortality occurs for people at older ages, where heart disease has declined and the mortality from cancer might also decline. So that's among older, retired individuals, for whom market earnings may be quite small, but for whom the importance, the value of consumption and non-market time can be quite large.

Third, there is discounting — and by discounting, we mean the usual time-preference arguments, but also, the probabilities of being alive at future dates. Medical advances against a particular disease are of greater value to individuals the closer those people are to the age of the onset of those disease.

So 20-year-olds don't care that much, in a present-value sense, about reductions in mortality from heart disease or the effects of Alzheimer's, because it's far off in the future. But as the baby boom hits those ages where heart disease and those other things become more relevant, we care a lot. And one of the other implications we'll get to is that there's a lot of us baby boomers around, so when you add up how much we care, it gets to be a very large number indeed.

Then there is complementarity — this is kind of an interesting implication of what we do.

Advances against one disease, like heart disease, raise the value of advances against other diseases, like cancer. To put it simply, if we're all going to die from heart disease at age 50, and cancer, the onset of cancer — just speaking hypothetically — occurred at age 60, then the advances against cancer aren't very valuable to us. But once we make advances against heart disease and we're likely to be around for those cancer-occurring years, then the value of investing in medical research that might make progress against cancer becomes high indeed.

So there's complementarity. When you make advances against one disease, it raises the returns — the economic value — of making advances against other diseases that could affect you.

Fifth, the social value of increased life expectancy is proportional to the size of the population. And this is really the public goods argument — that the benefits of these ideas, of these advances, are not just focused on one individual or a group. It's spread over the population as a whole. So the social value is the value of individuals times the number of people that will be affected.

One of the things that makes our numbers big is that we take what actually are quite large numbers at

the individual level, and we get to multiply them by big numbers, like the population of the United States. And that's how you get up to trillions of dollars.

Finally, the social value of increased life expectancy is larger when the age distribution of the population — this is the baby boom point I was talking about before — is concentrated just before the ages where reduced mortality can occur. As the baby boom moves into these ages where heart disease becomes relevant, the present value of the benefits to all of the baby boomers can get to be a very large number.

One of the questions that came up a little while ago is what's your base calculation for what the value of an additional life year is worth?

We base our calculations on the value of a statistical life on which there's a fairly large economic literature. One way to understand it is to think of this hypothetical: Suppose that a representative person would pay \$500 a year to achieve a one in ten thousand reduction in the annual probability of a disease-related death. So in a population of 10,000 people, that's going to save one statistical life per year. And given that everyone was willing, the 10,000 people were willing to spend \$500 each to effect that reduction in the probability of dying, that means that the value of that statistical life — that one life that would be saved, on average, per year — is 10,000 people times \$500, or \$5 million.

Now, the empirical evidence on these kinds of trade-offs, taken from the literature on occupational choice, is that a reasonable range for the value of a statistical life is somewhere in the range of \$3 million to \$7 million. So, for the purposes of our calculations, we're going to adopt those estimates from this related literature. So we used \$5 million — just the middle of that distribution — for a representative individual.

You can scale up if you don't like that number, or you can scale it down if you think the number ought to be lower.

Reasonable variations in what you would take that number to be isn't going to have much impact on our qualitative results. Because that these numbers are in the trillions. So if they were a third as large, they're still going to be in the trillions of dollars.

AUDIENCE MEMBER: But there seems to be a serious problem with this representative individual process. Because that's a distribution. We're all at risk at different levels. And I don't understand how variation comes into this. The variation in risk exposure, and genetic composition, and health hazards vary enormously among individuals.

MURPHY: It doesn't matter very much, because what you would have is some people willing to pay \$2,000, some people willing to pay \$100. But the average of the risk levels would be linear, for small risks. And therefore, you could average it out.

In fact, if there were variation, you can't even say which way it goes. It may actually increase the value. They might value it even more.

But if they're small risks, it's going to be close to making the average probability a reasonable estimate of the average of the willingness to pay. Because if you're talking risks of one in ten thousand, then you're going to be talking about if somebody is two in ten thousand, that's still relatively small. So he's

going to be willing to pay like a thousand. And the guy who is at zero is going to be willing to pay zero. So the average is going to come out to \$500.

I think, relative to the other problems, I think that one actually is not that large.

The biggest question is, what's that \$5 million number? Is that \$5 million number right, or should it be three or should it be seven or should it be two?

TOPEL: Now, we've told you that \$5 million is the value of a statistical life. Figure 1 shows you the way that value varies over the life cycle.

We've taken it all the way out to age 110, where the main reason for the decline out to zero there is that the probability of remaining alive in future years is getting very small indeed. So keep in mind that this value is the present value of remaining life. The older individuals are, the less likely they are to be alive in future years, so the lower that value is going to be.

The only point of Figure 1 is to show you the way that varies over the life cycle. And that's going to affect our calculations, because the way that varies with age interacts with the age at the onset of disease, when we talk about what the gains are to making progress against various diseases that occur at those ages.

MURPHY: That's important to realize, because implicit in our calculations is that if going to save somebody who is 80 years old, we're not using that \$5 million number for somebody who is 80 years old. In fact, the number, if you look on here, is more like \$800,000.

So, saving one person who is 30 is worth five or six times, in present value, what it would be worth saving somebody at age 80.

TOPEL: There's just a lot more years that you're saving. The person who is 80 doesn't have nearly the expected remaining life that would somebody who is age 30 have.

AUDIENCE MEMBER: I have a problem with the other end of the graph — the value of a zero-year-old infant. Not wishing to be unpleasant about it, but surely, one should value that more at a replacement cost. Do you really think the neonate can value the five-year-old?

MURPHY: I don't think we behave that way at all. If you asked me how much would I be willing to spend to save my month-old child, versus how much I'd be willing to spend to save my 20-year-old child, I don't see that I would say, well, the month-old, he's expendable — I can make another one.

TOPEL: But even so, if we took the beginning of that graph down, to you choose your number, and made it very steep at the beginning, up to some peak around age 25 or whatever it might be, it's not going to affect our results very much. Nobody dies there.

This paper is not about reduced infant mortality. This paper is about reduced old people mortality — cancer and heart disease and stuff like that, which infants typically don't suffer from.

So if we change the shape you want it, none of our fundamental results would be any different.

AUDIENCE MEMBER: It looks like your data shows that at every age, women are worth more than men.

MURPHY: For our calculations, we assume that the value of any given year at a particular age is the same for men and women. The difference in the graph, then, comes because of the difference in expected longevity. That when a woman dies, she would have had more years down the road than the man would. So that graph is reflecting the fact that women do in fact now live longer.

In some sense, it's an illustration of that complementarity point that Bob talked about a little while ago. That is, the greater your survival probability is now, the greater the return to saving you.

It's like the old story — if you've got a guy in the middle of the street about to be run over by a bus, curing his cancer is not worth a whole lot, because he's not going to be around very long to enjoy it.

TOPEL: What we've got here in Figure 4 is the increases in the value of life by age for men and women from 1970 to 1980, and then, separately, from 1980 to 1990.

And what you can see is the gain from 1970 to 1980 at an individual level. So we're talking about what does our representative individual, with the value of a life of \$5 million, gain from the reduced mortality that occurred from all sources between 1970 to 1980? And that's the red upper curve.

So it peaks there at around \$170,000 in the middle-age range, from about age 36 up to age 48, for men. And then, the gains for men are smaller from 1980 to 1990, which occurs almost exclusively because the gains in reduced mortality were smaller between 1980 and 1990 than they were between 1970 and 1980.

And then, looking at the female curve and the male curve for the value of a life at particular ages, the female curve was a little higher, but they were very close together. But the gains are smaller for women, because the gains in reduced mortality have been smaller for women.

And what you're going to see in a few minutes is that the main source of the gain for men that makes it bigger is reduced mortality from heart disease. That's the front on which most of the gains in reduced mortality have occurred.

So we accumulate these things up over the population, showing you the economic value of increases in life expectancy for 1970 to 1980, and again from 1980 to 1990, by age group and by gender.

So from 1970 to 1980, if we aggregate up over the male population — and we're aggregating over ages and everything, so we're taking into account the ages at which these diseases occur and the mortality occurs, and what the value of a life is at each of those ages — if we add this up over the population, this is in millions of dollars.

And so, you've got 20 million men, so that's twenty-and-a-half trillion dollars for men, from 1970 to 1980. Females got \$16 trillion, for a cumulative gain of about \$36 to \$37 trillion between 1970 and 1980. That's the value of the reduced mortality that occurred over that period.

From 1980 to 1990, the gains are smaller. The cumulative over the two groups is about \$21 trillion. So, from 1970 to 1990, the annual flow of value that you got was, on average, about \$2.8 trillion per year.

The next figure indicates the main sources, and that's reductions in heart disease death rates between 1970 and 1990.

We show you the boxes for men and for women. So now you can come back and understand why it is that the male gains were so much bigger than the female gains, and also, over what age groups those occurred.

The largest reduction in mortality from heart disease was for men age 75 to 84 — the second-to-the-right pair of columns.

The height of that column is about 1,600 deaths per 100,000 people — a reduction in the mortality rate of about 1.6 percent per year. So that's a pretty big number.

You can see, they're bigger for men. You can see that the ages at which these things occur are typically among older individuals, so mortality from heart disease for people in their 30s is quite low.

That's one of the reasons that we talk about that the people who value this the most, in a present-value sense, are going to be the people who are closest to the onset of those diseases. The gains are going to be largest for the individuals who are closest to those ages of onset of disease.

We show you how those gains are distributed between men and women. And you'll notice it doesn't look exactly like the bar chart that we just showed you a minute ago. And that's because as you move out to higher ages, two things are going on — you're getting closer to the onset of disease, but the expected value of remaining life is getting smaller as well.

So you get out to age 75 to 84, and you're closest to where the biggest gains have been in reducing mortality from heart disease, but it's also true that for men in that age group, their expected number of remaining life years is smaller, obviously, than for someone who's 45 years old. So that you have these two effects going in opposite directions. And a lot of the gains are behind you.

AUDIENCE: Each of these are representative individuals?

MURPHY: All the calculations are based on a representative individual.

AUDIENCE: So a two-year-old and an 80-year-old have the same value per year?

MURPHY: No. We have that profile of value of life. And that's derived from a profile of a valuation of individual years that we construct over the lifetime.

We basically took a profile of earnings, and used an earnings profile, and then made it depreciate at a fixed rate after retirement. So we started with a profile of the value of individual years that actually varied over the life cycle, and then used that to construct valuations of present value. And then, they go into those formulas.

AUDIENCE MEMBER: Did the remaining years left take account of the technological improvements that you're considering?

MURPHY: No.

TOPEL: These are purely retrospective.

MURPHY: Let me talk a little bit about how we did it. This is one of the few cases where I think, actually, the life table construction as it's usually done actually proves to be useful.

We sort of said, let's take the 1970 life table, where you have a death rate at each age. And we said, well, what if you lived in a world that was always going to be like that, for your entire life? How good is that of a world to live in? We then compared that to 1990, where you have the death rates in 1990 by age, and said, what if you were to live in that forever?

Inside of a comparison of those two worlds is a measure of how much better the '90s world is than a '70s world. It's not a measure of how much better it is to be born in '90 than it was to be born in '70, because that depends on what's going to happen in 2010.

Think about it in the analogy with the more usual economy we talk about. What was the level of productivity in 1970? What was the level of productivity in 1990? How much had productivity risen? And how much do we value that at?

TOPEL: Table 2 simply breaks out those gains over the two decades from '70 to '80 and '80 to '90.

Let's go to Figure 5, if you would — the economic value of disease reduction by age. Here's for men.

What we show in this figure is, given the remaining mortality after the reduction that's occurred between 1970 and 1990, what would be the value across age groups to curing various diseases per individual? So the gain to a representative individual of curing heart disease, for men, would peak at somewhere around \$275,000. This is completely wiping out heart disease.

The gains to cancer also peak at about the same age, in the early '50s. It's slightly less than \$250,000.

The returns to other diseases are substantially lower.

On AIDS, you notice it peaks much earlier, because the onset of AIDS typically occurs at a much younger age than for things like heart disease and cancer.

The values of others are much smaller, because the probability of dying of those things is smaller than for heart disease or cancer.

Here are the values for women. The peaks occur at different ages for women. Curing heart disease peaks at a little bit under \$200,000; curing cancer peaks at slightly more than \$200,000. But the value, on a per-person basis, of curing those diseases is very similar.

And then, we break out — in Table 4 — what the value of reducing deaths from those selected categories of disease will be.

You can see that men are very unlikely to die from breast cancer, so the value of curing breast cancer among men is not very high, but is substantial — over \$4 trillion — for women. The total value of curing cancer for women is on the order of \$22 trillion — only slightly below the value of curing cancer among men.

Which brings us, adding them together, to the \$46 trillion number, \$47 trillion number that we talked about before.

AUDIENCE MEMBER: I hate to slow you down, but just a point of clarification. Say you have an 80-year-old person, an 80-year-old woman. The value of curing these several diseases is going to be \$600,000 for this 80-year-old woman?

TOPEL: Oh, you mean, you're adding them up vertically?

AUDIENCE MEMBER: Is that what you did?

TOPEL: Yeah, if we cured every one of those things.

AUDIENCE MEMBER: But she doesn't have \$600,000. If it's not foregone earnings, is it the fear of dying this year that she's willing to pay an insurance policy for?

MURPHY: It's the willingness to pay for a change in the probability. For example, let's say I asked you how much would you be willing pay, I've got this gun pointed at your child's head that has a one-in-a-hundred probability of killing him. You might be willing to pay much more than one-hundredth of your income for that.

Our calculation would imply that the value of that would be this very large number.

AUDIENCE MEMBER: I know the life you save may be your own, but are you worried about the aggregation of this at the later age group? Because that seems like a big leap.

MURPHY: We do those kinds of calculations all the time, in economics. It doesn't have to, in some sense, add up. Because after I've paid for one, I'm now poorer than I was before. There's no reason that the willingness to pay for each of these individually would have to total up to less than their income.

It's true that if you offered them all out there, they couldn't afford them all. But given the types of progress that we're looking at, and the potential changes we're looking at, I don't think that that creates a serious problem.

TOPEL: Table 4 tries to give you a feel for what the total value or gains would be, measured in dollar terms, to curing these diseases.

Now, you might think, well, jeez, curing the disease might be out of the question. But you can do magnitudes off of these by asking what would be the economic value of making some progress against one of these diseases?

A 10 percent reduction in the probability of dying from cancer would be worth 10 percent of that \$46 trillion. Even a 1 percent reduction would be worth on the order of \$500 billion.

And the prospects of a 1 percent change in the probability might be something that's much more technically feasible when we think about investments in medical research. But it's still, even at the level of a 1 percent change in the probability of dying of a particular disease — here, of cancer — when the gains

are on the order of \$500 billion, and you compare that — and Mike talked earlier about the value over the last 30 years of being on the order of \$30 billion — the difference between potential benefits and the investments in research and development that might lead to those modest changes in mortality are quite large.

AUDIENCE MEMBER: But suppose the rate of return on the investments is 2 percent? In other words, suppose you have a low rate of innovation, as a result of the expenditure. You don't discover the silver bullet that's out there.

MURPHY: Let's take a hypothetical. Let's say that we start with this \$46 trillion number for cancer, and we say we could have a 10 percent chance of making ten percent progress against that. Okay? So that's expected progress of 1 percent.

How much should we be willing to spend on research? This number would say \$500 billion. And we've spent \$30 billion up till now. So, if doubling the current accumulated expenditure could have a 10 percent chance of a 10 percent improvement, these numbers would say that's clearly in the money.

And that is, in some sense, the basic message. I don't think we're anywhere near a definitive conclusion on all of this. But I do think that these kinds of calculations say, look at the potential, the historical gains, and let's first deal with factual things.

The historical improvements have been very large. Given estimates of what people are willing to pay for improvements, it's clear that there have been enormous gains for individuals from improved health. And as a rough way of talking, the gains from improved health over the last 40 years are on the same order of magnitude as the gains from increased productivity and growth in the more traditionally measured sector of the economy. So there has been no doubt that there have been enormous historical gains.

We also look at these numbers and say, using those same techniques, a potential for further gains is also there. Then you ask, well, can we achieve them? Can research really give us some of this piece?

And that's a piece that remains to be argued. But it seems to me that you don't have to think that there are enormous probabilities of the silver bullet to justify even substantial expenditures.

Now, somebody asked earlier about the cost of treatment. And if you think about it, cost of treatment is a much bigger number than is the investment in research.

For example, we spent \$35 billion on research. Well, we spent a trillion dollars on treatment. If there's any dimension of which you could argue that not everything is worthwhile, it would have to be that we would discover something that could reduce the death rate by ten percent, but the treatment cost would be very, very high. And just like we get big numbers by multiplying \$100,000 by 250 million people to get big numbers, you could get big numbers on the cost of treatment, as well.

But I think there's also a message in that for the types of research that are very potentially productive — that is, research on things that can make the improvements, for which the cost of treatment is relatively low. And there are a lot of people who think there are such treatments are out there. And our point would be that expending significant amounts on research could very well prove worthwhile on those types of things.

After all, the relative cost of research to treatment is very low. That is, treatment is a far more expensive thing than research. And if research with low-cost treatments is potentially possible, the calculus would seem to say that the potential gains are enormous.

And this is just for the U.S. If you put the whole world an enumerator of this thing, the research cost doesn't go up, but the potential benefit does, whereas the treatment undoes that. So if there is something out there, a shadow that's going to cover this up, it would have to be on the cost of treatment.

TOPEL: If there's a silver bullet that shoots us down, it's on the cost of what the treatment is going to be.

AUDIENCE MEMBER: If you look at the chart, then the peak period of the benefit in AIDS is between early 30s and about 50. Does that mean that people succumb to the disease earlier?

MURPHY: Well, remember, it's forward-looking. So when we measure the gain to somebody that's 30 years old, the gain there reflects their valuation of what that prospect is going to give them when they're older.

You could have a zero probability of dying at age 30. But in terms of how much you're willing to pay for progress, you're still willing to pay, because you're going to get a lower probability at age 50 and 55 and 60 and on in the future. All of these are forward-looking calculations.

The fact that it peaks at 30 means that's the age at which you have a lot of it out in front of you. That's why.

TOPEL: This is a present-value calculation.

MURPHY: It's not a contemporaneous return.

AUDIENCE MEMBER: All of the calculations here are done on mortality. But what about morbidity? I mean, morbidity is a very important factor.

Can you extend this economic model to morbidity as well as mortality?

MURPHY: Yes, the paper really does talk both about mortality and morbidity.

The average level of morbidity, in some sense, is embedded in our calculations, because when we ask how much are people willing to pay to extend their lives, that question is asked in the context of the existing level of morbidity out there. But for improvements in morbidity, what you really need to know is that same valuation question — how much is a person willing to pay to live, be able to walk, as opposed to be in a wheelchair, or be able to function without respiratory problems, or whatever other measure you can have of their current condition.

There are studies that try to measure that, and there are techniques that fit into our framework better than others. For example, one is the kind of equivalent valuation, where you ask people, well, living for six months or a year with this condition is as good as six months in perfect health, or something like that.

TOPEL: We need to weight those life years by something. But we haven't done it, yet.

MURPHY: And that will add to the numbers that we get.

TOPEL: So, to the extent that the research investments we're talking about also improve quality of life, or reduce morbidity, if you will, then, those calculations have not been included in the numbers you've seen here.

AUDIENCE MEMBER: When we ask people, how much would you pay to avoid a sudden death from X, Y, Z — a one-in-a-thousand chance — they say \$500. They're assuming that if they pay the \$500, that threat of death disappears, and their life is normal.

It might be that the treatments you're talking about are the proverbial "silver bullet," which cure and leave no morbidity of their own. But our experience with health care has been largely that spending on health care increases with the more research we have, because our treatments are not the silver bullets. And secondly, that they lead to greater and greater morbidity costs and postponed costs of treatment at the end of life, which itself gets more expensive with the elderly.

TOPEL: We agree. And that's why we said that if there's a silver bullet that can be pointed at this research, it's that if something fills the gap between this thing that we call the benefits and then some fairly low level of investment in medical research, it's got to be that the costs of implementing the procedures, or of implementing the ideas that are produced by the R&D, have to be large indeed in order to fill that gap.

MURPHY: But there are a couple of caveats here. If you look at the historical record, I don't think there's much evidence to say that at a given age, the level of morbidity is higher now than it was in the past.

Assuming that we could say that age-specific morbidity is not worse than it was in the past, our numbers for historical improvements would still be underestimates. Because if it is, in fact, the case that we've kept sicker people around, the rest of the population must have gotten healthier enough to offset that. Otherwise, you'd see it in the morbidity statistics. So, I think, in terms of historical improvements, that nets out.

Table 3 took the calculation to say, well, let's take those improvement numbers and subtract from those the higher costs of health care today from what it was in 1970. You get the '90 life table versus the '70 life table, but you get the lifetime expenditure pattern from 1990, as opposed to the lifetime expenditure pattern from 1970.

Now, that's a little unfair, in a couple of different ways.

On the one hand, a lot of that expenditure is not directed at reducing mortality. It's directed at making people's life more comfortable, and other things. And therefore, we've included all the of costs without all of the benefits.

On the other hand, not all of the benefits are due to health research, so we've maybe overstated the benefits a little bit. So, have your way on how you'd net out.

The bottom line is, for the 1970 to '80 calculations, it turns out, it doesn't matter much at all that we get a net gain of \$34 trillion. I think the original one was \$36 trillion. The '80 to '90 numbers are affected significantly more, where we're going to get a gain of \$16 trillion as opposed to \$22 trillion.

So we tried to do the thing you were asking about, which is net out the expenditures. We didn't know which of the expenditures were particularly associated with the life-extending innovations, so we put them all in there. In some sense, we threw in guys getting knee surgery when they're 25 years old in there, just because we didn't know how to take it out.

AUDIENCE MEMBER: There are so many things which we already know would reduce both morbidity and mortality that we don't do. Isn't it a little misleading simply to use the kinds of numbers — that \$5 million number that you give — when we know that so many of these expenditures aren't made? Aren't there questions about this model?

MURPHY: We've spent a lot of conversations on exactly this question.

You look at the data on occupational choice, and you say, look — in order to get somebody to take a riskier job, we have to pay them a lot more. And I think the data suggests that people don't take those risks lightly, and you've got to pay them a lot to take them.

But that would imply the cheeseburger I had for lunch costs \$26 — I don't know what the number is, I'm making this number up.

Your point is that calculation might imply that on different margins, people could get great benefits by changing their diet.

Now, there are two economic answers to that. One is that they really value those things a lot. The other one is that valuation really differs across different types of risk.

And we tried to look at some other ones, like airbags and traffic safety. There, the numbers are still a little more consistent.

AUDIENCE MEMBER: But what about the spending in health care itself, since that's what you're looking at: preventive measures, greater safety in the institutions themselves, greater standardization of procedures to avoid unnecessary deaths. We don't spend those kinds of numbers for these things.

MURPHY: Right. But if that's an indication that we don't have the right incentives and we don't do things correctly, then I don't think it casts doubt on these numbers. If that's an artifact of the fact that the real valuation that people put on improvements is much lower, then I think that's a much more serious problem.

TOPEL: That's why the cheeseburger answer sounds much more compelling than the one about what institutions would spend to protect those lives. Because the cheeseburger example says, look, I value these years of life at some high numbers. That's what our calculations are based on. And yet, people are still eating that \$26 cheeseburger. Why are they doing that?

AUDIENCE MEMBER: Never underestimate the power of denial.

TOPEL: But that's the other answer. They don't believe us when we tell them that a cheeseburger is not a good thing.

MURPHY: But now, you've really created a problem, because then you have to answer the question of what category do they put cancer deaths in? Is a cancer death like the cheeseburger, or is a cancer death like, you know, falling off a ladder or drowning in the ocean — in which people seem to put much higher values.

If you do get disparate values, it doesn't end the discussion — it just simply opens yet another can of worms about which of those alternative numbers you're going to use.

Obviously, from a research point of view, you'd love if they came out similar. Then, you could say, look, I can justify the same calculation from a bunch of ways. But that's clearly another area where we're trying to push our research, to try to see whether we see a consistency there in those numbers.

AUDIENCE MEMBER: In the last 10 years, we've had one — at least one — major medical breakthrough of large magnitude, and that being the discovery of helicobacter pylori as being the etiologication for peptic ulcers.

So, starting in 1984, you have a chap from Freemantle, Australia, Barry Marshall, who discovers the bacteria that causes the ulcers, and in 1991, the papers are published. Then you take this model, your morbidity formula model, and retroactively apply that to one disease, like gastric ulcers, to validate your model.

TOPEL: I don't know the answer to your question, because you're asking whether we can apply it to improved health from these gastric ulcers.

AUDIENCE MEMBER: But there is definitely morbidity and mortality associated with gastric and duodenal ulcers.

MURPHY: Let's focus on the mortality issue first. One of the things we want to do is go on a disease by disease basis and look for hard evidence where research leads to a breakthrough, breakthrough leads to changes in treatment, and changes in treatment lead to reductions in mortality.

This is not as clean as some equation that we might estimate that shows the connection between research and reductions in mortality. So we need to make the case for that bridge, that the research actually does what we hope that it does. And you've pointed that on that particular disease, it doesn't.

Clearly, the way we treat heart disease today is very different than the way we treated it 20 years ago. That's true across a number of diseases. So there is change going on out there.

How that's related to the underlying research is probably the question. But the idea that people do change and there are adjustments — they don't happen overnight. But that's not just true in medicine, that's true in every field.

When we discover a better way of making steel or anything else, it takes a while to diffuse, for those best practices to make their way into the actual usage.

And in that way, the task here is much more difficult than making the case for R&D more generally in the economy. The economists in the audience say, well, total factor productivity is going up at 1 percent a year, or something. That's a big number. That means a lot of value. It means you're going to get one percent more output forever. That's worth 30-something percent of GDP, if you're discounting at three-and-a-half, four percent, something like that.

So if you have those huge improvements, how much of that is due to research and development generally? Same problem, right? You've got all this research going on in the lab, and you've got productivity rising in the economy. And somehow, you have to put those two things together. The links are indirect; there are a lot of other factors that are affecting productivity.

And so, what we're doing here is really a mirror of what economists have been working on for a long time for the standard measured part of the economy.

What's interesting about it is, if our calculations are even roughly right, this is a part of the economy that's at least on the same order of magnitude, in terms of importance, but yet, for which we've devoted very little to try to measure what's behind these improvements, and how big these improvements are, and how we might be able to get bigger improvements in the future. So from an economist's point of view, it's a neglected part of the economy.

AUDIENCE MEMBER: My original question was, we have solved a major disease in the last decade — that being gastric and duodenal ulcers. Can your model be validated, going back on that data?

MURPHY: Validated in what sense? Our argument is how much people would have been willing to pay to achieve that.

TOPEL: Plus what calculations imply the value of that was. And then we can say, well, was that value bigger than what was spent on the research in order to develop those procedures that cured the disease?

I think it's highly likely that the answer is yes, it was bigger. But does it validate our model? I don't think we can do that. Does that particular example validate our model? No, I don't think it does that.

MURPHY: You could have a problem if what people were paying was vastly greater than what we say it would be worth, then you might say that would invalidate the model. But if it came out the other way, that people were getting a huge gain from this, well, they get a huge gain from a lot of innovations.

AUDIENCE MEMBER: Well, actually, we can see a change in the expenditure about that period. Because gastroenterologists are quite rarely found now. I'm not being funny — it's simply disappeared. So you know, there is actually true expenditure there, which could be measured as a change.

MURPHY: And that's a nice example, because that's an example of expenditure-reducing rather than expenditure-enhancing types of innovations. And there are other examples in medicine that certainly go in the expenditure-enhancing, where we used to have a treatment where we said, tough luck, and now, we actually have something we can do.

AUDIENCE MEMBER: Well, I totally agree that that's a great innovation, finding the treatment for

that. But you've got a selection bias, I think.

Suppose you looked at things and you didn't find out anything. You would find that all the money spent didn't do anything. So there, it wasn't worth it. So I'm not sure what you would get out of this picking out only the winners. You'd have to look at all the winners and all the losers in aggregate.

MURPHY: If you look at age-specific death rates from heart disease, it's going vroom! It's crashing. If you look at cancer on that same scale, it's a horizontal line. It's enormously different.

And that's true out there generally — there's huge heterogeneity. Go back to the productive economy side. That's true there, too, where you look at productivity in computer chips. We've just done gangbusters there.

This idea that we're not making uniform progress opens the issue of selection bias. And there, you've got to compare the probability that you wouldn't make any progress, and that's substantial.

TOPEL: We also don't want you to confuse the message, when we talk about that big decline in heart disease. We have not made the connection that says that that big decline in mortality from heart disease is due to any direct research outcomes, where some guy was grinding away in the lab at the University of Chicago. What we've offered it up is suggestive evidence of what the gains have been.

But those gains came from somewhere. They could have been from public health changes, which could trace its way back to research. It could be changes in people's lifestyles, which could trace their way back to research.

And that's why the connection between the research and the outcomes themselves is very difficult to make here. It's very difficult to make for R&D in general, and changes in productivity. Because it really is the same problem.

AUDIENCE MEMBER: In your research, do you address prevention of disease through, say, abstinence or greater education, like AIDS. And do you put some value in that?

MURPHY: We could talk about what the gains, potential gains are, associated with those. And we could also talk about the incentives to find various ways of reducing disease.

There's more than one way to skin a cat. And when you talk about things that are cost-increasing versus cost-decreasing, it's not clear that research always puts much emphasis on that. You're out there trying to figure out how to cure some disease. Our evidence would say the cost of the research is not the big story. The big story is how much is the treatment going to cost?

So, if I could spend twice as much on research and find something that was equally effective but much, even somewhat less costly, it's probably worth it.

Current research and private incentives for research are very different for something like a drug that I can patent versus something like information that probably is going to be difficult to get much of a return on — or, similarly, things associated with a particular type of equipment that I'm willing to invest in. Inventing a new procedure that I might get it named after provides some incentive. But, you know, it's not going to feed the family.

AUDIENCE MEMBER: I've been working some with AmGen on the capital budgeting problem of deciding whether to invest in a certain molecule in the hope that it will have therapeutic benefit. You don't see the problem of under-investment being too serious there, in the sense that the company gets half of that molecule if it works, and gets sufficient returns, if the incentive is appropriate.

MURPHY: I wouldn't say there's no problem. I would say there's less of a problem on that dimension than there is on something that's purely intellectual capital that cannot be capitalized on, which is the usual argument for why basic research is more likely to be underprovided than is product research.

Table 5 tries to address some of these issues. And we try to look at expenditures on health research and health-related research.

R&D for the health sector as a percentage of health expenditure is about three-and-a-half percent — thirty-five billion out of basically a trillion dollars in expenditures.

On the other hand, the economy as a whole is about two-and-a-half percent. So, it's not that different than the economy as a whole.

Of course, drugs and medicine, as a sector, is very high. It's 10 percent, versus three-and-a-half for the economy. So you can see that in a case where you have something patentable, it's much more likely that you're going to see substantial private investment.

It's even more skewed than that, because we've looked at all investment, including the government stuff. If you just looked at private, it would be even more skewed toward drugs than basic research.

AUDIENCE MEMBER: And that's a really important point. We're about 60 years into modern scientific pharmaceutical research. And an awful lot of drugs which were developed in the '40s and '50s and '60s which are now off-patent are continuing to find new uses. And it makes it incredibly difficult, because there's no patent protection, and there's no return on the intellectual property. For me to make any money out of it, I have to rely on NIH grants.

If an economist could come to me with a business plan that says, here's a drug you can't patent, but you can make money off of it, I'd be at your feet.

MURPHY: You're making an argument, almost, for being able to patent the use of a drug, rather than patent the drug itself. You want to sort of think each use of the drug as sort of a specific thing.

TOPEL: If you use it for this disease, you have to pay more.

MURPHY: Hard to enforce.

TOPEL: Well, thanks very much for your questions and patience.

MILKEN INSTITUTE
Kevin Murphy-Robert Topel Symposium
August 31, 1999

**The Economic Value of Increased
Longevity
And
Medical Research**

Kevin M. Murphy

&

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- **Topic:**

The social value of health and longevity, and its relation to medical research.

- **Goals:**

Provide an economic framework for valuing improvements in health and longevity.

Provide evidence on the uncounted social surplus in the United States due to increasing life-spans.

Develop evidence relating increased life-spans and improved health to basic medical research.

Basic Framework

- **Framework is economic. In valuing lives, we ask: “How much are people willing to pay for improvements in the quality of their lives?”**
- **Underlying theme is that medical research (and other basic research) is a public good – social returns may greatly exceed the private returns.**

Magnitude of Medical Spending in the US

- **\$35 billion spent on medical research in 1995**
- **\$13 billion from federal government – 21% of federal R&D**
- **46% increase in R&D between 1968 & 1995, while per-capita health spending doubled**
- **Health care as a % of personal consumption rising over time: 10% in 1980, 16% by 1995.**

Preliminary Empirical Results

- **Value of increased life expectancy alone (ignoring improvements to health) added \$2.8 trillion *per year* to national wealth from 1970 to 1990.**
- **This is more than half of average annual GDP over this period.**
- **\$1.5 trillion of this is due to reduced mortality from heart disease alone – an area where research may have had important effects**

Future potential gains are also large.

Present value of

- **Eliminating heart disease: \$48 trillion**
- **Eliminating cancer: \$47 trillion**
- **20% reduction in cancer: \$10 trillion**

Potential benefits are large enough that higher expenditures on research may be justified even if they yield only small reductions in mortality

General Approach

- 1. Develop a theoretical framework for expressing the value of changes in mortality and/or health.**
- 2. Using (1.), estimate economic values for changes in mortality/health – for both historical and potential future changes.**
- 3. Make an empirical connection between medical research, the stock of knowledge, and observed changes in mortality/health.**

Economic Framework

- **What are changes in mortality (lives saved) or changes in health “worth?” Only by answering this can we make useful public policy decisions.**
- **Economic approach: How much are people willing to pay to live a little longer, or be a little healthier?**

Concept of value as willingness to pay for life extension and improved health reflected in many elements of decisionmaking, e.g.:

- **Changes in diet and exercise in light of medical evidence**
- **Reduction in smoking**
- **Choices regarding safety equipment**
- **Occupational choices**

Basic idea: Increases in medical knowledge raise the probability of being alive at any future age, so the expected duration of life increases.

Our approach yields a specific, but flexible, form for the amount that a person would pay for life-extending innovations, or for improvements in health.

This approach has several important implications:

- 1. The value of increased life expectancy is proportional to the levels of income and consumption.*
- 2. The value of increased life expectancy depends on the value of non-market time.*

Particularly important for medical advances, where reductions in mortality are concentrated among older, retired, persons.

- 3. Because of discounting, medical advances against a particular disease are of greater value to those who are close in age to the onset of the disease.*

4. *Complementarity: Advances against one disease, say heart disease, raise the value of advances against other diseases, say cancer.*

5. *The social value of increased life expectancy is proportional to the size of the population.*

6. *The social value of increased life expectancy is larger when the age distribution of the population is concentrated just before the ages where reduced mortality occurs.*

How Much is a “Statistical” Life Worth?

- **Suppose that a representative person would pay \$500/year to achieve a 1/10,000 reduction in the annual probability of disease-related death.**
- **In a population of 10,000, expect to save 1 additional life/year.**
- **Value of statistical life = $10,000 \times \$500 = \5 million**
- **Empirical evidence: “Reasonable range” from studies of occupational mortality is \$3-\$7 million. For our estimates we use \$5 million for a representative individual**
- **Implies that an additional year of life for the representative prime-aged person is worth about \$166,000.**

Figure 1. Value of Life by Age for 1990

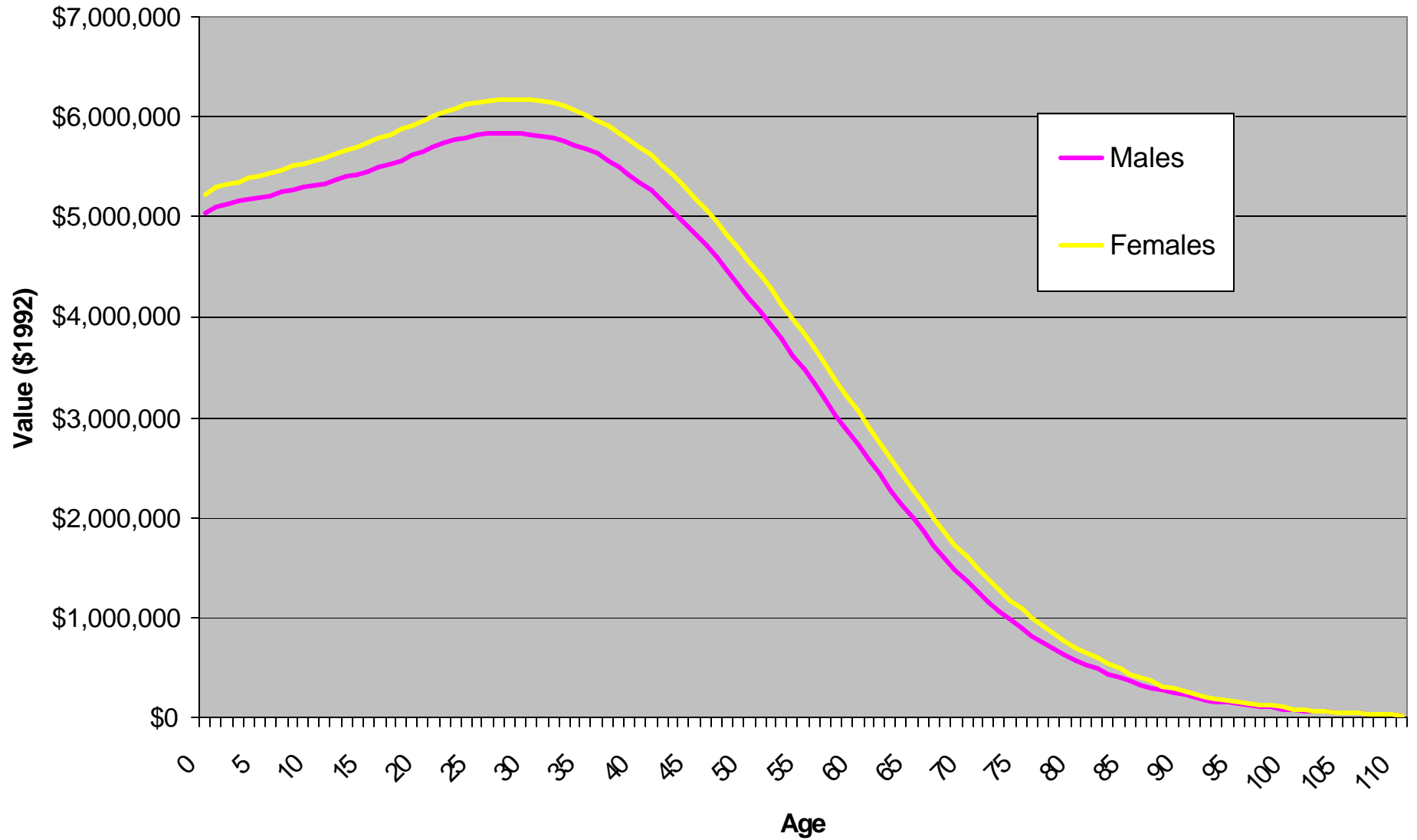


Figure 4. Increases in the Value of Life by Age for men and Women 1970 to 1980 and 1980 to 1990

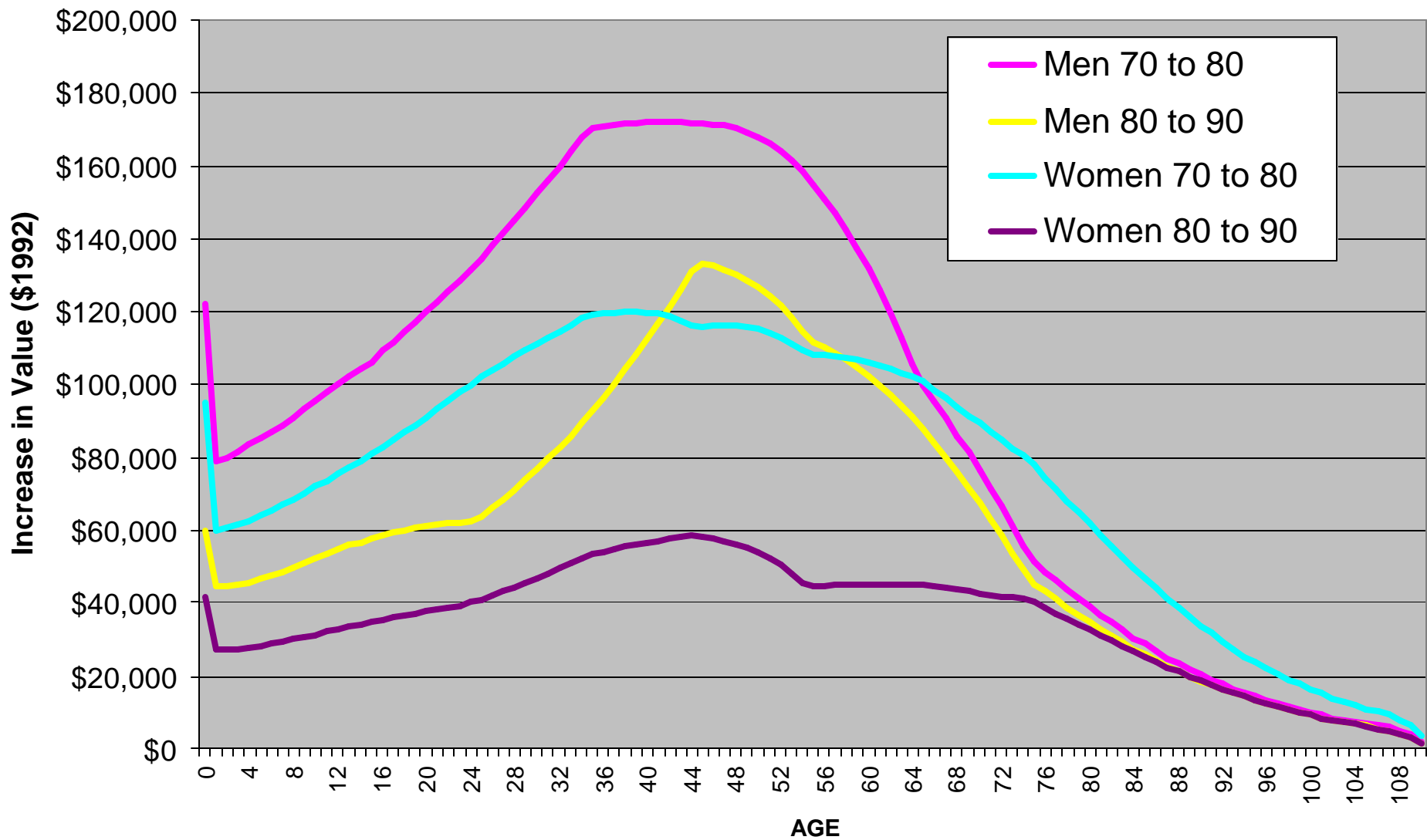


Table 1. The Economic Value of Increases in Life Expectancy from 1970 to 1980 and 1980 to 1990 by Age Group and Gender

		<u>Total Values (Millions of Dollars)</u>		
		70 to 80	80 to 90	70 to 90
				Annual
Males		\$20,547,654	\$13,333,130	\$1,619,017
Females		\$16,042,877	\$7,966,696	\$1,158,343
Total		\$36,590,530	\$21,299,826	\$2,777,360

Figure 2. Reductions in Heart Disease Death Rates 1970 to 1990

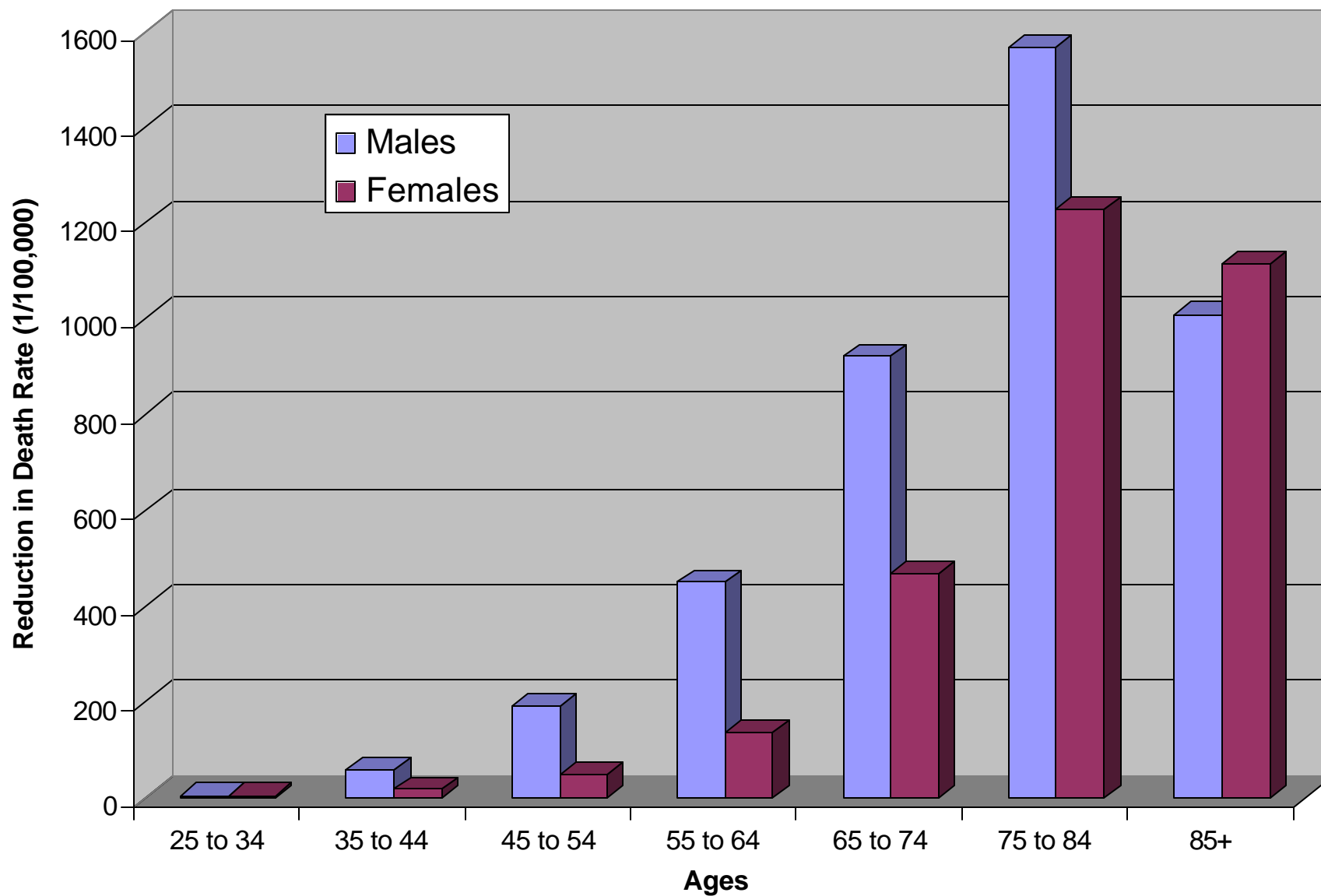


Figure 3. Economic Value of Reductions in Heart Disease Deaths From 1970 to 1990 by Age For Men and Women

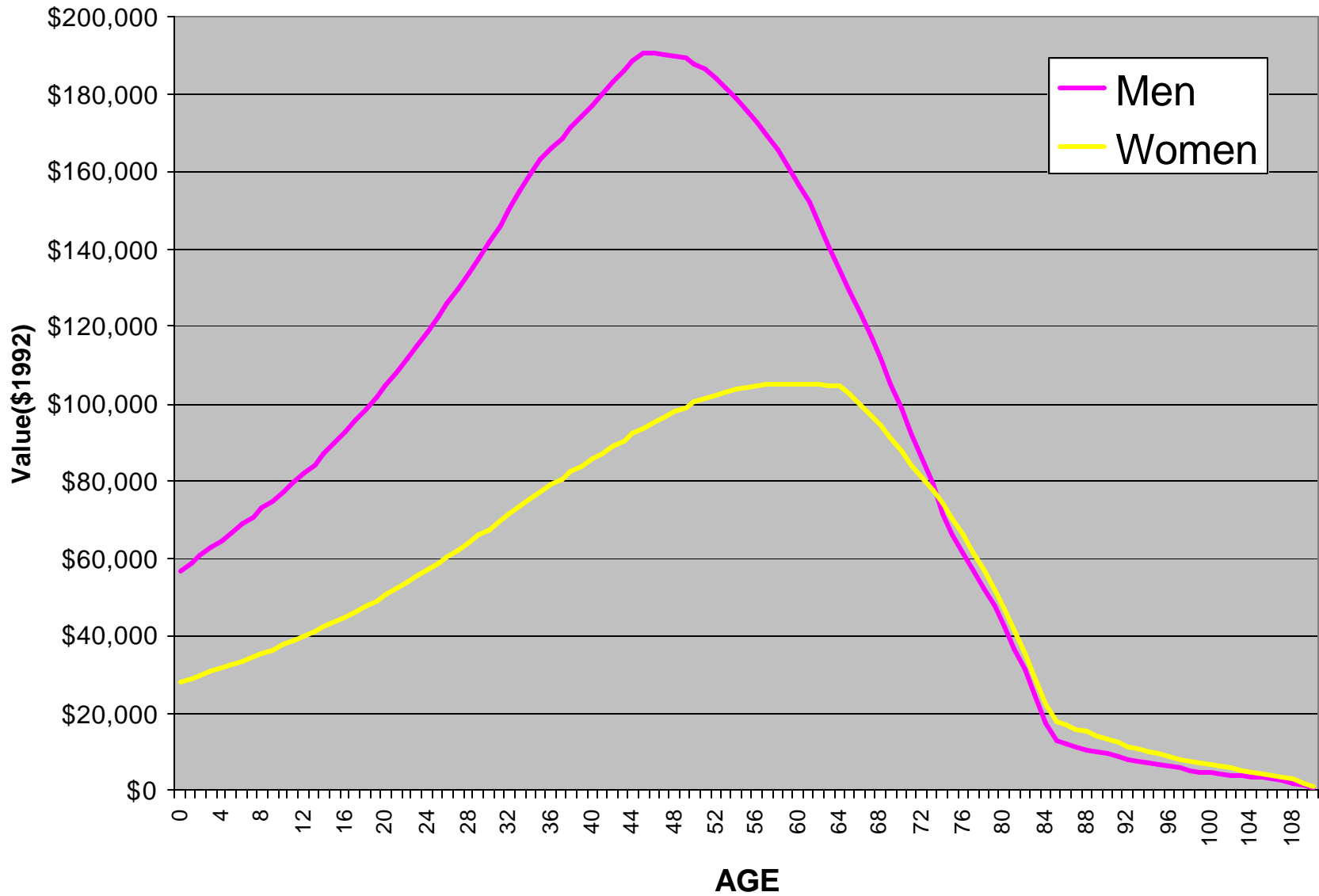


Table 2. The Economic Value of the Reduction in Heart Disease from 1970 to 1980 and 1980 to 1990 by Age Group and Gender

		<u>Total Values (Millions of Dollars)</u>	
		70 to 80	80 to 90
Males		\$9,831,282	\$10,107,711
Females		\$5,729,049	\$5,138,526
Total		\$15,560,332	\$15,246,237

Table 3. The Net Economic Value of Increases in Life Expectancy from 1970 to 1980 and 1980 to 1990 by Age Group and Gender

		<u>Total Values (Millions of Dollars)</u>		
		70 to 80	80 to 90	70 to 90
				Annual
Males		\$19,441,601	\$11,040,528	\$1,461,346
Females		\$14,781,280	\$5,426,623	\$980,800
Total		\$34,222,882	\$16,467,151	\$2,442,146

Figure 5. Economic Value of Disease Reduction by Age for Men

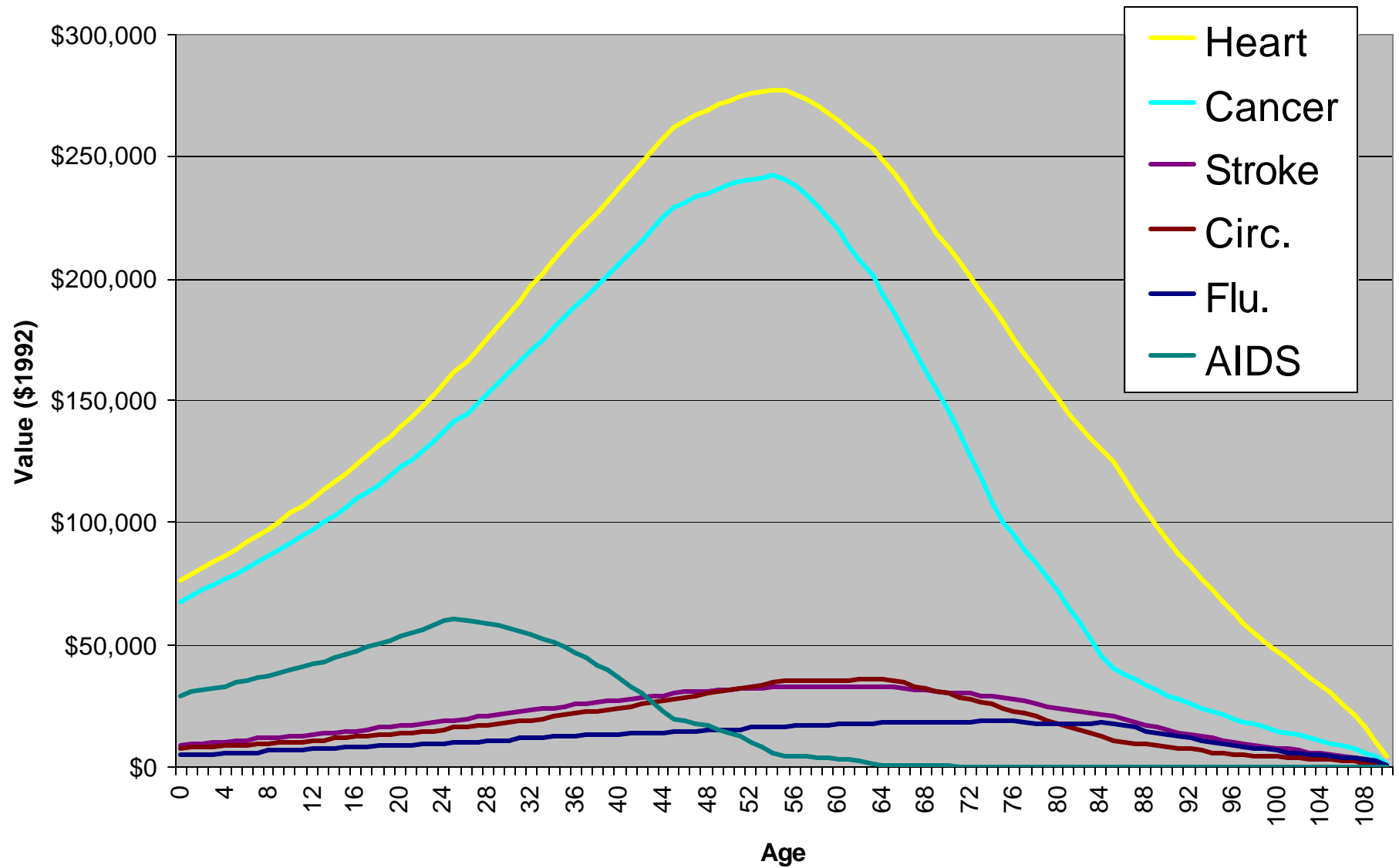


Figure 6. Economic Value of Disease Reduction by Age for Women

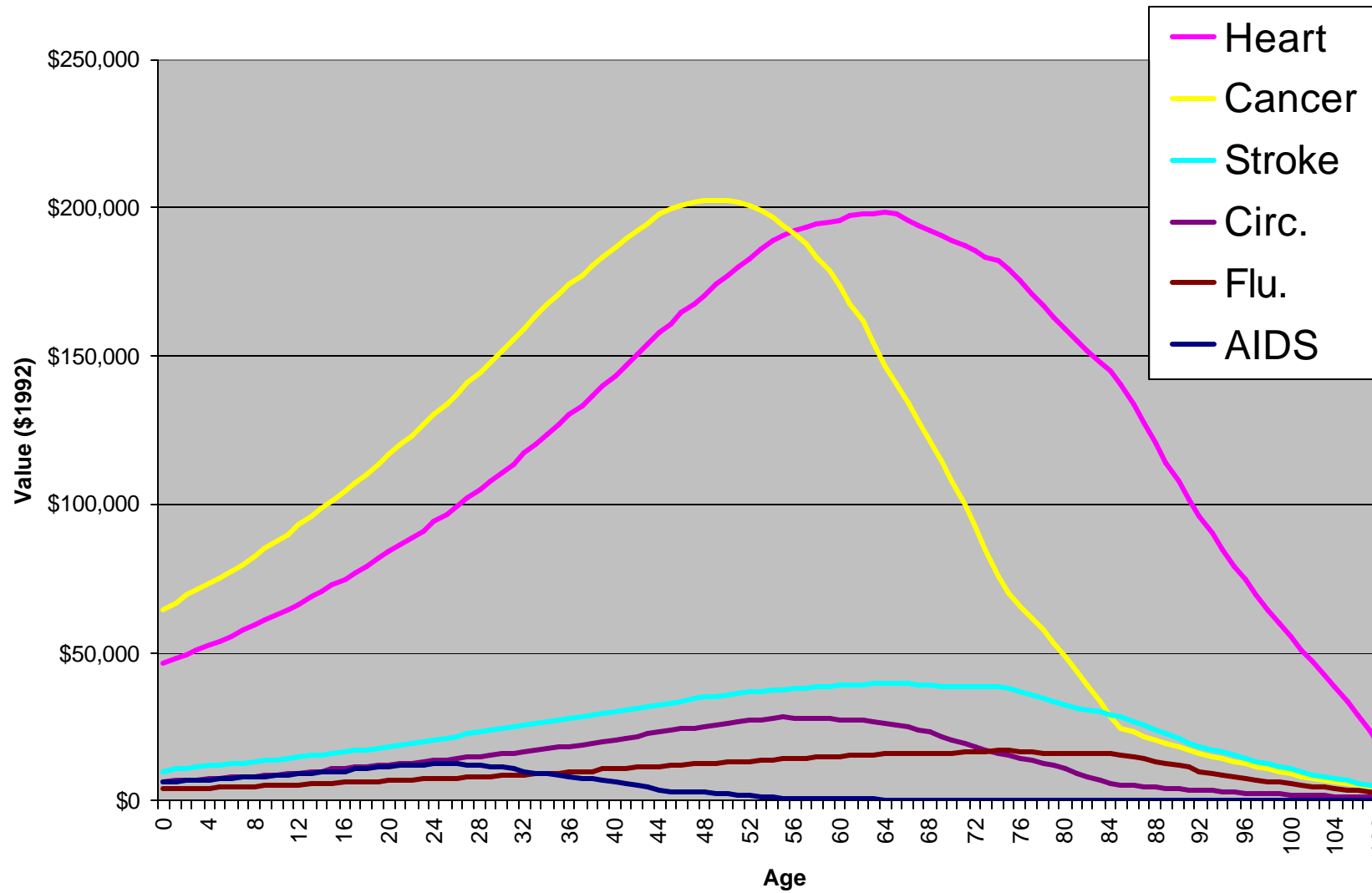


Table 4. The Economic Value of Reducing Deaths from Selected Categories of Disease Overall and by Gender

<u>Increase in Value of Life(\$1,000,000's)</u>				
<u>Disease Category</u>	<u>Men</u>	<u>Women</u>	<u>Total</u>	
Cancer	\$24,325,209	\$22,211,974	\$46,537,183	
Breast	\$25,080	\$4,617,170	\$4,642,251	
Digestive Organs	\$5,469,042	\$4,160,405	\$9,629,447	
Genital and Urinary	\$1,810,372	\$2,334,439	\$4,144,811	
Heart	\$28,636,005	\$19,711,577	\$48,347,582	
Stroke	\$3,472,990	\$4,156,135	\$7,629,125	
Circulatory Disease	\$3,085,051	\$2,654,387	\$5,739,438	
Flu.	\$1,841,048	\$1,591,013	\$3,432,061	
AIDS	\$6,277,524	\$1,262,572	\$7,540,097	

Table 5. Expenditures on R & D - Bio-medical and Aggregate by Funding Source for 1995			
	Expenditure		% Growth
<u>Biomedical R&D Funding</u>	<u>(\$1,000,000's)</u>	<u>% of Total</u>	<u>1986-1995</u>
Total Government	\$15,846	44.2%	49.8%
Federal Government	\$13,423	37.5%	45.8%
NIH	\$10,682	29.8%	50.7%
Industry(Total)	\$18,645	52.1%	125.6%
Private Non-Profit	\$1,325	3.7%	26.9%
Total	\$35,816	100.0%	80.1%
Spending on Health Care	\$1,021,500		64.7%
Health R & D as % of Health Expenditures	3.5%		9.3%
Health R & D as % of GDP	0.5%		46.6%
Health R & D as % of Total R & D	19.6%		57.5%
<u>Aggregate R & D Funding</u>			
Federal	\$63,147	34.5%	-13.2%
Industry	\$110,998	60.7%	36.1%
Other	\$8,868	4.8%	52.6%
Total R & D Funding	\$183,013	100.0%	14.3%
GDP	\$7,253,800		22.9%
Total R & D as % of GDP	2.5%		-7.0%

<u>R & D as % of Sales (Selected Industries)</u>	
Drugs & Medicines	10.4%
Office & Computing Equipment	8.1%
Communication Equipment	8.0%
Electronic Components	8.0%
Optical, Surgical & Photographic Equipment	8.0%
Scientific Instruments	6.6%
Industrial Chemicals	4.7%
Motor Vehicles	3.0%
Non-electrical Machinery	2.4%
Source: NIH Extramural Data 1996	
NSF Science and Engineering Indicators 1998	