

Measuring the Value of Improvements in Health and Longevity

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Steps in the Analysis

- (1) Define the economic question
- (2) Develop an economic framework
- (3) Review the underlying economics
- (4) Apply the economic framework to the data
- (5) Evaluate and interpret the results

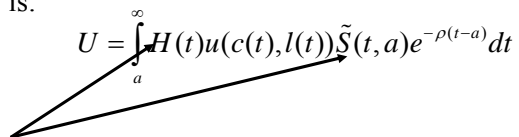
The Economic Issue

- Measure the gains to improvements in health and longevity
- Expand our measures of economic well being to include medical advances
- Measure the potential gains from future medical progress
- Assess incentives that determine health expenditures and the direction of medical advances

Theory

Basic Economic Framework

- We utilize the basic lifecycle model with utility depending on consumption, $c(t)$, and leisure, $l(t)$. We add two additional elements a survivor function, $S(t,a)$, and health, $H(t)$. The basic setup is:

$$U = \int_a^{\infty} H(t)u(c(t), l(t))\tilde{S}(t, a)e^{-\rho(t-a)} dt$$


Maximization Problem

- The setup described above leads to the following constrained lifecycle maximization problem:

$$L(a) = \int_a^{\infty} \{H(t)u(c(t), l(t))e^{-\rho(t-a)} + \mu[y(t) - c(t)]e^{-r(t-a)}\}\tilde{S}(t, a)dt + \mu A(a)$$

- This yields the familiar first order conditions:

$$H(t)u'_c(c(t), l(t)) = \mu e^{-(r-\rho)(t-a)}$$

$$H(t)u'_l(c(t), l(t)) = w(t)\mu e^{-(r-\rho)(t-a)}$$

Modeling Changes in Health and Longevity

- Health enters the model above in two ways improved health generates utility at a point in time as well as increases longevity
- It is useful to think about two types of health related improvements – those that improve the quality of life (raise $H(t)$ in our notation) and those that extend life (increase $S(t)$ in our notation)
- We refer to changes that improve health without affecting longevity as type H changes and we refer to changes that improve longevity without affecting the quality of life as type G changes.

Modeling Changes in Longevity

- The marginal value (willingness to pay) to reduce the death rate at age a is given by the marginal rate of substitution between the probability of death and consumption or:

$$\begin{aligned} -\frac{\partial U(a) / \partial \lambda(a)}{\partial U(a) / \partial A(a)} &= \frac{1}{\mu} \int_a^{\infty} \{H(t)u(c(t), l(t))e^{-\rho(t-a)} + \mu[y(t) - c(t)]e^{-r(t-a)}\}\tilde{S}(t)dt \\ &= \int_a^{\infty} \left[\frac{u(c(t), l(t))}{u'_c} + y(t) - c(t) \right] e^{-r(t-a)} \tilde{S}(t, a) dt \end{aligned}$$

- For notational simplicity it is convenient to work with the discounted survivor function which captures the effects of both discounting and mortality:

$$S(t, a) \equiv e^{-r(t-a)}\tilde{S}(t, a)$$

The Valuation Equation

- We consider a change in some parameter, α , such as a medical advance that changes the hazard function, $\lambda(t,a)$

$$\begin{aligned} \frac{\partial S(t,a)}{\partial \alpha} &\equiv S'_\alpha(t,a) = -S(t,a) \int_a^t \lambda'_\alpha(\tau, G(\tau)) d\tau \\ &= S(t,a) \Gamma_\alpha(t,a) \end{aligned}$$

- The change in survivorship can be valued using the valuation equation:

$$V_\alpha(a) \equiv \frac{U'_\alpha(a)}{\mu} = \int_a^\infty \left[\frac{u(c(t), l(t))}{u_c} - c(t) + y(t) \right] S(t,a) \Gamma_\alpha(t,a) dt$$

$$+ \int_a^\infty \frac{H'_\alpha(t)}{H(t)} \frac{u(c(t), l(t))}{u_c} S(t,a) dt$$

- The last term allows for the possibility that α affects the level of (H - type) health

The Valuation Equation

- For purposes of working with the valuation equation it is useful to work with full income and full consumption where these include the endowments and consumption of leisure (measured at the market wage) so that

$$c^F = c + wl$$

$$y^F = y + wl$$

- With these changes, the valuation for longevity extension becomes:

$$V_\alpha(a) \equiv \frac{U'_\alpha(a)}{\mu} = \int_a^\infty \left[\frac{u(c(t), l(t))}{u_c} - c^F(t) \right] + y^F(t) S(t,a) \Gamma_\alpha(t,a) dt$$

- The valuation equation given above tells us that there are two components of the valuation of extensions in longevity. These are:

- The value of full income (including the value of leisure) and
- The surplus on the consumption of goods and leisure

Implications of the Theory

- Willingness to pay for improvements in health is proportional to full income and full consumption, so willingness to pay rises with wealth.
- The relevant concepts of income and consumption include the shadow value of non-market time. Attempts to value life-years based on income or consumption expenditures alone will miss a large part of the story, especially when health improvements are concentrated at older ages.
- For given profiles of income and consumption, the value of a reduction in mortality or an improvement in the quality of life is larger when the survivor probability and/or health are high. This suggests a form of increasing returns in health improvements: in general medical and other advances that reduce mortality raise the value of *further* advances, because individuals are more likely to be alive to enjoy the benefits.

Implications (Cont.)

- The value of progress against a disease is greatest when the current age, a , is close to, but before, the typical age of onset of the disease. For example, for an ailment like cardiovascular disease, mortality-reducing progress () is likely to be concentrated at ages 60 and above. Then the expected present value of such progress will be greater for a 55 year-old than a 20 year-old because of both discounting and survivorship
- Wealth constant, improvements in both type- G and type- H health are more valuable when the surplus per dollar of full consumption is greater
- Mortality-reducing (type- G) improvements in health tend to be complementary: reductions in mortality from one disease raise the value of progress against other life-threatening ailments. So progress against heart disease raises the value of progress against cancer.
- Mortality reducing improvements in health raise the value of type- H improvements that increase with age. So reductions in mortality from heart disease raise the value of progress against Alzheimer's or arthritis.

Implications (Cont.)

8. Type- H improvements in health that both increase (decrease) with age are complementary with one another. For example, progress against Alzheimer's raises the value of progress against arthritis.
9. The current social value of a medical advance is proportional to the size of the current and future populations to which it applies.
10. Aggregate willingness to pay for progress against a particular disease will be highest when the age distribution of the population is concentrated near, but before, the typical age of onset of the disease. For example, the aging of the baby-boom generation has raised the social value of medical advances against age-related ailments.

Empirical Valuation Equation

- If we denote the surplus per dollar of full consumption by $\Phi(t)$ then the full valuation equation can be rewritten as:

$$V_a(a) = \int_a^{\infty} [y^F(t) + c^F(t)\Phi(t)]S(t, a)\Gamma_a(t, a)dt$$

$$+ \int_a^{\infty} \frac{H'_a(t)}{H(t)} c^F(t)[1 + \Phi(t)]S(t, a)dt$$

Empirical Evidence on Valuations

Our empirical strategy is to measure willingness to pay for improvements in longevity, based on observed choices

There are many sources of evidence on willingness to pay, occupational choice, consumption decisions (e.g. smoking), safety devices

We focus on the evidence based on occupational choice for which there is a large literature (e.g. Viscusi 1992)

Measuring Willingness to Pay

- Behavioral evidence indicates that people are willing to pay roughly \$500 to reduce their annual probability of death by about 1/10,000
- These magnitudes are the foundation for the valuations of improving longevity we present
- The framework we develop allows for the use of evidence on valuations from a wide range of sources

An Alternative Approach

- One alternative is to use evidence on inter-temporal substitution to place bounds on the value of life
- Inter-temporal substitution per-se is not directly related to valuations of changes in life expectancy
- However, the two are indirectly linked since the degree of concavity in the utility function is a major component of the value of life (which compares the marginal and average utility per dollar (see Rosen (1988,1994))
- This method provides somewhat of an independent check on our calibration exercise

Formula for Bounds on Value

- The surplus from living an extra year depends on the (full) income for that year and the surplus on consumption
- The surplus on consumption is equal to ratio of total utility to the marginal utility of consumption minus the level of consumption
- With concavity surplus rises with consumption since total utility rises and the marginal utility falls
- If we take Z_0 to be any fixed level of consumption then for $Z > Z_0$ we have

$$y^F + c^F \Phi(z) \geq y^F + c^F \frac{1}{\bar{\sigma} - 1} \left[1 - \bar{\sigma} \left(\frac{Z_0}{z} \right)^{\frac{\bar{\sigma} - 1}{\bar{\sigma}}} \right]$$

- Where σ is an upper-bound on the elasticity of substitution over the range Z_0 to Z

Table 3
Estimated Lower Bounds for the Value of a Life-Year
(Thousands of Dollars)

	<i>Upper Bound Elasticity of Inter-temporal Substitution ($\bar{\sigma}$)</i>					
z_0/z	1.5	1.2	1.1	1.0	.9	.7
.05	\$289	\$336	\$362	\$400	\$455	\$709
.10	\$261	\$291	\$308	\$330	\$362	\$492
.20	\$225	\$241	\$250	\$261	\$276	\$331

Empirical Implementation

- If we denote the surplus per dollar of full consumption by $\Phi(t)$ then the full valuation equation can be rewritten as:

$$V_a(a) = \int_a^{\infty} [y^F(t) + c^F(t)\Phi(t)]S(t,a)\Gamma_a(t,a)dt + \int_a^{\infty} \frac{H'_a(t)}{H(t)} c^F(t)[1 + \Phi(t)]S(t,a)dt$$

- For our empirical implementation we assume that preferences are homothetic and that the intertemporal elasticity of substitution is constant so that the parameter, $\Phi(t) = \Phi$, will be a constant.
- Since $c(t)$ and $y(t)$ are observable we can then estimate the parameter Φ if we have estimates of individual willingness to pay for some known change in the survival probability (i.e. a known change in the $\Gamma(t,a)$ function)

Measuring Willingness to Pay

- Behavioral evidence indicates that people are willing to pay roughly \$500 to reduce their annual probability of death by about 1/10,000
- These magnitudes are the foundation for our valuations of improving longevity
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The Economics of Our Approach

Our Approach

- Provides a simple but flexible formulation for measuring what people are willing to pay for life extending innovations or improvements in health
- Draws on existing evidence on the value of life
- Can be extended to allow for improvements in health in addition to gains in longevity

What our approach does not do

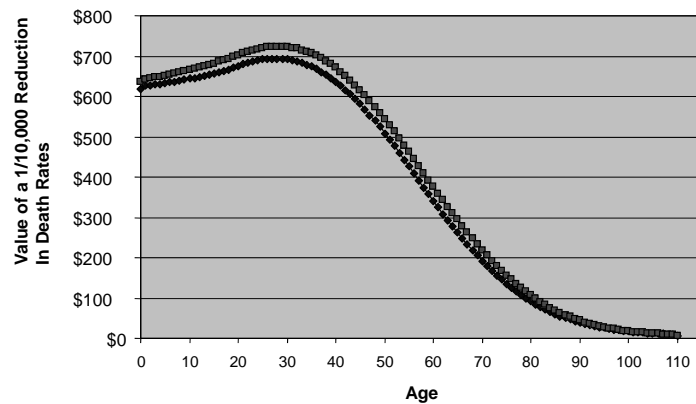
- We do not measure the contribution of health care expenditures to GDP – jobs etc. – these are costs not benefits
- We do not limit our measures to the increase in productivity from longer lives – people care about much more than productivity
- We try to measure what health and longevity contribute to individual well being – this is what matters

What we do

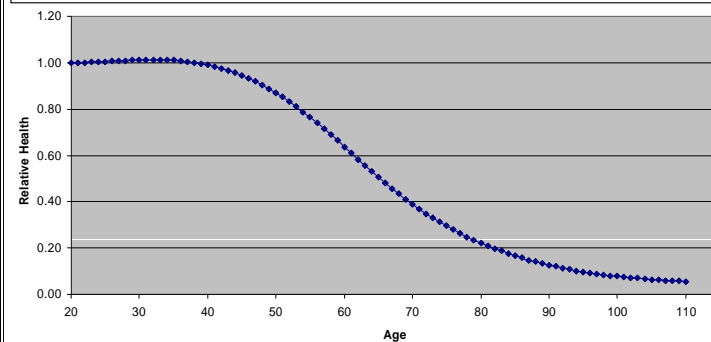
- Measure the value of life years gained, both past and prospective based on individual willingness to pay
- Attribute gains to progress against various diseases
- Assess the prospective value of progress against various life-shortening diseases
- Weigh the value of life years gained against increases in medical expenditure, both in total and at different ages

Empirical Results

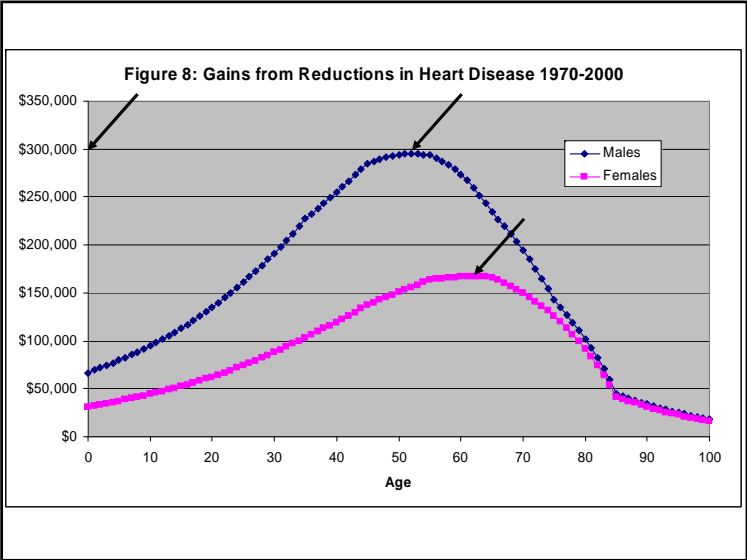
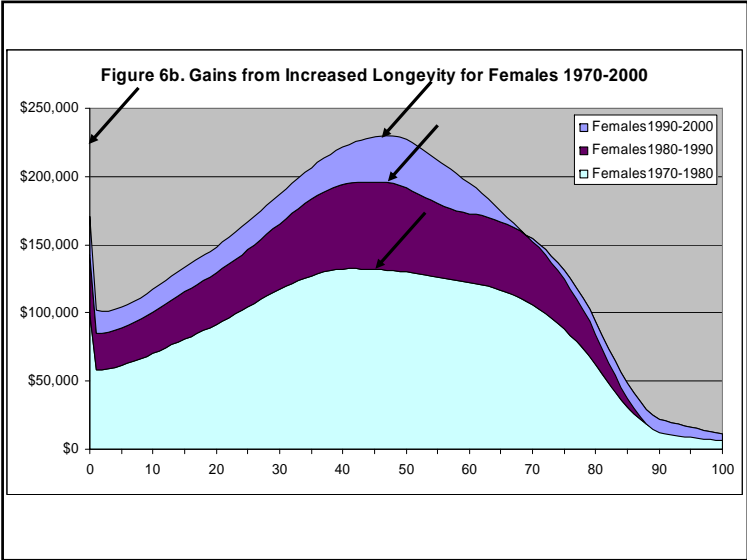
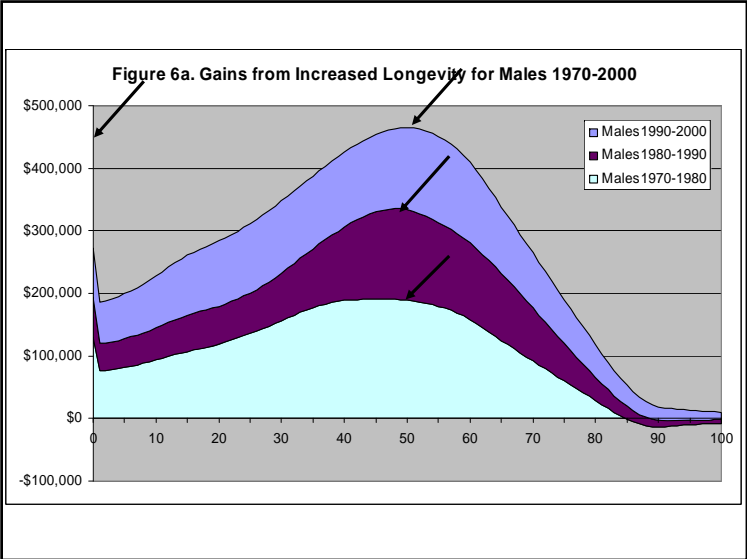
Figure 3: Values of 1/10,000 Reduction in Death Rates



Lifecycle Pattern of Health Implied by Consumption Data



Gains at The Individual Level



Aggregate Gains from Increased Longevity 1970-2000

	Aggregate Gains (Billions of \$2004)			
	1970-1980	1980-1990	1990-20	1970-2000
Males	\$26,699	\$15,471	\$19,153	\$61,323
Females	\$20,515	\$9,067	\$4,440	\$34,022
Total	\$47,214	\$24,538	\$23,593	\$95,345

What About Health Expenditures?

	U.S. Health Expenditures 1970-2000			
	1970	1980	1990	2000
Nominal Expenditures (\$Billions)	\$73	\$246	\$696	\$1,311
% of Total Consumption Expenditures	11.3%	13.9%	18.2%	19.6%
Real Expenditures (\$Billions 1996)				
Current Year Population	\$261	\$445	\$812	\$1,221
Fixed 1996 Population	\$369	\$548	\$883	\$1,143
Per Capita Expenditures (\$1996)				
Current Year Population	\$1,537	\$2,354	\$3,911	\$5,187
Fixed Population	\$2,171	\$2,897	\$4,249	\$4,855
Present Value of Total Expenditures (\$Billions 2004, Fixed Population)	\$16,209	\$24,414	\$39,342	\$50,933

Estimated Gains Net of the Increase in Health Expenditures

	1970-1980	1980-1990	1990-2000	1970-2000
Gross Gains (from Table 5)	\$47,214	\$24,538	\$23,593	\$95,345
Increase in Expenditures	\$8,206	\$14,928	\$11,591	\$34,725
Gains Net of Expenditure Growth	\$39,008	\$9,611	\$12,001	\$60,620
Expenditure Increase as a % of Gains	17.4%	60.8%	49.1%	36.4%

Caveats to the Net Gains Analysis

- Gains include improvements from many margins not just health care
- Health care costs include many expenditures other than those directed at longevity
- However, the comparison allows us to compare the size of two important trends

Longer Term Changes

- Recent improvements are reflective of longer term gains in longevity
- Gains were actually somewhat greater in earlier decades using a fixed valuation profile (like fixed basis GNP accounting)
- Gains have become increasingly concentrated at older ages in recent decades

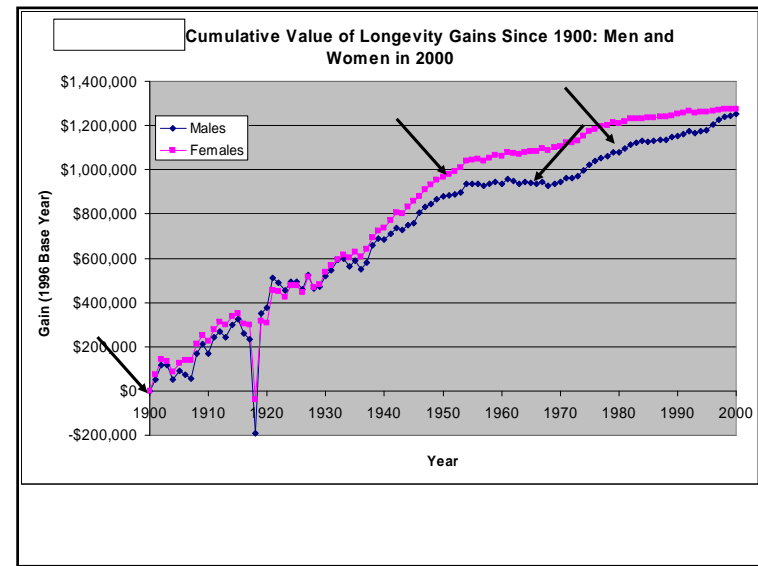
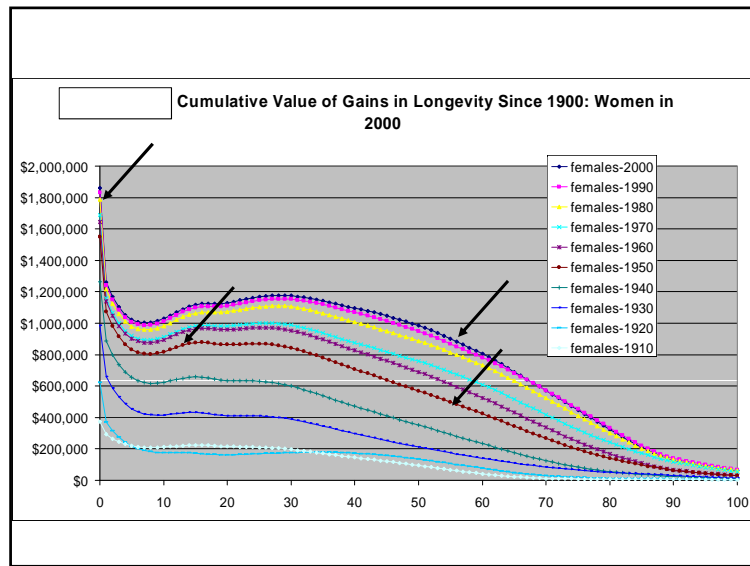
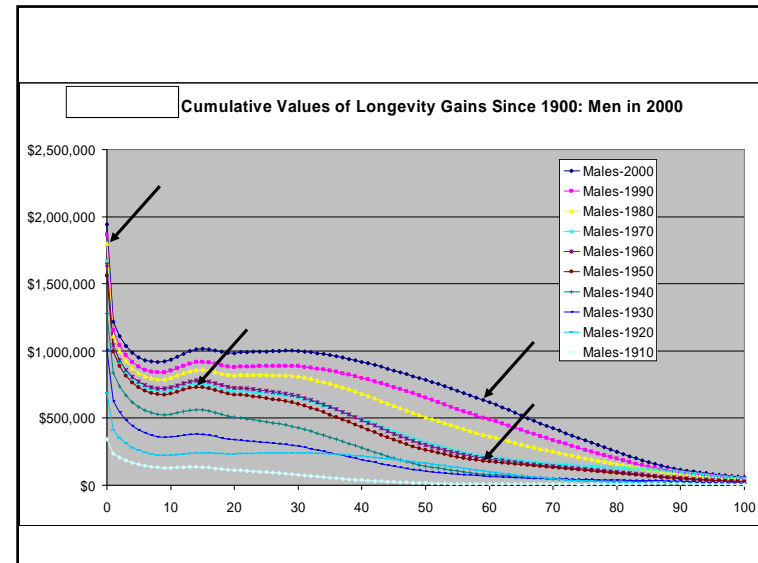
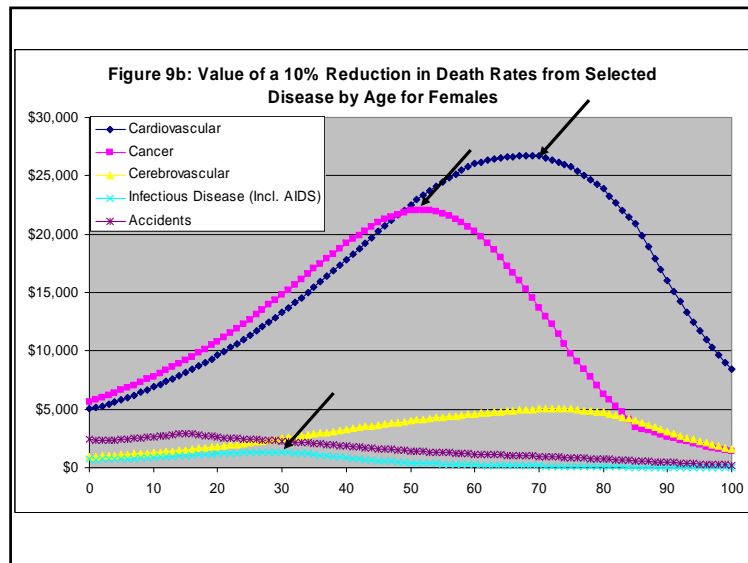
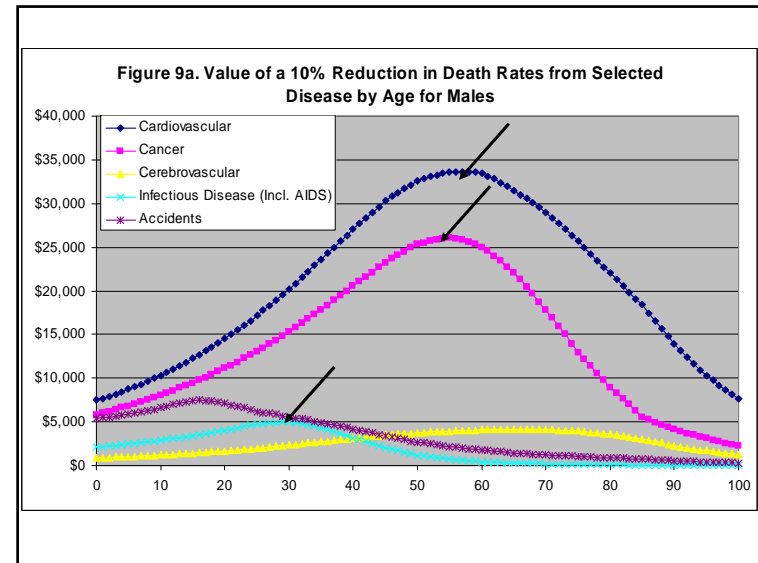


Table 4 Decade Averages of GDP and Production of Health Capital per Capita 1900-2000 (\$2004)										
	1900-10	1910-20	1920-30	1930-40	1940-50	1950-60	1960-70	1970-80	1980-90	1990-00
GDP	\$6,011	\$7,239	\$7,703	\$7,578	\$13,592	\$15,856	\$20,343	\$25,342	\$28,381	\$32,057
Health Capital	\$4,987	\$2,754	\$5,513	\$6,062	\$12,314	\$4,951	\$2,381	\$12,839	\$7,305	\$8,240
Total	\$10,998	\$9,993	\$13,216	\$13,640	\$25,906	\$20,807	\$22,724	\$38,181	\$35,685	\$40,297
Share of Health Capital	0.45	0.28	0.42	0.44	0.48	0.24	0.10	0.34	0.20	0.20



Gain from a Permanent 10% Reduction in Death Rates by Category of Disease (Billions of \$2004)

	Males	Females	Total
ALL CAUSES	\$10,651	\$7,885	\$18,536
MAJOR CARDIOVASCULAR DISEASES	\$3,254	\$2,471	\$5,725
DISEASES OF HEART	\$2,676	\$1,852	\$4,529
CEREBROVASCULAR DISEASES	\$393	\$460	\$852
MALIGNANT NEOPLASMS	\$2,415	\$2,261	\$4,675
RESPIRATORY AND RELATED ORGANS	\$847	\$557	\$1,404
BREAST	\$3	\$444	\$447
REPRODUCTIVE AND URINARY ORGANS	\$301	\$302	\$603
DIGESTIVE ORGANS	\$575	\$431	\$1,006
INFECTIOUS DISEASES (Including AIDS)	\$500	\$148	\$649

**Gain from a Permanent 10% Reduction
in Death Rates by Category of Disease
(Billions of \$2004) (Continued)**

	Males	Females	Total
CHRONIC OBSTRUCTIVE PULMONARY	\$343	\$331	\$674
PNEUMONIA AND INFLUENZA	\$214	\$194	\$408
DIABETES	\$237	\$249	\$486
CHRONIC LIVER DISEASE AND CIRRHOSIS	\$217	\$102	\$319
ACCIDENTS AND ADVERSE EFFECTS	\$977	\$421	\$1,398
MOTOR VEHICLE ACCIDENTS	\$519	\$247	\$767
HOMICIDE AND LEGAL INTERVENTION	\$324	\$90	\$415
SUICIDE	\$411	\$102	\$513

Implications & Analysis

Thinking More About Medical Research

- Due to distortions in the market for medical care (third party payers etc.) increases in costs may exceed the benefits for some advances
- These same distortions affect the composition of research and medical advances
- Favors output enhancing over cost reducing innovations
- Favors advances that can be patented over those that cannot
- Funding for medical research and appropriate cost containment are complementary

Thinking About Investments in Medical Technology

- Growth in the market for health care
- Market growth favors fixed cost technologies – drugs/ medical advances
- Growth in the demand for health care is seen as a curse by most – but may be a relative gain to fixed cost technologies
- Such technologies may be a key way to control the long-term growth in costs

Additional Results

- The economic value of disease reduction is increasing significantly over time
 - The value of disease reduction is rising along with the level of overall wealth
 - The value of progress against any one disease rises as we make progress against other diseases
 - The value of disease reduction is increasing as the U.S. population ages
- Appropriate efforts to control health care costs will increase the value of research

The Bottom Line

- Past improvements in health and longevity have had enormous economic value
- Potential gains from future reductions in mortality are also extremely large
- The results presented today should lead us to revise our estimates of the value of research upward
- Absent costs of treatment, very modest potential reductions in disease would justify significant expenditures on research. This leaves the cost of treatment as the open issue.

Balancing the Costs & Benefits

- In thinking about medical advances we must consider both sides of the equation
- Progress is important
- Controlling costs is important
- Controlling costs raises the value of medical advances
- Cost containment and medical progress compliment one another

A Simple Example

- 200 billion dollar “war on cancer”
- 50% probability of success – 50% probability of total failure
- Success = 10% reduction in cancer death rates
- Based on Murphy & Topel – value of success = \$5 trillion
- What about costs of care?

Costs of care

- Two scenarios:
 - “good” outcome = treatment adds 2.5 trillion (50% of value) to costs of care
 - “bad” outcome = treatment adds 10 trillion (200% of value) to costs of care
 - Assume each scenario is equally likely
- Three potential outcomes:
 - 50% chance of “Failure” = -\$200 billion
 - 25% chance of “Good Success” = +\$2.3 trillion
 - 25% chance of “Bad Success” = -\$5.2 trillion
- Expected gain = -\$825 billion

What matters in this calculation?

- Costs of research are small by comparison to costs and benefits (making them \$100 billion or \$300 billion has little effect)
- Probability of success matters some but not much
- Expected costs of care matter a lot
- **Question:** What can we do to improve the situation?
- **Answer:** Make good care decisions!

Example Continued

- Improve care system = don't implement if costs of care are high
- Chance of “failure” now 75%
- But expected gain now +\$425 billion
- Bottom line: appropriate cost containment RAISES the value of research by eliminating the major downside
- The potential downside to research is not failure but unaffordable “success”

How do we get there?

- Best solution: improve incentives and decisions in the delivery system – research will follow
- Second best: change the direction of research to look only for lowest costs solutions
- Both enhance the case for more research

What does it take?

- Improve incentives for doctors and patients to control costs
- Use technologies appropriately – not all or nothing – many treatments will be cost effective for some patients not for others
- Focus on treatments with low incremental costs – reduces problem of over use

Other Economic Factors

Value of improvements is rising:

1. U.S. population is aging
2. Incomes are rising
3. Past progress raises value of further progress
4. Worldwide market will grow enormously

Growing market makes research intensive low cost solutions increasingly attractive

Accelerating research has significant value

Potential Pitfalls

- Behavioral change is not free – people value behavior as well as health – people value eating and even smoking
- Behavioral change that mitigates gains in longevity does not diminish the value of progress and maybe increases it
- Behavioral factors increase in importance as care moves out of the hospital and into the household
- Patient inputs make education more important and inequality a bigger issue

Some Important Questions

- How do we value end of life care?
 - Does this require an alternative framework?
 - Do circumstances matter – “anticipated” versus “unanticipated” events?
 - How do we account for quality of life in our calculations?
- How do we help people change their behaviors?
 - Information
 - Taxes?
 - Marketing?
- How do we improve incentives?
 - Research – peer review versus market incentives
 - Allocation of care – individual incentives vs. system allocation
 - For what do we need insurance?