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Mortality effects of regulatory costs and policy evaluation criteria

W. Kip Viscusi*

Risk regulations directly reduce risks, but they may produce offsetting risk increases. Regulated risks generate a substitution effect, as individuals' risk-averting actions will diminish. Recognition of these effects alters benefit-cost criteria and the value-of-life estimates pertinent to policy analysis. Particularly expensive risk regulations may be counterproductive. The expenditure level that will lead to the loss of one statistical life equals the value of life divided by the marginal propensity to spend on health. Regulations with a cost of \$30 million to \$70 million per life saved will, on balance, have a net adverse effect on mortality because of these linkages.

1. Introduction

■ Policies that reduce mortality risks should be subject to the same standards for ensuring the efficacy of these resource expenditures as are other government expenditures. One economic criterion for assessing whether a particular policy is in society's best interest is the benefit-cost test, which requires that the policy provide greater benefits than the costs it imposes.

The guidance provided by the benefit-cost approach is not, however, always definitive. The treatment by benefit-cost analysis of all gains and losses as symmetrical is less compelling when the losers from these policies are not compensated than when they are. The reluctance to adopt this approach seems particularly great for matters concerning individual health. Legislative mandates for much U.S. risk and environmental regulation frequently prohibit the selection of policies based on a benefit-cost test, although the exact reasons for these provisions are not always well articulated. One potential concern is that policies affecting lives address inherently sensitive issues, so that using benefit-cost tests to judge lifesaving efforts is more controversial than, for example, using such an approach to site a municipal parking lot.

As a result, policy makers often use other, less restrictive approaches to select the appropriate risk reduction policy. One of the most clear-cut tests that any risk policy should pass is that on balance the policy should reduce the risk level.¹ Irrespective of one's views

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¹ This criterion presupposes that different risks are converted to a comparable, severity-weighted metric. For example, different causes of death, such as cancer and acute accidents, should be weighted to reflect their differing relative attractiveness. Empirical evidence on such weights appears in Viscusi (1992a).

on cost-risk tradeoffs, it certainly should be the case that any desirable policy will enhance safety, or what I shall term the "risk reduction test."

This seemingly innocuous requirement may be a binding constraint in some instances. There may be tradeoffs among the types of risk effects that arise from the policy. Banning artificial sweeteners may, for example, reduce risks of cancer but increase the risk of heart disease from obesity. A faster process for drug approval will increase the benefits reaped from new pharmaceuticals but raise the risks posed by approving unsafe drugs (a Type II error). These types of competing concerns sometimes lead analysts to employ what Lave (1981) terms "risk-risk analysis." Under the series of approaches using this framework, the policy focus is on the competing risk effects of different options rather than the cost-risk tradeoffs.

One such risk-related policy concern that the U.S. Office of Management and Budget (OMB) made a prominent issue in 1992 was whether the adverse wealth effects of risk regulation policies led to mortality increases that offset the risk reduction gains.² In its analysis, based on work by Lutter and Morrall (1992), OMB cited a court decision noting that the evidence in the literature pointed to a loss of one statistical life for every expenditure of \$7.25 million. If that estimate is correct, no policy with a cost per life saved above that amount would, on balance, have a risk-reducing effect. Moreover, many policies with a lower cost per life saved would fail a benefit-cost test and many more-lenient policy choice criteria.

The conceptual rationale for recognition of the role of risk reduction costs is well established. There is a negative correlation of societal income with risk levels, such as job risks and product risks (see Viscusi (1978, 1983)). Affluence also leads to lower rates of mortality. Analysts such as Wildavsky (1980, 1988), Keeney (1990), and Lutter and Morrall (1992) have pointed out that this negative relationship between income and health creates a new kind of tradeoff for government policy. Expenditures on safety may lead to a direct reduction of risk levels, but making society poorer through the opportunity cost associated with these efforts will cause some associated increase in risk. The issue from a risk-risk standpoint is whether on balance the adverse income effects on safety exceed the direct risk reduction effect.³

The regulatory cost-risk relationship raises a variety of fundamental issues for the economics of risk management. First, if health expenditures are endogenous, how should conventional willingness-to-pay measures be used to assess risk regulations in a benefit-cost context? Second, what is the character of the effect of risk policy expenditures on health? The influences involve a complex set of factors, including effects on risk levels, costs, and possibly wage rates and prices as well. Risk-taking actions, such as hazardous employment and purchase of risky commodities, may also be influenced. How will these various effects influence health expenditures, and what will be the ultimate effect on risk? Third, if our only policy concern is with reducing mortality risks, what is the appropriate policy choice criterion and how is it related, if at all, to guidelines for benefit-cost analysis? Does the policy lead to a net reduction in risk so that it passes the risk reduction test?

This article explores this class of issues, beginning with an assessment of how risk regulations affect investments in health in Section 2. The theoretical relationship is unambiguous, as the cost of risk regulations will necessarily reduce health expenditures and raise risk levels. This finding in turn affects the application of standard benefit-cost tests

² See the letter from James B. MacRae, Jr., Acting Administrator, Office of Information and Regulatory Affairs, U.S. Office of Management and Budget, to Nancy Risque-Rohrbach, Assistant Secretary for Policy, U.S. Department of Labor, March 10, 1992, and Statement of James B. MacRae, Jr. before the Senate Committee on Governmental Affairs, March 19, 1992.

³ The development here will focus on income effects in a single-period model. As Graham, Chung, and Evans (1992) have shown, the distinction between transitory and permanent income changes is often important in governing the effect of income changes on mortality.

as well as the risk reduction test. These issues are the subject of Section 3. The role of these wealth effects is to alter the appropriate value-of-life reference point for both the benefit-cost test and the risk reduction test. Section 4 presents some empirical estimates of these relationships, which indicate that the expenditure level per statistical life lost is from \$30 million to \$70 million.

2. The effect of risk regulations on health investments

■ The focus of this article is on how the costs of risk regulation affect health investment decisions and in turn influence mortality. The manner in which these cost effects are generated will depend in part on the context. In the case of product safety regulations, for example, consumers purchasing risky products will experience the direct influence of the regulation on the product risk, an effect of the regulation on the product price, and possibly a change in the risk-price tradeoff that they face for the product. In contrast, individuals who are more remotely influenced, such as shareholders in companies affected by regulations, may experience a drop in income as a result of the regulation but will not experience a direct effect on their health. Taxpayers at large who pay for government expenditures related to risk reduction efforts may be affected similarly.

This analysis will focus on a worker whose job risks are influenced by a risk regulation. The economic formulation is similar for workers and for consumers, with the main difference being that the product price is dependent on the risk rather than the wage rate. One can view the situation of a shareholder in a company as being a special case of the analysis of a worker. To make the transformation, set the shareholder's wage rate independent of the risk and let the risk regulation have no effect on the shareholder's safety level. Alternatively, in the case of broad environmental regulations, it may be that the safety level is affected, as is the individual's wealth, but there is no direct effect on any price or wage level pertinent to this consumer. Consideration of such alternative situations follows in straightforward fashion as special cases of the analysis below.

□ **The unregulated reference point: health investments and job risks.** Consider a situation of an individual worker on a hazardous job. The worker's level of risk is governed by market forces, so that government regulations affecting risk are assumed not to be binding. This unregulated framework will serve as the reference point for the subsequent consideration of situations in which there is a binding regulatory constraint.

The worker's risk level depends on the safety level s selected by the firm as well as the worker's own health investment h . These health investments may take the form of medical expenditures, but they also could be in terms of premiums paid for safer products, purchase of a house in an unpolluted area, or other mortality-related expenditures.⁴ It is plausible to assume that the firm's safety level s and worker's health investments h have a positive but diminishing effect on the probability of survival, and that jointly improving work-related and non-work-related safety has a diminishing effect on the probability of survival.⁵ Thus, the worker's probability of survival is given by $q(s, h)$, where $q_s > 0$, $q_h > 0$, $q_{ss} < 0$, $q_{hh} < 0$, and $q_{sh} \leq 0$. Similarly, the probability that the worker dies in any period is $1 - q(s, h)$.

The worker is on a hazardous job and receives a wage rate set by the equilibrium market schedule for compensation of risky jobs, $w(s)$. To reflect the existence of com-

⁴ As Fuchs (1986) observes, the relationship between health expenditures and mortality is difficult to disentangle since it is two-directional. Although his cross-sectional evidence does not indicate a significant relationship (p. 106), Fuchs observes that longer-run trends in mortality may have been affected by medical expenditures and advances (p. 280).

⁵ The strongest of these assumptions is that $q_{sh} \leq 0$. If this term is positive, the ramification is to make the effect of higher mandated safety levels on health investments ambiguous (see equation (6) below), which in turn may affect some of the signs of the subsequent components of the benefit-cost test terms.

compensating differentials for job risks in competitive markets and to ensure an interior solution, assume that $w_s < 0$ and $w_{ss} \leq 0$. The worker also has other income A , so that his total resources available for consumption are $A + w(s)$. Since the worker makes an expenditure of h on health, the resources available for consumption other than health are given by $A + w(s) - h$. The value of the health investment does not enter the utility function directly, but instead affects the probability of survival in any period.

Let there be two states of the world, one in which the worker survives and receives a utility value $U(A + w(s) - h)$ and the other in which the worker dies and has a bequest function $V(A + w(s) - h)$. These utility functions satisfy the usual properties. The worker would rather be healthy than dead $U(X) > V(X)$, which is the pivotal assumption for generating compensating wage differentials for job risks. The worker receives a positive but constant or diminishing level of marginal utility in each state ($U_x > 0, V_x > 0, U_{xx} \leq 0$, and $V_{xx} \leq 0$). Individuals also derive a higher marginal utility of income from any given level of income when they are healthy than when they are dead, or $U_x(X) > V_x(X)$. Each of these assumptions regarding health-state dependent utility functions has been documented empirically in the case of job safety.⁶

The worker's task is to select the optimal job risk s from the available wage schedule $w(s)$ and the optimal level of health care expenditures h to maximize expected utility, or:

$$\max_{s,h} EU = q(s, h)U(A + w(s) - h) + (1 - q(s, h))V(A + w(s) - h). \tag{1}$$

The first-order condition we obtain with respect to the selection of the optimal health care expenditure is given by⁷

$$\frac{1}{q_h} = \frac{U - V}{qU' + (1 - q)V'}, \tag{2}$$

and the first-order condition obtained by setting $dEU/ds = 0$ yields

$$\frac{-w_s}{q_s} = \frac{U - V}{qU' + (1 - q)V'}. \tag{3}$$

Combining equations (2) and (3), one obtains the result that

$$\frac{1}{q_h} = \frac{-w_s}{q_s} = \frac{U - V}{qU' + (1 - q)V'} \tag{4}$$

Marginal value of life for health investments
Marginal value of life for job risks
Utility change with ill health
Expected marginal utility of income

Equation (4) can be interpreted readily. The first term is the inverse of the derivative of the survival probability with respect to health care expenditures, or the marginal value of life for health investments. The second term is the marginal value of life for job risks, or the negative of the implicit price of safety in the workplace (i.e., the price of risk)

⁶ Viscusi and Evans (1990) specifically estimate the structure of state-dependent utility functions in the case of nonfatal job injuries, leading to the relationships indicated above. The key assumption pertains to whether the marginal utility of income is greater when healthy than when not. Since this assumption is satisfied in the case of nonfatal injuries, one would certainly expect it to be satisfied in the case of fatalities.

⁷ I assume that the second-order conditions for a relative maximum are satisfied. Note that

$$d^2EU/dh^2 = q_{hh}(U - V) + 2q_h(-U' + V') + qU'' + (1 - q)V'' < 0$$

and

$$d^2EU/ds^2 = 2q_s w_s (U' - V') + qU''(w_s)^2 + (1 - q)V''(w_s)^2 + qU'w_{ss} + (1 - q)V'w_{ss} + q_{ss}(U - V) < 0.$$

divided by the marginal effect of safety on the mortality rate. The final term in (4) is the difference in the utility between the two states divided by the expected marginal utility of income.

The final two terms comprise the compensating wage differential for health-state models, which is that the marginal value of life reflected in workers' risky job choices equals the drop in the utility level with an accident divided by the expected marginal utility of income. A perhaps more intuitive way of recasting the result is that the marginal value of life multiplied by the expected marginal utility of income equals the utility loss of an accident. These results for the health investment model directly parallel findings in the literature on compensating differentials and the value of life.⁸ The only difference is the addition of the role of the health investment term to the analysis.⁹ Equation (4) implies that individuals will equate the marginal value of life across the different decisions that they make, whether they pertain to health investments or job safety.¹⁰ Through health investments, one purchases incremental reductions in the mortality rate directly, whereas workers "purchase" increases in the safety level through lower wages.

Equations (1)–(4) summarize the individual choice problem for health investments and job safety when there is no binding government regulation. The marginal value of life terms that appeared on the left sides of equations (2)–(4) will provide useful reference points for subsequent analysis once government regulation is imposed. These terms will also be influential in setting benefit values for risk reduction for the various policy choice criteria.

□ **Health investments with binding safety regulations.** In situations in which the safety regulations are binding, the government chooses the level of safety s . Suppose that the cost of the regulation can be characterized by a lump sum charge R on the worker, where in effect the change in the worker's resources is given by $\Delta A = A - R$.¹¹ The other effect of the regulation on the financial resources of the worker is that it raises the safety level s , which in turn lowers the wage rate w . The analysis below will first consider the character of the constrained optimization problem in which government regulation establishes the value of s , and the worker selects the optimal health investment h . This framework will then be used to assess the influence of changes in the regulatory cost and in the level of s that is mandated.

The worker's optimization problem no longer includes a choice of the safety level s , but instead is restricted to the choice of the optimal health investment h , or

$$\max_h EU = q(s, h)U(A - R + w(s) - h) + (1 - q(s, h))V(A - R + w(s) - h). \quad (5)$$

This optimization generates the same first-order condition as in (2). The only difference is that R enters the U and V functions as indicated in (5). Moreover, the interpretation differs in that s is mandated by the government.

The primary matter of interest is the effect of regulation on the choice of the health investment h . This influence can be ascertained by totally differentiating (2) with appro-

⁸ In particular, see Viscusi (1979), equation (3), where the final term in that equation is identical to the last term in (4) above. This utility term is equated to the derivative of the wage rate with respect to the job risk in Viscusi (1979). The only difference in the two models is that the one in this article breaks the job safety relationship into two components—a safety level and an effect of the safety level on the mortality rate—and it adds a second choice component pertaining to health investments.

⁹ Health investment decision models have been developed by Grossman (1972), Tolley, Kenkel, and Fabian (1994), and, more specifically, Berger, Blomquist, Kenkel, and Tolley (1994).

¹⁰ This result hinges on the continuous nature of the risk-reducing choices. See Smith (1991) for a superb exposition of the difficulties that may arise from the indivisibility of many safety decisions.

¹¹ One can also formulate the regulatory cost impact more generally, as is done in Viscusi (1992b), but this lump-sum approach facilitates the analysis below.

priate change in the arguments of the U and V functions to incorporate the role of regulatory cost R . Totally differentiating and solving, one finds that

$$\frac{\partial h}{\partial s} = \frac{-q_{hs}(U - V) - q_h w_s(U' - V') + q_s(U' - V') + qU'' w_s + (1 - q)V'' w_s}{q_{hh}(U - V) + 2q_h(-U' + V') + qU'' + (1 - q)V''} < 0. \quad (6)$$

Each of the terms in the numerator of (6) is positive, and the denominator is negative. Higher mandated levels of safety will reduce worker health investments. Personal health investments to enhance one's survival prospects are substitutes for the level of safety in the workplace.¹²

The role of higher regulatory costs R is also unambiguous. Increases in regulatory cost will reduce one's health care expenditure:

$$\frac{\partial h}{\partial R} = \frac{q_h(U' - V') - qU'' - (1 - q)V''}{q_{hh}(U - V) - 2q_h(U' - V') + qU'' + (1 - q)V''} < 0. \quad (7)$$

No assumptions were required for this condition to hold other than that the utility functions in the two health states satisfy quite plausible and generally desirable properties. For example, we need not assume that health investments are increasing functions of assets.

Similarly, we can show that

$$\frac{\partial h}{\partial A} = -\frac{\partial h}{\partial R} > 0. \quad (8)$$

Increases in assets boost the value of health investments, and decreases in assets such as those due to regulatory costs reduce the value of health investments.

Summarizing, there are two types of offsets with respect to safety. First, the direct effect of the regulation on safety diminishes the incentive of individuals to invest in health because greater safety levels in the workplace and personal health investments are substitutes from the standpoint of increasing one's longevity. Second, increases in regulatory costs R are tantamount to a decrease in income. This influence in turn will decrease investments in health. This result is always true, given the quite plausible assumptions with respect to utility functions.

Consider the effects on different groups influenced by government regulation. Workers will be influenced by both the direct effect on risk and regulatory costs. Purchasers of consumer products whose prices decline with greater product safety will experience effects that are directly analogous to those outlined above. For public stockholders whose risk levels are not affected, the influence will be through the regulatory cost term R . If there is also an effect on public levels of safety, there will be a negative dh/ds effect, with the main exception being that the w_s terms in (6) will be set equal to zero if those affected are not workers. Pollution levels with public good characteristics are one such risk exposure for which there will be a risk effect but not a wage effect.

3. Benefit-Cost Criteria and Mortality Effects

■ The effects of regulation can be separated into two different categories. First, regulation imposes costs on the firm, which in turn will have effects on individual income. This cost effect includes the cost component in conventional benefit-cost analyses of regulation. However, these costs also have ramifications for individual risk-taking decisions.

¹² This result arises because of the assumptions that any particular health investment or change in the safety level has a positive but diminishing effect on mortality, and there is a negative cross partial effect of health investments and safety levels on mortality ($q_{hs} \leq 0$). If there were a synergistic effect between these two kinds of investment ($q_{hs} > 0$), then this relationship would not be as clear-cut and could conceivably be reversed.

The reduction in income will diminish health investments, adversely affecting mortality risks.

The second class of regulatory effects stems from the effect on levels of safety—the benefit component in benefit-cost analysis. Higher levels of safety will depress compensating wage differentials and also decrease the incentive to invest in other mortality-enhancing actions, such as health investments. The net effect is that there will be a decrease in health investments resulting from a higher level of safety.

The policy issue is whether on balance these various regulatory effects are desirable. This section will explore two different policy analysis tests that can be used to assess the attractiveness of a regulatory action. The first test is a generalized version of conventional benefit-cost analysis. The second is a less restrictive test: the risk reduction test, whereby the risk effects of the regulation should on balance reduce risk levels, irrespective of the cost. Perhaps the most interesting insight obtained from examining these two different approaches is that their components are closely linked.

□ **Benefit-cost tests with endogenous health investments.** Government regulation can be characterized by two different effects, an increase in the safety level Δs as well as a change in worker resources given by $\Delta A = A - R$. In addition, there are other financial effects arising from the influence of Δs on wages, but these will be recognized explicitly below.

The benefit-cost test for a policy to be desirable is that the regulation must have a favorable effect on expected utility for the representative individual. In practice, the representative person may be a composite of different groups. Parties benefiting from a regulation may differ from those who bear the regulatory cost. For example, health care expenditures may have a greater marginal effect on mortality at lower income levels. Ideally, the various response functions below should take this heterogeneity into account. However, the empirical components of the pertinent calculations are not sufficiently understood at the present time to warrant these refinements.¹³ The analysis here consequently will be based on broad national averages.

Let the optimal (s, h) choice pair before the regulation be denoted by (s^*, h^*) , and the optimal (s, h) pair after the regulation be (s^{**}, h^{**}) , where $s^{**} = s^* + \Delta s$ and $h^{**} = h(s^* + \Delta s, A + \Delta A)$. The condition that the policy increases a representative citizen's welfare is that

$$q(s^{**}, h^{**})U(A + \Delta A + w(s^{**}) - h^{**}) + (1 - q(s^{**}, h^{**}))V(A + \Delta A + w(s^{**}) - h^{**}) > q(s^*, h^*)U(A + w(s^*) - h^*) + (1 - q(s^*, h^*))V(A + w(s^*) - h^*). \quad (9)$$

Taking a first-order Taylor series approximation to the terms in the postregulation situation, using the preregulation values as the reference point, (9) can be rewritten as

$$\left[q(s^*, h^*) + \frac{\partial q}{\partial s} \Delta s + \frac{\partial q}{\partial h} \frac{\partial h}{\partial s} \Delta s + \frac{\partial q}{\partial h} \frac{\partial h}{\partial A} \Delta A \right] \left[U(A + w(s^*) - h^*) + U' \left(\Delta A + \frac{\partial w}{\partial s} \Delta s - \frac{\partial h}{\partial s} \Delta s - \frac{\partial h}{\partial A} \Delta A \right) \right] + \left[1 - q(s^*, h^*) - \frac{\partial q}{\partial s} \Delta s - \frac{\partial q}{\partial h} \frac{\partial h}{\partial s} \Delta s - \frac{\partial q}{\partial h} \frac{\partial h}{\partial A} \Delta A \right] \left[V(A + w(s^*) - h^*) + V' \left(\Delta A + \frac{\partial w}{\partial s} \Delta s - \frac{\partial h}{\partial s} \Delta s - \frac{\partial h}{\partial A} \Delta A \right) \right] > q(s^*, h^*)U(A + w(s^*) - h^*) + [1 - q(s^*, h^*)V(A + w(s^*) - h^*)]. \quad (10)$$

¹³ Two key empirical components driving the results are the marginal effect of health care expenditures on mortality, $\partial q/\partial h$, and the marginal effect of income on health expenditures, $\partial h/\partial A$.

If we set terms of the form $\Delta q\Delta U, \Delta q\Delta V = 0$, then this condition simplifies to¹⁴

$$\left[\frac{\partial q}{\partial s} \Delta s + \frac{\partial q}{\partial h} \frac{\partial h}{\partial s} \Delta s + \frac{\partial q}{\partial h} \frac{\partial h}{\partial A} \Delta A \right] \left[\frac{U - V}{q * U' + (1 - q*)V'} \right] > -\Delta A \left(1 - \frac{\partial h}{\partial A} \right) - \frac{\partial w}{\partial s} \Delta s + \frac{\partial h}{\partial s} \Delta s. \quad (11)$$

However, from (2), the value of the second bracketed term on the left side of (11) is simply the marginal value of life, $1/(\partial q/\partial h)$, so that this condition can be rewritten as

$$\left[\frac{\partial q}{\partial s} \Delta s + \frac{\partial q}{\partial h} \frac{\partial h}{\partial s} \Delta s + \frac{\partial q}{\partial h} \frac{\partial h}{\partial A} \Delta A \right] \left[\frac{1}{\partial q/\partial h} \right] > -\Delta A \left(1 - \frac{\partial h}{\partial A} \right) - \frac{\partial w}{\partial s} \Delta s + \frac{\partial h}{\partial s} \Delta s. \quad (12)$$

For the policy to pass a benefit-cost test, the safety impact multiplied by the marginal value of life must exceed the monetary costs of the policy.

The condition for a desirable policy can be rewritten in terms of a requirement on the budgetary costs of the regulation, which must satisfy

$$-\Delta A < \left[\frac{\partial q}{\partial s} \Delta s + \frac{\partial q}{\partial s} \frac{\partial h}{\partial s} \Delta s + \frac{\partial q}{\partial h} \frac{\partial h}{\partial A} \Delta A \right] \left[\frac{1}{\frac{\partial q}{\partial h} \left(1 - \frac{\partial h}{\partial A} \right)} \right] + \left[\frac{1}{1 - \frac{\partial h}{\partial A}} \right] \left[-\frac{\partial w}{\partial s} \Delta s + \frac{\partial h}{\partial s} \Delta s \right]. \quad (13)$$

The budgetary costs must be less than the safety effects multiplied by a term based on the value of life, plus the value of other pertinent monetary effects of the policy through lower wages for greater safety and reduced personal health investments.

A fundamental difference of inequality (13) from the standard benefit-cost test is that the introduction of the effect on health investments requires us to modify the value-of-life term that weights the safety effects. This influence arises because regulatory costs reduce the individual's health expenditures, thus reducing the net costs imposed by the regulation. Because of the presence of regulatory cost effects, the denominator of the value-of-life term now includes the component $(1 - \partial h/\partial A)$, which will be positive but less than one, provided that $0 \leq \partial h/\partial A \leq 1$.¹⁵ Depending on the degree of responsiveness of health investments to assets, there will be a corresponding increase in the value of life measure that is applied to the safety effects in the benefit-cost test. The safety effect to which this value is applied must, however, reflect all safety effects, including those in response to regulatory costs.

¹⁴ In particular, set both

$$[(\partial q/\partial s)\Delta s + (\partial q/\partial h)(\partial h/\partial s)\Delta s + (\partial q/\partial h)(\partial h/\partial A)\Delta A] [U'(\Delta A + (\partial w/\partial s)\Delta s - (\partial h/\partial s)\Delta s - (\partial h/\partial A)\Delta A)]$$

and

$$[(\partial q/\partial s)\Delta s + (\partial q/\partial h)(\partial h/\partial s)\Delta s + (\partial q/\partial h)(\partial h/\partial A)\Delta A][V'(\Delta A + (\partial w/\partial s)\Delta s - (\partial h/\partial s)\Delta s - (\partial h/\partial A)\Delta A)]$$

equal to zero. If instead one were to include these terms, the result would be that the $(U - V)$ term in inequality (13) be evaluated at the postregulation values of (h, s) rather than the preregulation values. Thus, one must take into account the effect of the regulation on the marginal willingness to pay for safety, where $(U - V)$ is evaluated at (h^{**}, s^{**}) rather than at (h^*, s^*) . This change is assumed to be of second-order importance.

¹⁵ Inspection of (9) and (10) provides no clear-cut guarantees that the sensitivity of health investments to asset levels is likely to be less than one. It does, however, seem to be a reasonable empirical conjecture that a marginal increase of one's assets by \$1 will not lead to an additional health investment of more than \$1. Moreover, this conjecture is consistent with the empirical evidence to be presented in Section 4.

Suppose the marginal value of a statistical life— $1/(\partial q/\partial h)$ —is \$5 million. Then if we exclude other monetary effects of the regulation (i.e., the final term in (13)) and, in the absence of any health spending effect of regulatory costs (i.e., $\partial h/\partial A = 0$), all policies that impose an average cost per life saved of less than \$5 million will pass a benefit-cost test. If, however, the value of $\partial h/\partial A = .5$, then all policies with an average cost per life saved of \$10 million or less will pass a benefit-cost test since there is a \$5 million personal health expenditure saving with every \$10 million in costs.

Conventional benefit-cost analysis and utilization of value-of-life estimates are affected by the recognition of the effect of regulatory costs on individual health investments. These concerns are not simply pertinent to the related issue of whether on balance the mortality effects of the regulation are positive. Rather, they suggest that there must be a modification of the value-of-life number that is used in weighting safety effects. Section 4 will address the empirical evidence on the actual magnitude of $\partial h/\partial A$.

□ **The risk reduction test.** A less stringent test for risk regulations is to require that on balance the effect of the regulation on mortality is beneficial. In particular, even if the risk gains may not be commensurate with the costs, at the very minimum the regulation should enhance safety, rather than diminish it.

In terms of the effects indicated above, what this test requires is that the following condition be met:

$$\Delta q = \frac{\partial q}{\partial s} \Delta s + \frac{\partial q}{\partial h} \frac{\partial h}{\partial s} \Delta s + \frac{\partial q}{\partial h} \frac{\partial h}{\partial A} \Delta A > 0. \tag{14}$$

The mortality risk effect consists of three components: the direct effect of the regulation on safety and consequently on mortality, the effect on mortality through the decrease in health investments that result from an increase in safety, and the effect on mortality of the decrease in health investments that result from a decrease in worker assets resulting from the increase in regulatory costs. If we collect the safety-effect terms and the asset-effect terms on different sides of the inequality, we obtain the result that the safety effects must exceed the asset-related influence on safety, or

$$\Delta s \left[\frac{\partial q}{\partial s} + \frac{\partial q}{\partial h} \frac{\partial h}{\partial s} \right] > -\Delta A \left[\frac{\partial q}{\partial h} \frac{\partial h}{\partial A} \right]. \tag{15}$$

We can rewrite this condition to indicate the nature of the cutoff with respect to the direct effect of the regulation, measured in terms of the average cost per life saved:

$$\frac{1}{\frac{\partial q}{\partial h} \frac{\partial h}{\partial A}} > \frac{-\Delta A}{\Delta s \left[\frac{\partial q}{\partial s} + \frac{\partial q}{\partial h} \frac{\partial h}{\partial s} \right]}. \tag{16}$$

For the regulation to be desirable, the average cost per life saved must be below some critical threshold. Table 1 summarizes the key value-of-life concepts as they relate to the different tests. For the risk reduction test, this critical threshold is the term given by the left side of (16), which represents the inverse of the marginal effect of health expenditures on mortality multiplied by the marginal effect of assets on health.¹⁶ The combined influence of these terms is to make the critical cutoff value dependent on the responsiveness of mortality to changes in assets.

¹⁶ In their analysis of regulatory cost effects, Lutter and Morrall (1992) designate this term the marginal willingness to spend on life.

TABLE 1 Summary of Value-of-Life Concepts for Regulatory Policy Tests

Test	Key Mortality Valuation Term	Implications
Standard benefit-cost test	$\frac{1}{\frac{\partial q}{\partial h}}$	Marginal value of life
Benefit-cost test with endogenous health investments	$\frac{1}{\frac{\partial q}{\partial h} \left(1 - \frac{\partial h}{\partial A} \right)}$	$\frac{\text{Marginal value of life}}{1 - \text{marginal propensity to spend on health}}$
Risk reduction test	$\frac{1}{\frac{\partial q}{\partial h} \frac{\partial h}{\partial A}}$	$\frac{\text{Marginal value of life}}{\text{Marginal propensity to spend on health, or marginal expenditure per statistical life lost}}$

This mortality risk cutoff value of $1/[(\partial q/\partial h)(\partial h/\partial A)]$ is higher and consequently less restrictive than the marginal value of life, $1/(\partial q/\partial h)$, provided that $0 < \partial h/\partial A < 1$. Suppose, for example, that an increase of \$1 in one's assets led to an increase in health expenditures of \$.10. In that instance, the cutoff value-of-life term for the breakeven risk effect test would be ten times the estimated value of life.

This formulation also highlights the key parameters of interest and links them to conventional benefit value measures. Estimates of $1/(\partial q/\partial h)$ are available from the literature dealing with individual value-of-life estimates in the labor market and other contexts. Since (4) implies that the marginal value of life should be the same in the labor market as for health expenditures, we can simply use labor market estimates of the value of life to assess the value of $1/(\partial q/\partial h)$. The second term of interest is the value of $\partial h/\partial A$. The sensitivity of health expenditures to income has been a long-term issue of concern in the health economics literature, and I shall review these estimates below.

Finally, we can ascertain the value of the critical threshold term directly by estimating the sensitivity of mortality rates to income. How much of a decrease in income must there be to lead to the loss of one statistical life? I shall report estimates below as well. Thus, we can estimate the value-of-life cutoff term for the mortality risk test either directly through the mortality-income relationship or indirectly by combining estimates of the value of life and the sensitivity of health expenditures to income.

4. Empirical evidence on the mortality risk tests

■ The key tests for policy desirability hinge on variations of the implicit value of life. In each case, the value of life estimate is adjusted by a factor that depends on the marginal propensity to spend on health out of one's income.

The second value-of-life figure—the income loss that leads to one statistical death—can be viewed in two different ways. First, it can be viewed as the implicit value of life divided by the marginal propensity to spend on health. This formulation links the two tests for policy attractiveness and helps establish consistency across the tests. The disadvantage of this approach is that there remains some controversy over the appropriate value of life to be used for benefit assessment, and as will be indicated below, defining what constitutes health-related expenditures is a nontrivial task.

Another approach we could undertake is to evaluate the term on the left side of (16) directly. That expression is the inverse of the marginal effect of an increase in one's income on mortality. Or, viewed somewhat differently, what level of expenditure is needed to prevent one statistical death? This value can be calculated directly from mortality-in-

come relationships. Such estimates would provide a single statistic to capture the relationship embodied in this test. There are, however, potential shortcomings of this approach as well. Chief among these is that there is simultaneity between income and mortality, making it difficult to estimate this relationship.

The discussion below will explore both methods to calculating the value-of-life threshold for policies that have a beneficial effect on mortality.

□ **Health care expenditures and income.** Both the benefit-cost test and the risk reduction test hinge on the marginal propensity to spend one's income on health. To assess this value, we must first ascertain the set of consumption expenditures relating to the mortality risk. Making this distinction raises nontrivial classification problems. First, although we can identify health-related expenditures fairly readily, not all of these are related to mortality. Some, for example, may be related to morbidity effects, the alleviation of pain, prevention of nonfatal health outcomes, and the reassurance value of seeing a doctor. The fact that health expenditures may be for reasons other than mortality extension will tend to make health care expenditures an overestimate of the share of consumption devoted to mortality concerns.

Health care expenditures are not, however, the only allocations that affect mortality. Food expenditures affect mortality, as do the safety attributes of products. Compensating differentials for risky jobs and price reductions for unsafe products reflect how safety is often bundled with other commodity attributes in the marketplace.

The discussion below will make the simplification of focusing primarily on health expenditures. However, by indicating the potential importance of factors such as food, it will also be possible to perform a sensitivity analysis to indicate how the results might change depending on the marginal propensity to spend on health.

A useful starting point for analyzing the marginal propensity to spend on health is to consider the average propensity to spend on health. In 1991, individual medical care expenditures in the United States represented 12% of personal income. However, much of personal income (13% on average) is devoted to taxes, where many of these tax expenditures are devoted to health-related programs, such as Medicare. If we focus on the medical care component of disposable personal income, we obtain a 14% share for health-related expenditures.

If the role of medical care is added to that of food, then we obtain considerably higher allocations for health-related expenditures. The combined share of medical care and food is 25% of personal income and 28% of disposable personal income, although clearly not all of these expenses are mortality related. In terms of the overall order of magnitude, the relative share of health-related expenditures on average ranges from .1 for medical care to .3 for medical care and food.

Estimates of the marginal propensity to consume health-related services out of one's income rather than the average propensity to consume can be obtained using standard econometric methods. There have been several approaches along these lines.

First, we could utilize international data, pooling time-series and cross-sectional data on a variety of countries to obtain estimates of the marginal propensity to consume health care out of one's income.¹⁷ Estimates reported in Viscusi (1992b) indicate a value of $\partial h/\partial A$ around .09 using Organization for Economic Cooperation and Development data for 1960–1989 and a range of .09–.12 using U.S. time-series data for 1960–1989.

These estimates are quite consistent with the implications of the average propensity-to-consume results. However, the reliance on time-series data does have important limi-

¹⁷ As is indicated in Phelps (1992), there has been little change in the implications of these studies since the initial study by Newhouse (1977). Perhaps the major advance has been the availability of more detailed data across countries, but personal income continues to be the dominant explanatory variable.

tations. Chief among these is that it captures not only the role of income but also technological change over time. Ideally, one would like to fix the technologies except for including the effect of income growth on technological change.

Cross-sectional evidence fixes the technologies. However, cross-sectional studies based on health care decisions have the problem of there being substantial private and public insurance coverage. Indeed, in a situation in which there was complete insurance coverage, no income effects would be observed.

Among the higher income elasticity estimates for medical care that have been reported are those for the high-deductible plans in the RAND Health Insurance Experiment, where these elasticities range from .2 to .4.¹⁸ Because these estimates pertain to high-deductible plans, they will be less susceptible to the depressing effect of insurance on estimated elasticities than would the lower-deductible insurance coverage. These estimates are also somewhat higher than those obtained by Newhouse and Phelps (1976), in which they found a wage income elasticity for hospital services of .08 and for physician services of .14. The elasticity range of less than 1.0 for cross-sectional evidence has also been found by other authors, as, for example, Fuchs (1986) found an income elasticity of the demand for the quantity of physician services of .04–.41. However, he also reports an income elasticity of the purchase of insurance for physician services of .76–1.61.¹⁹

If, for the sake of concreteness, we use the midpoint of the RAND Health Insurance Experiment income elasticity estimate range of .3 in conjunction with a health care share of disposable personal income of .14, we obtain an estimated marginal propensity to consume out of income $dh/dy = (h/y)\eta$, (where η is the income elasticity of the demand for medical services) of .04. Thus, the estimate based on cross-sectional studies such as these appear to be roughly one-third of the size of what is obtained using average propensity-to-spend statistics or marginal propensity-to-spend findings from international data.

Table 2 reports the implications of these different estimates of marginal propensity to spend on health for the benefit-cost threshold value of life. Table 2 provides a summary of the value-of-life estimates and their associated threshold values taking into account the influence of the marginal propensity to spend on health. To establish comparability across studies, Table 2 summarizes results only from studies that report not only an implicit value of life but also an average earnings value for the sample of workers, thus making it possible to put all the results in terms of a comparable income value.²⁰ The findings for a larger, more comprehensive set of studies both in and outside the labor market are reported in Viscusi (1992a, 1993), where the main finding is that most of the value-of-life studies tend to cluster in a range with implicit value of life in 1990 dollars of three to seven million.

If we use evidence based on cross-sectional data and assume a marginal propensity to spend on health in the range of .05, then we obtain the estimates that imply a relatively low benefit-cost threshold value of life. For the estimates of average propensity to spend on health care such as .1, .2, or .3, the other columns in Table 2 are pertinent.

Because of the nature in which these factors of marginal propensity to spend on health enter inequality (13), even a sixfold variation in their magnitude does not create a stark change. From the standpoint of benefit-cost analysis, recognition of the influence of government risk policies on individuals' financial resources has only a modest effect on the value-of-life cutoff that is pertinent for decisions.

In contrast, the risk reduction test threshold spending level per life lost is quite sensitive to the marginal propensity to spend. As indicated in the term on the left side of

¹⁸ Personal correspondence of Joseph Newhouse with the author, June 17, 1992.

¹⁹ These two sets of estimates appear on pp. 87 and 101 of Fuchs (1986).

²⁰ Comparability is established using an income elasticity of the value of life of 1.0. This estimate is consistent with the income elasticity of the value of job injuries reported in Viscusi and Evans (1990).

TABLE 2 Implications of Labor Market Studies of the Value of Life for the Spending Threshold per Life Saved

Author (Year)	Implicit Value of Life (\$millions)	Value of Life for Typical Worker (Avg. 1991 Earnings \$18,442)	Benefit-Cost Threshold Value of Life		Breakeven Risk Effect Threshold per Life Saved (\$ millions)	
			Marginal Propensity to Spend on Health	Marginal Propensity to Spend on Health	Marginal Propensity to Spend on Health	Marginal Propensity to Spend on Health
Smith (1974)	7.2	5.9	.05	.1	.2	.3
Thaler and Rosen (1976)	.8	.5	.5	.6	.7	2
Viscusi (1979)	4.1	3.1	3.3	3.4	4.4	10
Viscusi (1981)	6.5	6.8	7.2	7.6	9.7	23
Marin and Psacharopoulos (1982)	2.8	4.6	4.8	5.1	6.6	15
Leigh and Folsom (1984)	9.7; 10.3	6.5; 6.6	6.8; 7.0	7.2; 7.3	8.1; 8.3	22; 22
Dillingham (1985)	2.5-5.3; 0.9	2.3-4.7; 0.8	2.4-5.0; 0.8	2.6-5.2; 0.9	2.9-5.9; 1.0	7-15; 3
Moore and Viscusi (1988a)	2.5; 7.3	2.4; 6.9	2.5; 7.3	2.7; 7.7	3.0; 8.6	8; 23
Moore and Viscusi (1988b)	7.3	5.6	5.9	6.2	7.0	19
Kniesner and Leeth (1991)	7.6	4.0	4.2	4.7	5.0	14
	3.3	3.4	3.6	3.8	4.3	11
	.6	.4	.4	.4	.5	1

Note: Data in column 1 are drawn from Viscusi (1992a, 1993).

(16), this threshold cost value varies inversely with the marginal propensity to spend on health. The effect is to lead to a quite dramatic range in the threshold value per life saved depending on the marginal propensity to spend. In the case of a \$5 million value of life for a typical worker, which is approximately the midpoint of a larger set of studies reviewed in Viscusi (1992a, 1993), there are marginal mortality test spending thresholds of \$100 million (.05 value of $\partial h/\partial A$), \$50 million (.1 value of $\partial h/\partial A$), \$25 million (.2 value of $\partial h/\partial A$), and \$16.7 million (.3 value of $\partial h/\partial A$). Focusing on the midpoint of the estimated value of life range of \$5 million and a marginal propensity to spend on health equal to the average propensity to spend of roughly .1, then the average cost per life saved for regulations cannot exceed \$50 million, or the net effect of the government regulation on mortality will be adverse. Thus, this test provides a mechanism for ensuring that the net effect of risk regulations will be beneficial.

□ **Direct estimates of the mortality-income relationship.**²¹ Rather than estimate the level of expenditure that will lead to one statistical death by using implicit value-of-life estimates coupled with the marginal propensity to consume on health, we can rely on studies that have directly estimated the influence of individual income on mortality. No existing studies provide a reliable index of the relationship.

There are several problems that researchers have encountered in trying to isolate the effect of income levels on mortality. First, income levels and mortality may be influenced by other personal characteristics that affect longevity. No study includes all of these influences. They include the role of schooling, based on Grossman (1972), and rates of time preference and individual self-control, as shown by Fuchs (1986, 1992). Cross-sectional studies that examine the effect of differences in income levels consequently will reflect in part the role of omitted personal characteristics correlated with income and which affect mortality. Second, individual income levels affect health status, so that causality may be two-directional. As society has become more affluent, health has also improved. Being in good health may improve one's earnings prospects. Third, problems arise in establishing the specific mortality link to the income. Studies of family income, for example, typically indicate that higher family income raises the life expectancy of the household head. However, other family members will also be affected by higher levels of family income. There are inherent difficulties in sorting out the public-good nature of family expenditures and the extent to which one individual in the family as opposed to the entire family is the beneficiary of the income in terms of the mortality effects. Although longitudinal evidence on the mortality-income relationship is likely to be instructive, cross-sectional evidence is so muddled by these concerns that it does not provide a reliable basis for policy.

The estimates in the income-mortality literature yielded the following estimates of the income loss that will lead to the loss of one statistical life (in 1991 dollars): \$31.9 million in Hadley's (1982) study of U.S. family income, \$2.9 million in the U.S. Joint Economic Committee's study of the 1973 recession, \$1.8 million in Anderson and Burkhauser's (1985) study of retirement history data, \$2.6 million in Duleep's (1986) study of social security mortality data, and \$12.0 million in Keeney's (1990) study using death certificate data.

These income loss-mortality estimates generally imply an expenditure per statistical life lost that is usually lower than that implied by the value-of-life studies, viewed in conjunction with the marginal propensity to spend on health. Indeed, many of these estimates are in the same range as many estimates of the implicit value of life from the standpoint of prevention. For reasons that are quite clear from the theoretical exposition above, the level of expenditure that will lead to the loss of a statistical life will certainly be higher than the value an in-

²¹ Lutter and Morrall (1992) provide a more comprehensive survey of this approach that differs from the estimates here in some minor respects. For example, in Viscusi (1992b) I use personal income rather than GNP in my econometric study.

dividual would place on saving a statistical life. In view of the problems associated with isolating the effect of a change in income on mortality as well as the importance of establishing consistency in the empirical methodologies used for benefit-cost tests as well as the risk reduction test, it would seem that estimates of the mortality value threshold can best be constructed using the findings from the value-of-life literature.

5. Conclusion

■ Increases in income lead to investments in one's health that improve individual health status, and conversely, decreases in income lead to deteriorations in health. This latter relationship is especially important with respect to government policies and the costs they impose. The decreased income that results from these efforts produces a decrease in longevity-enhancing investments, creating the potential for particularly expensive risk policies to be counterproductive. The income loss–mortality risk effect may exceed their direct effect in reducing risk.

Recognition of this relationship leads to modification of the value-of-life numbers one would use within the context of benefit-cost analysis. In particular, this test becomes more stringent. Moreover, consideration of the income loss–mortality linkage introduces a new test, which is that on balance a policy should have a beneficial effect on mortality risks.

There are strong analytical similarities between the benefit-cost test and the risk reduction test. Each of these conditions hinges on a critical value per life saved. In the case of the benefit-cost test, recognition of the health investment response to income losses leads to a modification in the value-of-life estimate one uses in assessing the attractiveness of policies. Similarly, one can examine the condition that the mortality risks of a policy be beneficial in terms of whether the average cost per life imposed by the policy exceeds a threshold, where this threshold is linked to the implicit value of life.

Both value-of-life measures have strong similarities in terms of their underlying determinants. Each can be written as functions of the implicit value of life and the marginal propensity to spend on health out of one's income. Preliminary empirical estimates indicate that if the implicit value of life is in the range of \$5 million, then the value-of-life measure that is pertinent for benefit-cost analysis is approximately \$5.6 million. The risk component of this calculation changes as well, however. The cutoff value-of-life measure for the risk reduction test will be \$50 million.

Recognition of the role of the health investment linkage consequently will not have a substantial effect on the benefit-cost test that is used to assess policies. However, in circumstances in which agencies do not adopt a benefit-cost approach, recognition of this relationship will lead to a new test that is less demanding. Although \$50 million per life is a relatively high number, it may be a binding constraint in many instances. Regulatory oversight efforts by the U.S. Office of Management and Budget have typically been successful in restructuring or rejecting proposed new risk regulations only if the cost per life saved is in excess of \$100 million.²² Some recent policies on balance may increase individual mortality risks because of the high costs they impose relative to the benefits they provide. Consideration of the mortality risk effects consequently may have important policy ramifications.

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²² See Viscusi (1992a) for supporting evidence for the past two decades of regulatory oversight.

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