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Author(s): John W. Pratt and Richard J. Zeckhauser
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Willingness to Pay and the Distribution of Risk and Wealth

John W. Pratt and Richard J. Zeckhauser

Harvard University

Willingness to pay (WTP), most economists believe, is an appropriate benefits metric for government expenditure and regulatory policies that reduce risks to human life. It depends, however, on the distribution of risk and wealth. Currently, society's expenditures overemphasize concentrated risks, say after-the-fact treatment as opposed to prevention. A "dead-anyway" effect complements excess attention to intense interests in explaining this. Our normative criterion for spending on risk reduction is what a rational, albeit uninsured, individual confronting lotteries on future risks to life and wealth would choose for himself. This requires correcting WTP to eliminate the dead-anyway effect but continues to reflect that wealth enhances the utility of living.

"Let a six-year-old girl with brown hair need thousands of dollars for an operation . . . , and the post office will be swamped with nickels and dimes to save her. But let it be reported that without a sales tax the hospital facilities of Massachusetts will deteriorate and cause a barely perceptible increase in preventable deaths—not many will drop a tear or reach for their checkbooks." This famous passage (Schelling [1968] 1984, p. 115) crystallizes the fact that we are often willing to pay more for a specified reduction in risk to an identified

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life than to a statistical life.[1] Similarly, medical expenditures can be divided between prevention, which reduces risk by a small amount for a large number of individuals, and therapy, which reduces risk by a much larger amount for a small number of identified individuals. It is often alleged that our society devotes an imbalance of resources toward treatment after the fact as opposed to prevention and that our biomedical research dollars tend to be focused excessively on efforts that will provide big benefits to small groups of identified sufferers as opposed to moderate benefits for much wider groups, many of whose members may not be known.

Why do we observe these tendencies? The little girl makes the situation concrete, brings the image of the sufferer to mind. The value of saving this life gets magnified. Contributing may even provide consumptive pleasure (which paying taxes does not). Politicians and newspaper columnists are masters of the concrete approach: a story about a specific out-of-work family may prove many times more powerful than statistics on unemployment. The "certainty effect" may also contribute: fixed gains in probability are perceived to be more significant if they change a probability to one or zero. Thus a reduction in the probability of death from .3 to .2 is valued less than a reduction from .1 to zero.[2]

Political factors may play a role in leading society to expend excessive resources on risks to identified lives. Concentrated interests are better able to mobilize pressures that can change political outcomes. Owing to the problem of mounting collective action, small per capita benefits going to large groups of individuals, by contrast, are likely to get underweighted (Olson 1971, pp. 165–67).

There has been an explosion of literature addressing the severe errors society makes in confronting risks. Breyer (1993) offers an insightful analysis from the standpoint of an economically oriented administrative law expert, ultimately asking how one can create an effective regulatory system. Viscusi (1992) gives a contemporary view of economic approaches, focusing in particular on the life valuations implicit in the responses of individuals and of society to risk.

Psychologists, lawyers, and economists have collectively advanced our knowledge of how we actually assess and ameliorate risks. However, our theory of how truly rational individuals should choose to

[1] Actually the situation is worse. Schelling's operation will only "prolong her life until Christmas."

[2] See the discussion of the Russian roulette problem (Tversky and Kahneman 1979, p. 283), where going from four bullets to three in a six-chamber gun is perceived as less valuable than going from one to zero. The rational decision maker should actually pay more for removing one of four bullets since there is a one-half chance he will be dead anyway and his money will then be worth less. This effect is analyzed below.

moderate risks has advanced relatively little in the quarter century since Schelling's literary presentation of the concept of willingness to pay to save lives.[3] And even if we could measure exactly aggregate willingness to pay to reduce risk, its relation to desirable social action is complex, as we shall see below.[4]

This paper attempts to advance the theory of rational choice by individuals confronted by life-threatening risks and by government agencies choosing on their behalf. Section I asks the question, How is willingness to pay to reduce a risk affected by its concentration? Section II asks, How should government, seeking to maximize the welfare of its citizenry, employ willingness to pay to guide its decisions? Section III concludes with a summary of the policy implications of our findings.

We focus on issues that arise when no perceptual or political biases are present[5] and where the values of outside parties for preserving a life play no role. We are concerned with the valuation of rational individuals for preserving their own lives. The building block of our discussion is a von Neumann–Morgenstern utility analysis that determines an individual's willingness to pay for a specified reduction in risk, depending on current risk level and quality of life, where the latter depends on wealth and possibly other factors.

We distinguish between risks to statistical lives and risks to identified lives, using the term "identified lives" informally to refer to relatively small groups of individuals known to be at high risk levels. Thus the relevant variables are the number or fraction of individuals at risk, the level of initial risk, and the magnitude of the risk reduction. For example, to the six-year-old girl, an identified life, the oper-

[3] There has been an explosion of empirical literature on willingness to pay, most of which draws inferences from the choices of rational workers demanding wage differentials as compensation for risk (see Rosen 1986; Viscusi 1992).

[4] Implicitly we are taking a cost-benefit approach to risk reduction, with the personal preferences of the individual at risk defining the benefits. Leonard and Zeckhauser (1986) address the justification for this approach.

[5] Zeckhauser and Viscusi (1990) find that such biases must be significant, since many of society's risk-reduction expenditures are far out of line with any pattern that could come from any rational prioritization. Government risk-reduction activities in some arenas, as they observe, are officially precluded from considering costs. A study by the Office of Management and Budget (OMB) looking at government regulations in 1992 found that the cost per premature death averted ranged from $0.1 million to $107 million, considering only risks in which there was a baseline mortality of at least one per thousand exposed (Office of Management and Budget 1992, p. 12, table 2).

Viscusi (1992, pp. 104–6), drawing on an earlier study by Lichtenstein, demonstrates that individuals tend to overestimate small risks relative to larger risks. In the OMB study, for some government regulations dealing with risks offering low baseline mortalities, there were substantially higher costs per death averted. Presumably the reason was that the political or regulatory process or both implicitly dramatically overestimated these exceedingly low risks.

ation reduces a certain death to a probability $1 - r$ of death, where r is the chance that the operation will succeed. The guardrail at the danger spot on the highway, saving one statistical life on average, reduces the already small risk for each of 1,000,000 passersby by one in 1,000,000.

I. Aggregate Willingness to Pay for Risk Reduction

Given an aggregate level of risk (expected deaths), P, within a population, how does willingness to pay (WTP) to reduce that risk by the absolute amount R depend on how the risk and risk reduction are spread within the population? In other words, how does the concentration or diffusion of risk affect aggregate willingness to pay? For simplicity, we assume that the risk-reducing intervention has no costs, such as pain, beyond dollars; the quality and length of life that is preserved are independent of the context; all individuals begin with the same amount of money; and there are no externalities of valuation. Hence only the individuals' preferences for their personal outcomes enter the analysis.

Under our assumptions, aggregate WTP to reduce a risk that affects many individuals is merely the sum of what each individual beneficiary would pay. Suppose that n individuals are at risk. With aggregate risk P, each of the n individuals has risk level $p = P/n$. The aggregate reduction in risk, R, offers each individual at risk the reduction $r = R/n$. Our question about aggregation is thus, How does aggregate WTP to reduce aggregate risk P by the amount R depend on the number exposed, n? If, for a fixed P and R, aggregate WTP rises as n increases, that implies a premium for statistical lifesaving. If WTP rises as n shrinks, then identified lifesaving is valued more highly.

Let us first consider the individual. With complete contingent claims markets, he could insure against being at high risk or could pay differentially out of his estate (should he die despite the intervention) for purchases of survival increments. In the realistic case we address without contingent claims markets, such possibilities are excluded. Thus the individual must pay out of current wealth once his risk level and lifesaving opportunities are determined.

Formal Analysis

An individual adhering to the axioms of von Neumann–Morgenstern utility theory has the utility function $U(s, w)$, where s is a variable that takes the value one if the individual dies and two if he survives, and

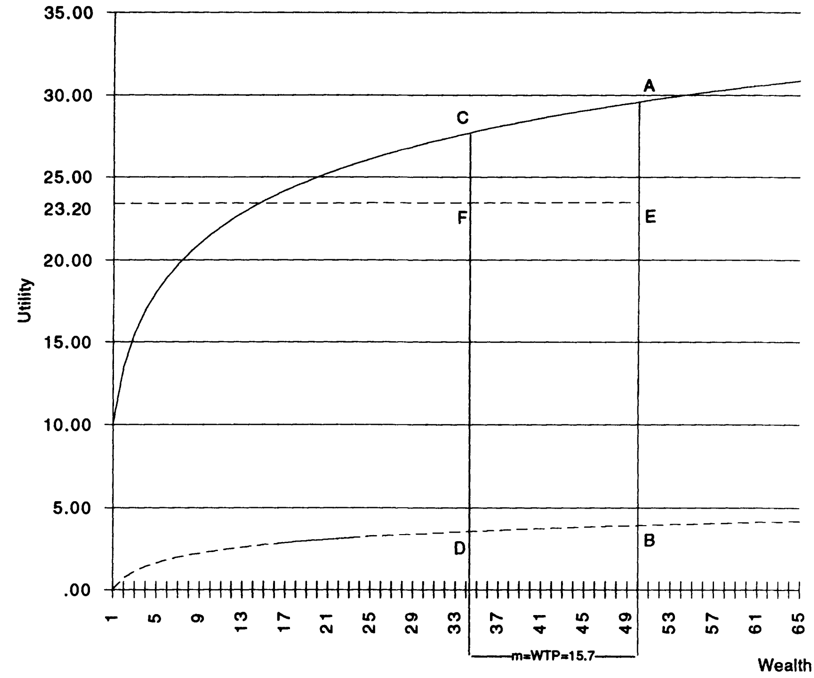

FIG. 1.—Individual willingness to pay to reduce risk: reduction from .25 to .1875 (a = 10, b = 5, w = 50).

w is wealth. Presumably $U(1, w) < U(2, w)$. The individual begins with death probability p and wealth w. He is given the opportunity to purchase a reduction r in risk of death, to $p - r$. What is his WTP, the maximum amount that he would pay for this reduction?

The individual's initial expected utility, U_0, is

$$U_0 = pU(1, w) + (1 - p)U(2, w).$$

The maximum amount, m, he would pay for a reduction r in death probability (increment r in survival probability) is determined by the equation

$$(p - r)U(1, w - m) + (1 - p + r)U(2, w - m) = U_0. \qquad (1)$$

Figure 1 represents m geometrically for the case, considered at greater length below, in which $U(1, w) = \ln(w)$ and $U(2, w) = a + b\ln(w)$. The specific parameter values[6] are $a = 10$, $b = 5$, and $w = 50$; initial risk is .25, and it is cut by .0625. The original lottery gives

[6] To assure that $U(1, w) < U(2, w)$ and that the marginal utility of wealth is always higher in the survival state, as assumed below, after-expenditure wealth must exceed $e^{-a/(b-1)}$ and we must have $b > 1$.

the individual a .25 chance of point B (death) and a .75 chance of A (survival), or an expected utility of 23.2, as shown at point E. A reduction in the risk of death to .1875 is offered. If the individual pays $m = 15.7$ for this reduction, his new lottery offers a .1875 chance of D and .8125 of C, a linear weighting that yields F. This also offers an expected utility of 23.2, thereby satisfying equation (1).

To learn more about m, we must know how the marginal utility of money, denoted here as $U'(s, w)$, is affected by the two states (life and death) and by wealth. (We use the prime throughout to represent derivatives with respect to w and assume risk aversion in each state; hence $U'(s, w)$ is decreasing in w for each s.)

Our analysis below considers the usual situation in which an individual values dollars more highly in life than in death, that is, $U'(1, w) < U'(2, w)$. The individual may have no heirs or none that are in need, or he may simply value his family's marginal consumption more now than if he were dead.[7]

The "Dead-Anyway" Effect and the "High-Payment" Effect

The "dead-anyway" effect, which pushes us to pay more for reducing risks on identified lives, arises because the dollars the individual expends have a larger chance of coming from the low-valued state, namely "dead." An individual with a fatal disease may rationally spend virtually all his wealth for a small chance of cure.

The "high-payment" effect, which cuts in the opposite direction, arises because all the cost of reduction is being imposed on one person (or a few), who grows poorer as he buys more risk reduction.[8] Risk aversion creates the high-payment effect: The more risk is concentrated, the more those bearing the risk will be paying, thereby increasing their marginal utility of income. This implies that for a given absolute utility gain achieved through risk reduction, concentrating

[7] It is possible that the marginal utility of money is greater when $s = 1$ than when $s = 2$. Such circumstances could arise because an income-earning individual might be altruistic toward his surviving family members, who will be denied his earnings once he is dead. Such lower income pushes them back toward the steeper portion of the utility of wealth curve. These income earners may buy life insurance, indicating that wealth has higher marginal utility in the death state. On the other hand, if they respond to the tax-favored status of whole-life insurance, they may be overinsured with $U'(1, w) < U'(2, w)$.

[8] One polar and probably unrealistic case assumes that survival and the utility of money are unrelated, say $U(s, w) = s + V(w)$. Then $U'(1, w) = U'(2, w)$: WTP is no greater contingent on death than contingent on survival. For that case, when $V'' < 0$, aggregate WTP within a population for a given increment in survival will be greater the larger the number among whom it is spread, since spreading the payment diminishes the income effect on utility.

risk will reduce the amount individuals are willing to pay for this gain. A community living near a toxic waste dump might pay $1 million to eliminate a one-tenth expected death. Yet a typical individual confronted with that entire one-tenth risk would hardly spend $1 million to eliminate it.[9]

How does willingness to pay vary according to the initial level of risk for the entire population and to the proportion of people sharing equally in the initial risk level and the beneficial reduction in risk? For example, assume that the initial expected risk is one life, the reduction in risk is one-fourth of its initial value, the proportion of the population sharing the risk is 100 percent, and the population size is 100. Then we have 100 people at .01 chance of death, each reducing it to .0075.[10] If the proportion sharing the risk were 1 percent, then we would have one person at 1.0 risk, who would secure a reduction to .75.

Using the utility function shown in figure 1, figure 2 illustrates the trade-off between the two concentration effects. Three different curves are given: one for a reduction in initial risk level by one-fourth of its value, one for one-sixth, and one for one-tenth. Obviously, WTP is greatest for the greatest reduction, that is, one-fourth. Note that the curves have three different shapes. For high risk reduction (one-fourth), the amounts expended are sufficient that the high-payment effect predominates; the curve rises throughout. For moderate risk reduction (one-sixth), the high-payment effect is predominant when only a small percentage of the population is at risk; however, beyond 1.37 percent at risk (shown by a hash mark), the dead-anyway effect is more powerful, leading the curve to turn down. For small risk reduction (one-tenth), the high-payment effect never outweighs the dead-anyway effect; WTP falls throughout.

An important lesson emerges from this diagram. Depending on particular parameter values, either concentration effect can outweigh the other. The dead-anyway effect is relatively more influential the less the magnitude of the risk reduction and (not shown) the higher the initial level of risk.

II. Willingness to Pay as a Policy Guideline

Economists frequently recommend willingness to pay as a guideline for policy, say in deciding whether to construct a town swimming

[9] If the measure is willingness to accept risk rather than willingness to pay to avoid it, the wealth effect (what is usually called an income effect) would exert the opposite influence. Concentrating the risk will require higher payments to place the affected individuals back on their initial indifference curves.

[10] If one person on average will die, it could be that, depending on the way risks are resolved, perhaps two or three will die, perhaps none.

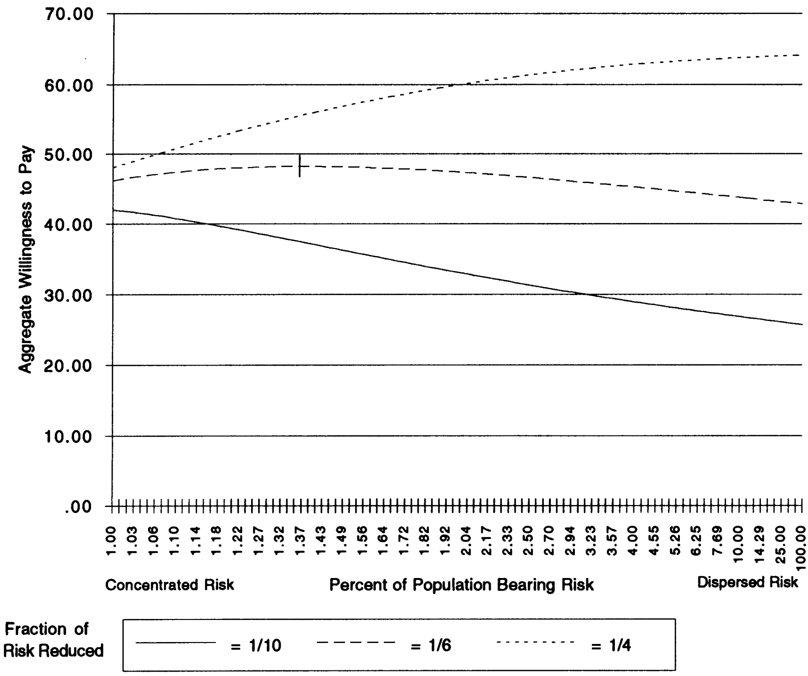

FIG. 2.—Aggregate willingness to pay for risk reduction: .01 per capita initial risk (a = 10, b = 5, w = 50).

pool or tennis courts, even though the expenditures will come out of government funds. The implicit guideline for policy is that a project should be undertaken if it offers a potential Pareto improvement; that is, with transfers a Pareto improvement could be achieved.

Strong objections are often raised on the basis of income distribution. In some absolute sense, rich people's dollars are less valuable. Hence voting by dollars overweights their welfare. If poor people swim and rich people play tennis, a WTP calculation might lead to a higher total for the tennis courts, even though the absolute utility gain might be greater for the pool. Such a miscalculation could be key in the real world, where utility-increasing transfers often do not get made because of transactions costs.[11]

The issues surrounding wealth and WTP also arise in relation to

[11] It is difficult to draw contingent claims contracts before lotteries on wealth are run and to monitor behavior to avoid moral hazard given redistributional measures. Given unequal outcomes, transactions costs also prevent altruistic transfers from those who would collectively be willing to make them. Moreover, political power, which determines what risk-reducing expenditures are actually made, reflects no particular welfare criterion with which we are familiar.

risk reduction; indeed they become more salient in this policy arena. As health care proposals from across the political spectrum reflect, our society cares much more about the health care consumption and risk exposure of the poor than it does about other aspects of their well-being.

We shall address this issue, and more general concerns about the use of WTP as a guideline for public expenditures, by an original-position argument, asking what individuals would agree to before they knew their wealth, their risk level, or other aspects of their future welfare (Rawls 1971). In this framework, social WTP is treated as an ex ante construct.

When is WTP an appropriate guideline for policy? In a market economy, in the absence of externalities of valuation, if individuals are paying for themselves and calculate suitably on a marginal basis, the outcome for each individual will have marginal WTP equal to the cost of further risk reduction. But what if society, rather than individuals, is spending the resources? Then aggregated individual WTP may not be an appropriate guideline. The world is in a second-best situation. The individual at high risk, having little expected value for his money because of the dead-anyway effect, would choose to spend profligately. (Note that the high-payment effect does not apply when society's dollars are being spent.) Society, however, is spending dollars raised from everyone and should not spend according to WTP calculations conducted for an individual whose dollars are severely depreciated because of a high risk of death.[12]

Consider this point in the context of health care expenditures paid for by society as a whole. Ex ante, the members would maximize expected utility by using a guideline that invoked not WTP, but WTP corrected for the expected marginal utility of a dollar in a manner described below, that is, to eliminate the dead-anyway effect. This guideline represents a second-best solution to the problem that contingent claims markets are incomplete.[13]

[12] Some health care commentators would object to allowing individuals to spend their own dollars for risk reduction, even though those dollars would be depreciated because of a high risk of death. Their argument, presumably, is that health care is "different" and that citizens care about how much others spend on it, possibly caring that they spend too much. A closely related argument is that it is unfair to let some individuals purchase better health care than others. The unspoken implication is that society is better off if these individuals buy yachts with the money they are forbidden to spend on health care. (In an individualistic economics framework, the best defense of this point of view is perhaps that the long-term supply curve of health is highly inelastic, and the pecuniary transfers associated with increases in demand will be undesirable. A more cogent explanation, well outside the normal economic framework, is that there is good-specific envy.)

[13] A wealth effect akin but not identical to the high-payment effect is that the cost of risk reduction affects marginal WTP for further risk reduction (except in the separa-

Take biomedical advances as an example. With the nation's concern about medical costs, considerable attention is paid to new, exceedingly costly innovations. Goddeeris (1984) suggests that there is a natural diffusion of such technologies from the few who would derive great benefit from them to the many for whom benefits are less substantial. Given society's inability to commit not to provide such technologies to low-value beneficiaries, the new technologies may not be worth the resources they cost. (For example, substantially more lives could be saved elsewhere for equivalent expenditures.) Many knowledgeable commentators identify technological advances as a principal cause of the escalation of medical costs in the United States at a rate far faster than inflation.[14]

Weisbrod (1991) has alerted us to the tendency for technology to be cost-enhancing rather than cost-saving. (For example, cost-control efforts do not appear to have benefited greatly from the dramatic historical reductions in information processing costs, though much of medicine involves information processing.) Part of the problem, no doubt, is that our political and medical systems respond excessively to identified major beneficiaries.[15] Our legal system reinforces this process. (A recent California case is instructive. A woman with advanced breast cancer was denied a bone marrow transplant by a health maintenance organization. Her heirs sued and recovered $89 million.)

Benefits Concentration and Attention by the Political Process and Individuals

Our argument above assumes full rationality, with costless information transfer and processing. The political process, a principal mechanism for allocating health-promoting and risk-reducing sources, falls a bit short. Attempts to influence politics encounter a natural free-rider problem. Hence, the more concentrated benefits are, with total benefits held fixed, the more likely it is that substantial pressures will be mounted (Olson 1971).

If the beneficiary group is well organized for other reasons, coordination problems in mounting pressures will be reduced. The rapid mobilization of attention to and action on AIDS represents this pro-

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ble, risk-neutral case). This effect is reflected in our formulas and further complicates the exactly correct use of WTP. We shall keep this matter in the background because our main concerns lie elsewhere.

[14] Cutler and McClellan (1995, p. 26) conclude, e.g., that all of the 4 percent annual expenditure growth for heart attacks in elderly Medicare beneficiaries from 1984 to 1991 was due to increased "use of intensive cardiac procedures."

[15] Celebrity also helps, as Mickey Mantle discovered with his swift liver transplant.

cess at work. There is an extreme concentration of risk among gay males, a politically mobilized constituency that shares goals in other areas, as opposed, say, to the group that suffers from diabetes.

This is an example of the more general problem with third-party payment through health insurance and failures of commitment by the participants: When they get to the line of scrimmage, doctors and patients may not live up to ex ante commitments to spend only up to the point at which marginal benefit equals marginal cost. Thinking about WTP before the whole process gets underway provides a helpful guideline in approaching these commitment and allocation issues.

Our mobilization for action discussion also relates to individuals taking risks on their own behalf. In many contexts it is difficult for individuals to inform themselves about risk. The cost of securing such information is likely to be far less than proportional to the magnitude of the risk. For this reason alone, we can expect individuals making decisions for themselves to take more efforts to avoid higher probability risks.[16]

Aggregate WTP with Ex Post Differences in Risk and Wealth

Consider a group of identically situated individuals about to confront a lottery that will determine their wealth, their risk level, and the technological possibilities for reducing their risk. All risk reduction is purchased collectively but can be targeted at different individuals. The tax system is externally imposed. How much should the risk for each be reduced? We shall find that the answer to this question can be expressed in terms of comprehensible concepts of WTP. The individuals each start with identical prospects on risk and wealth; in effect they begin and decide behind the Rawlsian veil of ignorance. They will subsequently learn their personal state x, and wealth $w(x)$, received with probability $f(x)$. They agree to an expenditure schedule $e(x)$ and associated payment $\bar{e}$, which together maximize expected utility.

The value of $\bar{e}$ is the mean expenditure per individual:

$$\bar{e} = Ee(\tilde{x}) = \sum_x f(x)e(x), \tag{2}$$

where E denotes expectation. Let the risk conditional on x and expenditure $e(x)$ be $p(x, e(x))$. Then the ex ante expected utility is

[16] There is a factor cutting in the opposite direction. If individuals are unable to accurately distinguish levels of risk, they will tend to homogenize them. If information acquisition were the only concern, we would expect, ex post, to devote relatively too much attention to lower probability risks that have been overestimated.

$$EU(\tilde{s}, w(\tilde{x}) - \bar{e}) = \sum_x f(x)\{p(x, e(x))U(1, w(x) - \bar{e}) + [1 - p(x, e(x))]U(2, w(x) - \bar{e})\},$$

which is a function of the set of variables $e(x)$, one for each x. With the notation $p_e(x, e) = (\partial/\partial e)p(x, e)$ and $U_\Delta(w) = U(2, w) - U(1, w)$ for the absolute utility gain from being alive, the derivative of the ex ante expected utility with respect to $e(x)$ is

$$-f(x)p_e(x, e(x))U_\Delta(w(x) - \bar{e}) - f(x)EU'(\tilde{s}, w(\tilde{x}) - \bar{e}).$$

Setting this derivative equal to zero, we find the optimality condition that

$$-p_e(x, e(x)) = \frac{EU'(\tilde{s}, w(\tilde{x}) - \bar{e})}{U_\Delta(w(x) - \bar{e})}. \quad (3)$$

In other words,

$$\text{marginal risk reduction} = \frac{E(\text{marginal utility of income})}{\text{utility of life at wealth } w(x) - \bar{e}}.$$

Note that if $w(x)$ is constant, then the denominator is constant and the numerator simplifies to the expected marginal utility of post-expenditure wealth, namely

$$EU'(\tilde{s}, w - \bar{e}) = \bar{p}U'(1, w - \bar{e}) + (1 - \bar{p})U'(2, w - \bar{e}),$$

where $\bar{p} = Ep(\tilde{x}, e(\tilde{x}))$; that is, the expected marginal utility of income is simply the probability of death times the marginal utility of income in death plus the probability of life times the marginal utility of income in life, evaluated at postexpenditure probability $\bar{p}$ and wealth $w - \bar{e}$ throughout. This yields the following major point.

1. For $w(x)$ constant, it is best to achieve the same marginal risk reduction per dollar at every risk state x.[17] If $w(x)$ is not constant, the optimum has $p_e(x, w(x))$ inversely proportional to $U_\Delta(w(x) - \bar{e})$.

The foregoing results are expressed in terms of the marginal effect of expenditure on risk and utility. Taking reciprocals relates them to WTP. Thus $-1/p_e(x, e)$ is the marginal reduction in risk obtainable by increasing the expenditure e at x. At the optimum, this equals $U_\Delta(w(x) - \bar{e})/EU'(\tilde{s}, w(\tilde{x}) - \bar{e})$, which is the marginal WTP ex ante for additional reduction to risk. Three additional important points to observe follow.

[17] We leave aside nonindividualistic concern for the distribution of risk across society. Behind the veil of ignorance, a von Neumann–Morgenstern utility maximizer with an equal chance of being A or B will be indifferent between a situation in which A bears risk $2p$ of death and equally wealthy B bears nothing, and one in which both bear risk p.

2. If $w(x)$ is not constant, then marginal WTP will be higher for the wealthier since $U_\Delta(w - \bar{e})$ is increasing in w, given our assumption that $U'(1, w) < U'(2, w)$. Before knowing their wealth, citizens would agree that the wealthier the life the greater the value of reducing risks to it.[18] However, ex post WTP overstates the relative benefits to saving wealthier lives, since wealth also affects the marginal utility of income. Appropriate corrections for this are the subject of point 3.

3. Ex post marginal WTP would replace ex ante expected marginal utility of income, $EU'(\tilde{s}, w(\tilde{x}) - \bar{e})$, by postlottery (on x) expected marginal utility of income,

$$p(x, e(x))\,U'(1, w(x) - \bar{e}) + [1 - p(x, e(x))]\,U'(2, w(x) - \bar{e}).$$

These expected marginal utilities differ whether or not $w(x)$ is constant. Starting with ex post WTP measured at $w(x) - \bar{e}$, to obtain the relative value of reducing risks to different lives—for example, as might be required for a cost-effectiveness analysis—one would have to correct by multiplying by postlottery expected marginal utility of income. Dividing these relative quantities by ex ante expected marginal utility of income would then provide the appropriate absolute guideline, which might be used in cost-benefit calculations.

4. There may be a third argument v in the utility function, also dependent on x, that affects the quality of life directly.[19] Thus utility would be $U(s, w(x) - \bar{e}, v(x))$. For example, $v(x)$ could be health status, with those at higher risk having a lesser health status. Then $v(x)$ will affect the calculations above through its effect on $U_\Delta(w(x) - \bar{e}, v(x))$ as well as (potentially) on the expected marginal utility of income. To the extent that WTP differences due to $v(x)$ reflect differences in life quality, they should be carried through and reflected in society's risk-reduction decisions.

Implementation of Our Principles

The principles underlying our formulas—relating to both life quality and wealth—could and should be implemented. Legislation pending in Congress in the spring of 1996 would implement the use of

[18] In this sense, the utility gains from recreation—our swimming vs. tennis example—are not the same as those from reducing risks. Given that wealth enhances the utility of being alive, that fact must be recognized if risk-reduction expenditures are to be efficient. It is widely believed that society follows this guideline. For example, it is alleged that poorer areas are more likely to be the sites of toxic waste dumps. Critics often raise ex post equity objections.

[19] It has long been proposed that the argument v, quality of life, be incorporated into lifesaving discussions. Most discussions of risk reduction talk in terms of lives saved. A more precise and appropriate measure of gain would quantify life years saved and correct those life years for quality (Zeckhauser and Shepard 1976).

risk-benefit analysis for a range of federal regulatory decisions. Should this initiative become law, there will be widespread debates on how risk-reduction benefits should be measured. Congress itself, executive agencies, or judicial decisions could require appropriate attention to the principles laid out above. With experience, these same considerations could help to guide direct government expenditures that affect risk.

The most heated discussion is likely to surround the treatment of wealth differences. An appropriate mechanism recognizes the benefits that wealth provides for quality of life but corrects for ex post differences in the expected marginal utility of income. Alternatively, policy makers could seek an absolute measuring stick to determine the value of lives at different wealths. Assume, for example, that we thought that the pleasure received from cigarette smoking and the risk incurred were independent of wealth. Then by examining the incidence of smoking across income categories, we could derive an implicit value function for lives at different wealths.

Lutter, Morrall, and Viscusi (1995) report on the propensity of individuals at varying levels of income to engage in risky activities. They estimate the following income elasticities of demand for these activities: smoking (−.22), drinking (−.23), and exercise (.14). It would be possible to infer an absolute value of life (in terms of utility) with some assumption about the distribution of pleasure from the unhealthful activity, call it $f(a)$. At any income level, we would assume that individuals choosing and paying for themselves would engage in the activity if it has risk α, utility gain U_α, and $\alpha U_\Delta(w) < qU_\alpha$, where q is the probability of living for individuals engaging in the activity. If $G(w)$ is the fraction refraining from the activity at wealth w and F is the cumulative distribution of U_α in the population, then $U_\Delta(w) = F^{-1}(G(w))q/\alpha$, where $F^{-1}(G(w))$ is the fractile of the distribution of U_α corresponding to the fraction refraining from the activity at wealth w. Although F, q, and α could depend on w, we have in mind the case in which they do not.

Schelling published his classic "The Life You Save May Be Your Own" more than a quarter century ago. Yet, despite an onslaught of empirical work (Viscusi 1992), process considerations often overwhelm economic principles in the design of regulatory processes associated with lifesaving.[20] Appropriate treatment of wealth in this context may not come quickly.

This analysis, like most economic studies, assumes that individuals have a common utility function (Stigler and Becker 1977). If risk

[20] See, e.g., the interview of Sally Katzen, administrator of the Office of Information and Regulatory Affairs at OMB (Niskanen 1993).

reduction derives from a public good, say new medical knowledge, the benefits to different parties should be summed in the usual Samuelsonian manner (Samuelson 1954), with benefit and tax amounts normed by expected marginal utility of income. If risk-reducing benefits are privately conveyed, say with an expensive medicine, differences in preferences could in theory be catered to by a choice among health plans. Individuals with high valuation of risk reduction would choose expensive plans, offering services that would be cost ineffective for most individuals.[21] And local communities, following the Tiebout hypothesis, would offer different bundles of risk relating to police services or road conditions.

A final implementation issue relates to the budget. In the discussion above, we assumed that the budget was optimized, but our four central points also hold when, more realistically, the budget is externally imposed. Then $\bar{e}$ in (2) is given, and introducing a Lagrange multiplier λ for this constraint merely adds λ to the numerator of (3). If the budget is too low, λ is positive and the marginal risk reduction at the constrained optimum is larger than at the unconstrained optimum; the reverse is also true. Points 1–4 remain true in either case.

If preferred, an approach by way of the budget is quite easy when $w(x)$ is constant, proceeding as follows. Expected utility is

$$EU(\tilde{s}, w - \bar{e}) = p(\bar{e})U(1, w - \bar{e}) + [1 - p(\bar{e})]U(2, w - \bar{e}),$$

where $p(\bar{e}) = \min E\{p(x, e(x))\}$ over schedules e such that $Ee(\tilde{x}) = \bar{e}$. The derivative with respect to $\bar{e}$ is

$$-p'(\bar{e})U_\Delta(w - \bar{e}) - EU'(\tilde{s}, w - \bar{e}).$$

Thus optimality has

$$-p'(\bar{e}) = \frac{EU'(\tilde{s}, w - \bar{e})}{U_\Delta(w - \bar{e})};$$

that is, the marginal risk reduction obtainable by increasing $\bar{e}$ is equated to the same utility ratio as before. The fact that the marginal risk reduction per dollar is the same at every x follows from the definition of $p(\bar{e})$ by a simple Lagrangian argument.

Complete Contingent Claims Markets

In the examples above, there were no contingent claims markets. Individuals could not insure against the financial consequences of being discovered to be at high risk, nor could they contract for extra

[21] Asymmetries of information might bring adverse selection to the fore and make it difficult to sustain significant differences among plans.

payment should they survive. When such markets do exist, the following result applies.

THEOREM. Consider a situation with complete, fair contingent claims markets in which individuals face identical initial prospects. Aggregate WTP for a specified level of risk reduction is independent of the distribution of risk and wealth, and the pattern of potential risk reduction.

For a proof and discussion, see Pratt and Zeckhauser (1993).

III. Concluding Remarks

A wide range of government policies—from health care to the environment, from product safety to biomedical research—seek to reduce risks to human life. In a democratic society, expenditures on such policies should be directed by the preferences of the members. The metric, therefore, at least most economists would now agree, should be willingness to pay to reduce the risk.

If WTP is the accepted guideline, how should it be measured and used? More specifically, if one recognizes, as shown in this paper, that aggregate willingness to pay will depend on how concentrated a specific risk might be, does this imply that society's dollars might well be spent in a manner that does not maximize lives saved per dollar spent?[22] If, as in the real world, complete contingent claims markets are not available, even with equal-wealth individuals, WTP per unit of risk reduction will depend significantly on the level of risk and the magnitude of reduction that is offered. One might conjecture, therefore, that to respect individual preferences, even with equal wealth, we should spend much more at the margin to reduce some risks than others, implying that maximum risk reduction would not be achieved for the dollars society spends. That conjecture is wrong.

To respect individual preferences when money is being spent out of collective coffers, we should examine the trades and agreements they would have undertaken had they been able to do so. Consider a group of individuals with identical prospects, starting in some initial position, knowing that they will live in a world in which contingent claims markets are incomplete. We have shown that such individuals, whether their ex post wealths turned out equal or not, would choose to use corrected ex post WTP, namely WTP multiplied by the ex post expected marginal utility of income, to provide relative weights for risk-reduction expenditures by society.

[22] We reiterate our simplifying assumptions that individuals start with identical prospects and that the quality and length of all lives saved are the same.

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