# Statistical vs. Identified Lives in Benefit-Cost Analysis

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## Abstract

Economic evaluation of projects involving changes in mortality risks conventionally assumes that lives are statistical, i.e., that risks and policy-induced changes in risk are small and similar among a population of anonymous individuals. In reality, baseline mortality risks and policy-induced changes in risk often differ among individuals. We examine the effects of information about heterogeneity of risk on economic evaluation. Although social welfare, defined by aggregate expected utility, is unaffected by information about risk heterogeneity, the outcome of benefit-cost analysis (BCA), i.e., the unweighted sum of individual compensating or equivalent variations, is sensitive to this information. The effect of information on the outcome of BCA depends on i) whether information is about heterogeneity of the baseline and/or change in risk, ii) whether risk is valued using willingness to pay (WTP) or willingness to accept (WTA), iii) the status quo policy, and iv) whether individuals are risk-averse or risk-neutral in wealth. We show that BCA does not justify a systematic bias in favor of identified lives in the allocation of safety expenditures and suggest some political factors that may explain this bias.

## 1. Introduction

Societies spend large quantities of resources to help identified victims (Lamm, 2001; Richardson and McKie, 2003). But spending large amounts to benefit only a few may be inefficient. Moreover, the question arises why some people receive particular attention and not others. The special concern toward identified lives can drive important priorities in risk management, like the choice between prevention and mitigation policies (Corso et al., 2002). More generally, information about whom a policy benefits may have an effect on the chances that the policy will be adopted. This effect is potentially important for benefit-cost analysis (BCA) of health and safety policies and for the study of the valuation of health and mortality risk.

The economic literature on the value of life has, from the beginning, clearly distinguished between identified and statistical lives. In the first paragraph of his seminal paper, Schelling (1968) writes *"It is not the worth of human life that I shall discuss, but of 'life-saving,' of preventing death. And it is not a particular death, but a statistical death.*" Economists have since been very cautious to be clear that the standard valuation approach – purposely labeled the "value-of-statistical-life" (VSL) approach – applies only when changes in risk are small and similar among the affected population. As Viscusi (1992) states "*This need to think in terms of statistical lives as opposed to certain lives defines the main character of our choice problem.*" We see at least two advantages of this approach. First, the focus on statistical rather than identified lives is consistent with the traditional *marginal* approach to the valuation of public goods (Samuelson, 1954, Bergstrom, 1982). Second, it lessens the scope for ethical and psychological concerns (Schelling, 1968).

But this focus on statistical lives leaves open the question of how to evaluate a project that may save, or may threaten, the lives of a few identified people. One may judge that the VSL approach is inappropriate because lives are not "statistical enough." But what should one do instead? Scholars have clearly recognized that identified and statistical lives are not the same (Schelling, 1968, Weinstein et al., 1980, Keeney, 1995, and especially Pratt and Zeckhauser, 1996),[1] but how this affects the application of BCA is less clear.

The distinction between identified and statistical lives is not sharp, but a continuum characterized by available information about heterogeneity of risk. People are neither identical nor anonymous, and neither baseline risks nor policy-induced changes in risk are always small or identical across people. In general, both baseline risks and risk changes differ among individuals because of differences in exposure to factors presenting the risk (e.g., sources of pollution, traffic conditions) and differences in susceptibility (e.g., related to age, sex, health status, genetics, behavior). In practice, however, information about how risks and policy-induced changes in risk differ among individuals is often so limited that one has little choice but to treat the risks as similar. Individuals may be conceived as facing a compound lottery. In the first stage, their initial risk and policy-induced risk change are drawn from the population distribution, and in the second stage the outcome of the risk is realized. Before information about the outcome of the first stage is available, risks are identical across individuals.

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[1] In particular, Pratt and Zeckhauser (1996) adjust for the effects of heterogeneity of wealth and risk by examining optimal safety expenditures behind a Rawlsian veil of ignorance where individuals have no information about their own wealth and risk exposure.

The main objective of this paper is to examine how information about heterogeneity of risk and of policy-induced changes in risk influences economic valuation and hence the outcome of BCA. Specifically, we investigate how the results of BCA depend on information about individual risks and risk changes. We compare these results with maximization of aggregate expected utility, an objective which is independent of information about risk heterogeneity when, as in our analysis, people are otherwise identical. We find that the effects of information about risk heterogeneity on the outcome of BCA depend on several factors, including whether the information concerns the baseline and/or change in risk and whether willingness to pay (WTP) or willingness to accept (WTA) measures are used. In addition, we find that BCA does not provide systematic support for giving greater priority to identified than to statistical lives.

Our analysis meets a well-known conceptual issue, "Broome's paradox."[2] This paradox may be presented as follows. Consider a project that is anticipated to kill one person from a population of similar individuals (e.g., the project may put construction workers at risk). It may be that if the identity of the one who would die was unknown, the project would pass a net-benefit test and be adopted. Yet, if this person's identity was known he might require infinite compensation for the loss of his life and the project would fail the net-benefit test and be rejected. This is a paradox in the sense that the only difference between the two situations is knowing the identity of the person who will die, and this it may be argued (Broome, 1978; Heinzerling, 2000) should not ultimately affect the social decision rule.[3] Broome's paradox is a useful starting point for our analysis.

The remainder of the paper is organized as follows. In Section 2, we present a simple example based on Broome's paradox which highlights the effect of information about heterogeneity of policy-induced changes in mortality risk on BCA. In Section 3, we review the standard model of value per statistical life. Using that model, we examine in Section 4 how information about heterogeneity of policy-induced changes in mortality risk affects each of the four measures of economic valuation: compensating and equivalent variations for reductions and increases in mortality risk. In Section 5, we examine the effects of information about heterogeneity in baseline risk. We show in Section 6 that altruism (concern for others' well-being) does not in general justify the special concern with identified lives. In Section 7, we conclude with a discussion of policy implications and of other factors that may help to explain the special concern with identified lives.

## 2. A Paradox of Benefit-Cost Analysis?

Consider an economy with two people, H and L. Each has initial wealth $w$ and probability $p$ of surviving the single period we consider. Each is risk-neutral in wealth and has no bequest motive. Consequently, each individual has expected utility (EU)

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[2] Broome's (1978) provocative paper raises a number of issues for BCA. Many of these issues are addressed in a set of critical papers (Buchanan and Faith, 1979; Jones-Lee, 1979; Williams, 1979). On the issue of interest to this paper, Ulph (1982) suggests that Broome's paradox arises due to an inappropriate social welfare function, i.e., a utilitarian framework. Our discussion differs since we work within a utilitarian framework.

[3] Broome (1978) presents another version of the paradox that we sum up as follows: Suppose information about who will die is not available today, but will be available tomorrow. If the project is up for consideration today, it may be acceptable, but tomorrow it will be deemed unacceptable by an infinite margin. Thus re-evaluating the project one day later would lead to rejecting it as "infinitely wrong." See also Heinzerling (2000) who argues that the evaluation of projects that affect mortality risks should not depend on whether the lives at risk are identifiable.

$$\text{EU} = pw. \tag{1}$$

Consider a project that will impose mortality risk on both people. The average incremental mortality risk is $e$. The benefit of the project to each person is $s$.

If people do not know their individual incremental risks (or if the incremental risks are identical), then each has expected utility

$$\text{EU/no info} = (p-e)(w+s). \tag{2}$$

Defining social welfare as the sum of the two individuals' expected utilities, average social welfare is as given by eqn. (2). Moreover, if the two individuals face different incremental risks but the total risk in the economy is fixed (i.e., the expected number of lives lost is fixed), then eqn. (2) also describes per-capita social welfare.

Now consider the effect of information about individual risks. For simplicity, assume H (high) faces incremental risk *2e* and L (low) faces no incremental risk. Average social welfare given information is

$$\text{EU/info} = 0.5(p-2e)(w+s)+0.5p(w+s)=(p-e)(w+s). \tag{3}$$

Social welfare with information is the same as in the no-information case. In this example, information about individual changes in risk does not affect social welfare, as Broome (1978) suggests. Moreover, observe that the project will enhance social welfare if and only if

$$(p-e)(w+s) > pw. \tag{4}$$

Now examine how BCA would handle the situation. BCA involves comparing the monetary-equivalent values of social benefits and costs. The per-capita benefit is $s$. The costs are the total compensation required to induce the people to accept the mortality risks. The compensating variation to accept a risk $x$, $C(x)$, is defined by

$$(p-x)\left[w+C(x)\right] = pw \tag{5}$$

which implies

$$C(x) = xw/(p-x). \tag{6}$$

In the case without information about individual risks, the per-capita cost is

$$\text{C/no info} = ew/(p-e). \tag{7}$$

With information about individual risks, the per-capita cost is

$$\text{C/info} = 0.5[2ew/(p-2e)]+0.5[0] = ew/(p-2e). \tag{8}$$

Since C/info > C/no info, the decision recommended by BCA may depend on whether or not the individual risks are known.[4] Specifically, if

$$\text{C/no info} < s < \text{C/info, i.e., } ew/(p-e) < s < ew/(p-2e), \tag{9}$$

then BCA will suggest the project should proceed if there is no information about individual risks, but should be rejected if individual risks are known.

Another approach to BCA is to ask if there is any lump-sum transfer $y$ such that the project with transfer is Pareto superior to rejection of the project. In the present case with information, the question is whether there is an amount $y$ that could be transferred from L to H such that H prefers to adopt the project, i.e.,

$$(p-2e)(w+s+y) > pw, \tag{10}$$

and L prefers to adopt the project, i.e.,

$$p(w+s-y) > pw. \tag{11}$$

Eqn. (11) implies that $y < s$, i.e., L cannot provide compensation greater than $s$ if he is to prefer the project with transfer to its absence. So the maximum expected utility of H cannot exceed that obtained when $y = s$. It is clear that eqn. (10) may not be satisfied since the survival probability $(p-2e)$ can be arbitrarily close (or even equal) to zero, and so with finite $s$ the inequality is violated.

Note that if one wants to maximize social welfare (SW) defined as the sum of the two individuals' expected utilities, it is optimal to transfer all the benefits of the project to the person with higher survival probability. That is, the maximum of

$$\text{SW} = (p-2e)(w+s+y) + p(w+s-y) \tag{12}$$

is obtained for $y = -s$. Since there is assumed to be no bequest motive, any wealth given to a person who dies contributes no well-being to the society.[5] This shows that SW can be made higher under information about individual risks than under no information. In contrast, recall that BCA can lead to the recommendation to adopt the welfare-enhancing project only in the no-information case.[6]

Why is it possible that the project increases social welfare with or without information about individual risk, but may not be even a potential Pareto improvement with information about individual risk? The BCA criterion aggregates welfare gains and losses across people in monetary terms. The relationship between survival probability and the monetary value of utility increments can be highly non-linear. In our example, as survival probability approaches

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[4] Eqn. (7) makes clear that the compensation could be infinite for $e = p$, as Broome (1978) suggests. The example will show that this extreme case is not required to induce the type of paradox proposed by Broome.

[5] Indeed, social welfare can be further increased by transferring not only the project benefits but all wealth from H (with smaller survival probability) to L (with larger survival probability).

[6] This example also suggests that information may have a negative value for the society. Suppose the condition in eqn. (9) holds. Then if society evaluates the project using BCA, information would lead it to reject the project. Without information, the project would be accepted and SW would increase.

zero, the monetary value of a unit of utility approaches infinity. In contrast, the expected-utility criterion adds increments of expected utility, which are linear in probability. Measuring in utility units, changes in individual risk (holding population risk constant) and information about individual risk have no effect on social welfare. Measuring in monetary units, information may have a large effect since the monetary value of the harm increases more rapidly for the person whose risk is increased than it decreases for the person whose risk is decreased (i.e., the indifference curve for wealth and risk and the compensation function for risk are both convex, as will be shown below).

This example illustrates a well-known point: adding compensation is not the same as adding utility.[7] If one wants to use monetary compensation as a proxy for adding utility, one needs to adjust compensation for differences in the marginal utility of consumption between people. It is well-known that adding unweighted compensation is valid in a first-best economy in which a social planner is able to implement lump-sum transfers so as to equalize marginal utility of consumption across people (Samuelson, 1954). But it is also well-known that implementing optimal lump-sum transfers, or weighting compensation by the inverse of the marginal utility of consumption, confronts the problem of non-observability of utility, which BCA avoids by seeking to determine only whether a proposed change is a potential Pareto improvement (i.e., satisfies the Kaldor-Hicks compensation test).[8]

The logical point conveyed by the example is that without information individuals are identical and thus there is no need to weight their compensation for any difference in marginal utilities. In this case, the unweighted sum of compensation is a correct indicator of social welfare. This is not true with information about differences in individual risks. Indeed, information makes the situation asymmetrical and marginal utilities may differ between individuals. Consequently, whether lives are statistical or identified may matter for the outcome of BCA. In the remainder of the paper, we study the effects of individual-specific information about risks on the outcome of BCA, i.e., on the sum of unweighted individual compensation.

## 3. The Value-of-Statistical-Life Model

In this section, we present the standard one-period value-of-statistical-life (VSL) model. An individual maximizes a (state-dependent) expected indirect utility given by

$$\mathrm{V}= pu(w)+(1-p)v(w) \tag{13}$$

where $p$ is the probability of surviving the period, $u(.)$ is the utility of wealth if he is survives, and $v(.)$ is the utility of wealth if he dies (e.g., the utility of a bequest). This model was introduced by Drèze (1962) and Jones-Lee (1974) and has been commonly used in the VSL literature (e.g., Viscusi and Aldy, 2003).

We adopt the standard assumptions that $u$ and $v$ are twice differentiable with $u > v$, $u' > v' \geq 0$, $u'' \leq 0$ and $v'' \leq 0$. That is, state-dependent utilities are increasing and concave. At any wealth level, both utility and marginal utility are larger if alive than dead. Indifference

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[7] See, e.g., Blackorby and Donaldson (1990) and Johansson (1998). In the context of mortality risks, see, e.g., Pratt and Zeckhauser (1996) and Armantier and Treich (2004).

[8] Pratt and Zeckhauser (1996) propose adjusting empirical estimates of WTP for mortality risk reduction to account for differences in marginal utility of wealth associated with total mortality risk.

curves over $(w,p)$ are represented in Figure 1. Under our assumptions on $u$ and $v$, the indifference curves are decreasing and convex.

VSL is the marginal rate of substitution between wealth and survival probability, i.e., (the negative of) the slope of the indifference curve at $(w,p)$. It is defined by

$$\text{VSL} = -\frac{dw}{dp} = \frac{u(w)-v(w)}{pu'(w)+(1-p)v'(w)} > 0. \tag{14}$$

VSL may vary across individuals since it depends on $w$, $p$ and on the shape of the utility function through $u$ and $v$. But notice that VSL is a marginal rate of substitution, and hence it does not capture any individual heterogeneity in the risk change. VSL provides a good approximation to an individual's monetary compensation for a given change in risk only if the change $dp$ is small. At the population level, average VSL provides a good approximation to the social value of a change in population risk if all risk changes in the population are small. A formally equivalent situation is that of a few individuals facing a significant change in risk, but these individuals are anonymous within the population (to themselves and to others). Our analysis will require us to depart from this marginal approach, or equivalently from this anonymity assumption.[9]

The expression for VSL in eqn. (14) is useful for identifying two effects that will be important for our analysis. The first is the dead-anyway effect (Pratt and Zechauser, 1996). It states that VSL increases with the initial level of risk, i.e., decreases with survival probability $p$ ($\partial \text{VSL}/\partial p < 0$). In Figure 1, this is equivalent to saying that the indifference curve is steeper at B than at A. The intuition is that an individual facing a large total probability of death has little incentive to limit his spending on risk reduction since he is less likely to survive and have other opportunities for consumption.[10] In eqn. (14), the value of the numerator is independent of $p$ and a decrease in $p$ reduces the value of the denominator (since $u' > v'$). The second effect is the wealth effect. It states that VSL increases with initial wealth $w$, i.e., $\partial \text{VSL}/\partial w > 0$. This is equivalent to saying that the indifference curve is steeper at C than at A. The intuition for this effect is two-fold. First, wealthier people have more to loose if they die (i.e., the numerator in eqn. (14) increases with $w$ because $u' > v'$). Second, the utility cost of spending is smaller (or no larger) due to diminishing marginal utility (risk aversion) with respect to wealth (i.e., the denominator in eqn. (14) does not increase because $u'' \leq 0$ and $v''(.) \leq 0$). These two effects imply that VSL increases as one moves upward and leftward along an indifference curve, and so the indifference curves are convex. In Figure 1, VSL at D is greater than VSL at A, because of both the dead-anyway and the wealth effects.

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[9] It is also important to acknowledge that identifiability may impair rational decision-making when the threat of death is present. This is recognized in the following paragraph from Schelling (1968): "*The avoidance of a particular death – the death of a named individual– cannot be treated straightforwardly as a consumer choice. It involves anxiety and sentiment, guilt and awe, responsibility and religion. If the individuals are identified, there are many of us who cannot even answer whether one should die that two may live.*" In the following, we will abstract from this problem that may play an important role for practical BCA, e.g. for the elicitation of individual WTP in surveys. Observe however that opposite arguments may be used with statistical lives due to the small probabilities involved, like the insensitivity to probabilities (Hammitt and Graham, 1999).

[10] For the same reason, he also has little incentive to limit his expenditures on other goods.

## 4. Information about Heterogeneous Changes in Risk

The example in Section 2 showed that information concerning how changes in risk vary in the population can matter if the policy decision is based on BCA. The strength of this effect depends on the non-linearity of the compensation function, as given in eqn. (6) $C(x) = xw/(p-x)$. The crucial property is the convexity of this function, which we now demonstrate.

Consider two individual-specific risk increments, $x_1$ and $x_2$. In the absence of information about individual-specific risk, each individual faces an expected risk increment of $\bar{x} = 0.5x_1 + 0.5x_2$ and requires compensation $C(\bar{x})$ (see Figure 2). Under perfect information, each knows his specific incremental risk and average compensation is $0.5C(x_1) + 0.5C(x_2)$. Information increases average compensation iff $0.5C(x_1) + 0.5C(x_2) \geq C(\bar{x})$, which is true when $C(x)$ is convex. It is easy to understand that convexity of the compensation function is a necessary and sufficient condition for information about individual-specific risks to increase average compensation for any distribution of individual-specific risks in the economy (holding average risk fixed). It is also obvious that convexity of the indifference curves over $(w, p)$ implies that $C(x)$ is convex.

Analyzing the convexity of $C$ is equivalent to comparing the compensation required for successive risk increments. Compare the compensation required for an incremental risk increase of $x$ to the compensation required for a second equal increment $x$ once the first has been made. Convexity of the compensation function implies that compensation for the second increment must be larger than for the first. There are two differences in the compensation for the second unit compared with the first one: i) survival probability is lower, $p-x$ compared with $p$; and ii) wealth is higher, $w + C(x)$ compared with $w$. The first difference increases compensation through the dead-anyway effect, and the second increases compensation through the wealth effect.

In the remainder of this section, we use the standard VSL model (13) to study how information affects both WTA and WTP. As we have just seen, this amounts to studying the convexity of the compensation functions for changes in risk. We will consider two different status quo or default cases: at the status quo the project is not implemented, and at the status quo the project is implemented. Hence four cases will be studied. We will see that the conclusions differ in each case.

### *4.1 WTA for implementing a risk-increasing project*

Generalizing the introductory example, we first consider WTA for a risk-increasing project. Let $C(x)$ be the WTA (compensating variation) defined by

$$(p-x)u(w+C(x)) + (1-p+x)v(w+C(x)) = pu(w) + (1-p)v(w) \tag{15}$$

with $0 \leq x \leq p$. Differentiating with respect to $x$ gives

$$C'(x) = \frac{u(w+C(x)) - v(w+C(x))}{(p-x)u'(w+C(x)) + (1-p+x)v'(w+C(x))} > 0. \tag{16}$$

Differentiating once again with respect to $x$ gives, under our assumptions on $u$ and $v$, $C'' > 0$. As noted above, the convexity of $C$ is immediate from the convexity of the indifference curve. Indeed, we have $C(\bar{x}) < 0.5\left[C(x_1) + C(x_2)\right]$ (see Figure 3). Since WTA is convex in risk increments, it increases with information about individual risk changes. Note that both the dead-anyway effect and the wealth effect are positive in this case, as shown above.

This case shows that information about individual risk changes increases the (monetary-equivalent) cost of the risk-increasing project and induces a bias in favor of the status quo. With more information, a project that would have been accepted may be rejected, thus preventing an increase in mortality risks in the economy. This is the case illustrated by Broome's (1978) paradox.

### *4.2 WTP for implementing a risk-decreasing project*

Let $P(x)$ be the WTP (compensating variation) for implementing a risk-decreasing project defined by

$$(p+x)u(w-P(x)) + (1-p-x)v(w-P(x)) = pu(w) + (1-p)v(w) \tag{17}$$

with $0 \le x \le 1-p$. Differentiating with respect to $x$ gives

$$P'(x) = \frac{u(w-P(x)) - v(w-P(x))}{(p+x)u'(w-P(x)) + (1-p-x)v'(w-P(x))} > 0\,. \tag{18}$$

Differentiating once again with respect to $x$ gives, under our assumptions on $u$ and $v$, $P'' < 0$. Again, observe from Figure 3 that this result is immediate from the convexity of the indifference curve. Indeed, we have $P(\bar{x}) > 0.5\left[P(x_1) + P(x_2)\right]$. As a result, WTP is concave in risk reductions and thus decreases with information about individual risk changes. Note that, in this case, both the dead-anyway effect and the wealth effect are negative.

This case shows that more information decreases the (monetary-equivalent) benefit of the risk-decreasing project and, like the previous case, induces a bias in favor of the status quo. More information may lead to rejecting a project that would have been accepted, thus forgoing an opportunity to reduce mortality risks in the economy.

### *4.3 WTA for not implementing a risk-decreasing project*

Let $C_n(x)$ be the WTA (equivalent variation) for forgoing a risk-decreasing project defined by

$$pu(w+C_n(x)) + (1-p)v(w+C_n(x)) = (p+x)u(w) + (1-p-x)v(w) \tag{19}$$

with $0 \le x \le 1-p$. Differentiating with respect to $x$ gives

$$C_n'(x) = \frac{u(w) - v(w)}{pu'(w+C_n(x)) + (1-p)v'(w+C_n(x))} > 0\,. \tag{20}$$

Differentiating once again with respect to $x$ gives

$$C_n''(x) = -\frac{(C_n'(x))^2[pu''(w+C_n(x))+(1-p)v''(w+C_n(x))]}{pu'(w+C_n(x))+(1-p)v'(w+C_n(x))}. \tag{21}$$

Under our assumptions on $u$ and $v$, $C_n'' > 0$. As a result, WTA is convex in risk reductions and thus increases with information. In Figure 3, $C_n(\overline{x}) < 0.5\left[C_n(x_1)+C_n(x_2)\right]$. Note that, in this case, the dead-anyway effect is negative and the wealth effect is positive, suggesting that the latter effect dominates. Note also that it is not possible *a priori* from Figure 3 to infer the sign of the second derivative of $C_n$.

This case shows that more information increases the (monetary-equivalent) benefit of the risk-decreasing project and induces a bias in favor of the status quo (implementing the project). In this case, more information may lead to adopting a project that would have been rejected, and thus to reducing mortality risks in the economy.

### *4.4 WTP for not implementing a risk-increasing project*

Let $P_n(x)$ be the WTP (equivalent variation) to prevent implementing a risk-increasing project defined by

$$pu(w-P_n(x))+(1-p)v(w-P_n(x)) = (p-x)u(w)+(1-p+x)v(w) \tag{22}$$

with $0 \le x \le p$. Differentiating with respect to $x$ gives

$$P_n'(x) = \frac{u(w)-v(w)}{pu'(w-P_n(x))+(1-p)v'(w-P_n(x))} > 0. \tag{23}$$

Differentiating once again with respect to $x$ gives

$$P_n''(x) = \frac{(P_n'(x))^2[pu''(w-P_n(x))+(1-p)v''(w-P_n(x))]}{pu'(w-P_n(x))+(1-p)v'(w-P_n(x))}. \tag{24}$$

Under our assumptions on $u$ and $v$, $P_n'' < 0$. As a result, WTP is concave in risk increments and thus decreases with information. In Figure 3, $P_n(\overline{x}) > 0.5\left[P_n(x_1)+P_n(x_2)\right]$. Note that, in this case, the dead-anyway effect is positive and the wealth effect is negative, suggesting again that the wealth effect dominates. Note also that it is not possible *a priori* from Figure 3 to infer the sign of the second derivative of $P_n$.

This case shows that more information decreases the (monetary-equivalent) cost of the risk-increasing project and induces a bias in favor of the status quo (implementing the policy). More information may lead to adopting a project that would have been rejected and thus increase mortality risks in the economy.

## 5. Information about Heterogeneous Baseline Risks

In the preceding sections, the initial risk is common across individuals although the risk changes can differ. We now consider a variant in which individuals face different initial risks. This variant is similar to a problem first analyzed by Pratt and Zeckhauser (1996).

There are $N$ risk-neutral people in the economy with initial wealth $w$. Among these $N$ people, only $R \leq N$ are at risk, and of these $R$ people $d \leq R$ will die. None of the $N-R$ others will die. A reduction in $R$ may be interpreted as increasing individual-specific information, or as a change in the distribution of risk in the population.

We return to the simplest possible assumptions, as in our initial example, i.e., $u\left(z\right)=z$ and $v\left(z\right)=0$. Social welfare in this economy equals

$$\mathrm{SW}=(N-R)w+R\frac{R-d}{R}w=(N-d)w. \tag{25}$$

Observe that SW is independent of $R$. Suppose that a risk-reducing project will save $n$ lives $(n \leq d)$ for a given per-capita cost $F$. The net effect of the project on social welfare is also independent of $R$.

Let us now look at how BCA would handle the situation. Let $P(R)$ be the WTP (compensating variation) for the project of each of the $R$ people who benefit, defined by

$$\frac{R-d+n}{R}\left[w-P(R)\right]=\frac{R-d}{R}w, \tag{26}$$

which yields

$$P(R)=\frac{n}{R-d+n}w. \tag{27}$$

Both individual WTP $P(R)$ and total (monetary-equivalent) benefits $RP(R)$ are decreasing in $R$. The use of BCA thus does not yield the same outcome as that obtained from social welfare maximization. Specifically, information will affect the former outcome, not the latter.

It is interesting to note the direction of the bias. Indeed, the monetary value of the benefit of the project is larger when the number of people who are identified as at risk is smaller, i.e., a "benefit-concentration" effect. Observe that that this result is opposite the one obtained in Section 4.2, where aggregate WTP decreases with information about individual risk reductions. Here information about which people face larger risk reductions increases aggregate WTP. Better information about individual-specific risks may lead to adopting a project that would otherwise be rejected, thus decreasing mortality risk in this economy.

Alternatively, we can evaluate WTA (compensating variation) for a risk-increasing project. Suppose that a risk-increasing project will kill $r$ people in this economy $(r \leq R-d)$ for some social benefit. Let $C(R)$ be defined by

$$\frac{R-d-r}{R}\left[w+C(R)\right]=\frac{R-d}{R}w \tag{28}$$

which gives

$$C(R)=\frac{r}{R-d-r}w. \tag{29}$$

Individual WTA denoted $C(R)$ decreases with $R$, as does the total (monetary-equivalent) social cost $RC(R)$. In this case, better information as to which people face additional risk increases the aggregate WTA. Better information may lead to rejecting a project that would otherwise be accepted, preventing an increase in mortality risk, as in Broome's (1978) paradox.

To summarize, under risk neutrality with respect to wealth, more information about the concentration of risk and risk change can lead to lower mortality risks in the economy. This can occur through either of two pathways: adopting risk-reducing projects that would be rejected, and rejecting risk-increasing projects that would be adopted, with poorer information about the concentration of risks and benefits.

What is the effect of a change in $R$ in a model with risk aversion? No general result can be obtained, as was first suggested by Pratt and Zeckhauser (1996: 753). To see this, consider the following example. Take the utility function

$$u(z)=\sqrt{z} \text{ and } v(z)=0 \tag{30}$$

together with the following set of parameter values: $w=1$, $d=50$, and

$n=20$. Then we have

$$P(R)=w\left[1-\left(\frac{R-d}{R-d+n}\right)^2\right]=\frac{40(R-40)}{(R-30)^2} \tag{31}$$

so that $RP(R)$ is increasing over $R\in[50,60]$ and decreasing over $R>60$. Consequently, information about how many people are at risk has an ambiguous effect on aggregate WTP.

The non-monotonicity of $RP(R)$ emphasizes the presence of two effects: when $R$ decreases fewer people will pay but each is willing to pay more. This example proves that is not possible *a priori* to determine which effect dominates under risk-averse preferences.

This example suggests that the effect of information about the concentration of risk in an economy is less easy to sign than the effect of information about differences in risk changes from a common baseline analyzed in Section 4. This can be easily understood. In the case of information about which people are at risk, there are not one but two sources of individual-specific risks: risk over the baseline probability and risk over the change in probability. In the cases we have considered, these risks are perfectly positively correlated in the sense that the individual risk reduction is proportional to the baseline risk.

One might consider the simpler problem of analyzing only heterogenous baseline risks. Assume now that people have different survival probabilities $p$ but the risk reduction is the same for everyone. We can show that information about baseline risks has an ambiguous effect in this case as well. Take the same risk-averse utility function as in (30). Then compute the WTP (now denoted $P(p)$) as in eqn. (17) to obtain

$$P(p)=\frac{wx(2p+x)}{(p+x)^2}. \tag{32}$$

From Section 4.2 it is easy to understand that the convexity of $P(p)$ in $p$ determines the effect of information about baseline probability on aggregate WTP. Yet, from eqn. (32) the sign of this effect is ambiguous, as the sign of $P''(p)$ depends on the sign of $p-x/2$. Consequently the effect of more information about heterogeneous baseline risk depends on the values of $p$ and $w$. Again, it is easy to see that this ambiguity disappears under risk-neutrality,[11] in the sense that more information about baseline probabilities always increases aggregate WTP and aggregate WTA for all values of $p$ and $w$.

In contrast to the effects of information about heterogeneity of risk reduction, analyzed in Section 4, this section shows that the effects of information about heterogeneity in baseline risk on the monetary-equivalent value of changes in risk are in general ambiguous. This ambiguity results when differences in risk changes are perfectly correlated with differences in baseline risk and also when the risk changes are common across individuals (equivalently, when there is no information about heterogeneity of risk changes). An exception occurs for the case of risk neutrality with respect to wealth, where, for all values of $p$ and $w$, the effects of information about either risk concentration or heterogeneous baseline risks increases aggregate WTP for a risk-reducing program and aggregate WTA for a risk-increasing program.

## 6. Altruism and the Identifiable Victim Effect

In this section, we consider altruistic individuals. Altruism is an important and natural concern in the matter of saving lives. Moreover, it is widely believed that there is an "identifiable victim effect": people are willing to pay more to save the lives of others when these lives are easily identifiable than when they are statistical (see, e.g., Jenni and Loewenstein, 1997; Heinzerling, 2000; Small and Loewenstein, 2003). Typically, there is an empathic response to rescuing well-identified people (or animals) in precarious circumstances.

There is little hope of capturing all the channels underlying such empathic responses in a simple economic model (recall the quote from Schelling (1968) in footnote 9). In any case, our previous model did not have a chance to do this since there was no consideration of altruism.[12] In this section we consider altruistic preferences and examine the effect of information on the valuation of life. As usual, it is insightful to start with an example.

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[11] By risk-neutrality we mean $u(z)=z$ and $v(z)=kz$ with $k\in[0,1[$.

[12] In model (13), a natural interpretation of the utility function $v(.)$ is a bequest function. This may be viewed as a form of altruism, toward one's children for instance. But this is not the form of altruism that is important here. We study altruistic motives for other people's utility (not only one's children's), i.e., one's preferences over other people's mortality risks.

Two identical risk-neutral individuals have survival probability $p$ and initial wealth $w$. We distinguish between private (self-interested) and social (private plus altruistic) preferences. Each individual has private expected utility EU = $pw$. They care for each other's well-being so that their respective *social* expected utilities $V$ may be written

$$V = pw + \alpha pw, \tag{33}$$

where $\alpha$ is their (identical) degree of altruism. We assume the individuals are pure altruists, i.e., their concerns for other people respect, or are aligned with, the other people's preferences.[13] A risk-reducing project that increases the survival probabilities of each person by a probability increment $x$ is under evaluation.

*Private* WTP for the project is equal to

$$P = xw/(p+x). \tag{34}$$

It is easy to see that each person's social WTP for an increase in his own and the other person's survival probability is equal to $(1+\alpha)P$, i.e., the sum of *private* WTP, $P$, plus the *altruistic* WTP, $\alpha P$. This latter term represents the WTP for the increase in the other person's survival probability. Accounting for altruism augments the aggregate private WTP by the quantity $2\alpha P$. This raises the question: To evaluate a project when preferences include altruism, should one sum private WTP or social (private plus altruistic) WTP?

It is interesting to examine social welfare in this economy. Observe that without the project we have SW = $2(1+\alpha)pw$. With the project, we have SW = $2(1+\alpha)(p+x)(w-c)$ where $c$ denotes the per-capita cost of the project. In comparing these expressions, the term $(1+\alpha)$ cancels and the result depends on whether $(p+x)(w-c)$ is larger than $pw$. Hence the choice of whether to adopt the project does not depend on the degree of altruism, and is the same as the choice with selfish preferences. Why is that?

The point is that (pure) altruistic motives may be ignored in BCA. The sum of private WTP is an adequate estimate of the monetary-equivalent benefits of the project in the sense that if this sum exceeds the sum of the private costs of the project, then the project is a potential Pareto improvement for altruistic people. This point was first stressed by Bergstrom (1982), elaborated by Jones-Lee (1992), and generalized by Bergstrom (2005). The argument is simple, although not trivial. A pure altruist benefits when the project reduces another person's risk, but is harmed when the project imposes costs on the other person. The net effect of the project on altruistic WTP is of the same sign as the net effect of the project on the other person's private WTP.

An implication of this observation is that considerations of altruism do not in general affect the valuation of identified vs. statistical lives in BCA. This does not imply that the identifiable victim does not exist, only that altruism (specifically, pure or non-paternalistic altruism) does not explain the effect and may be ignored in BCA.

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[13] See Jones-Lee (1992) for an analysis of the implications of both pure (i.e., benevolent, non-paternalistic) and paternalistic altruism (e.g., safety-focused altruism) for the valuation of life.

## 7. Policy Implications

A standard economic result is that public projects with positive expected value should be adopted (Arrow and Lind, 1970). This result assumes an economy with either complete markets or a large number of individuals who can share risks. In this economy, the sum of individual compensating variation for a project is consistent with the maximization of social welfare, with or without information on the distribution of the project's effects across individuals. This is because complete markets or risk-sharing yield an efficient outcome in the sense that individuals can equate their marginal utilities. However, when risk-sharing opportunities are limited, the rule of acceptance for public projects is less clear and the adequacy of BCA as a method for identifying gains in social welfare is not guaranteed.

An important case of limited risk-sharing is when a bad outcome decreases marginal utility, a property of the standard state-dependent model for valuing mortality risk described by eqn. (13). In that case, it may be that some individuals could never be compensated for their loss, as suggested by Broome's paradox. As a result, marginal utilities may differ among people and BCA may not be a correct indicator of social welfare. Individual-specific information about mortality risks may matter for BCA. In particular, the results of a BCA may depend on whether lives are statistical or identified. We have studied some theoretical determinants of this difference. Let us sum up some results:

1. The effects of information about interpersonal differences in the risk change due to a project depend on whether one evaluates a project using WTP or WTA measures.

    a. WTA, whether compensating variation for a risk increase (Section 4.1) or equivalent variation to forgo a risk decrease (Section 4.3), is larger with more information about heterogeneity of the risk change. As a result, information about how the project affects individuals' risks may lead to rejecting a risk-increasing project that would have been accepted (as in Broome's paradox) or accepting a risk-decreasing project that would have been rejected with less information. In both cases, information about heterogeneity leads toward lower aggregate risk in the economy.

    b. WTP, whether compensating variation for a risk decrease (Section 4.2) or equivalent variation to prevent a risk increase (Section 4.4), is smaller with more information about heterogeneity of the risk change. As a result, information about how the project affects individuals' risks may lead to rejecting a risk-decreasing project that would have been accepted and accepting a risk-increasing project that would have been rejected with less information. In both cases, information about heterogeneity leads toward higher aggregate risk in the economy.

    c. As a corollary, there is no necessary relationship between the extent to which risk changes are statistical or identifiable and the degree of protection endorsed by BCA.

2. When baseline risks are heterogeneous, the effect of information on BCA is in general ambiguous (Pratt and Zeckhauser, 1996). When individuals are risk neutral with respect to wealth, more information about baseline risk can lead to increases in both types of compensating variation, i.e., WTP for a risk-decreasing policy and WTA for a risk-increasing policy, and can therefore lead to more protective decisions (i.e., those that yield smaller aggregate mortality risk in the economy).

3. Altruism does not in general explain the identifiable victim effect. This is a consequence of a more general result that (pure) altruism need not be considered in BCA (Bergstrom, 2005).

It is interesting to compare BCA with cost-effectiveness analysis (CEA). In CEA, changes in health risk are often evaluated by the expected change in quality-adjusted life years (QALYs) in the economy.[14] Evaluation of the effects of a program on mortality risk is unaffected by whether lives are statistical or identified, or by information about heterogeneity of risks or risk changes in the economy (holding constant population risk as measured by aggregate expected QALYs). This result is immediate since the expected change in QALYs is linear in the probabilities. Hence if individuals' preferences for survival are consistent with QALYs, CEA may be consistent with social welfare maximization (Hammitt, 2002).[15] Interestingly, Hadorn (1996) reports that the impartiality of the QALY approach was contested in the famous Oregon priority-setting exercise. The approach was perceived as introducing an ordering that undermined treatments for people facing life-threatening conditions, thus violating a preference for giving priority to identified victims.[16]

Overall, neither BCA nor CEA provide general support for prioritizing identified over anonymous people in life-saving policies. To conclude, we discuss three political factors that may explain such a prioritization: responsibility, lobbying and demagogy.[17]

First, it is important to recognize that persons in charge of safety decisions may have, or feel, a responsibility to help identified people. In particular, there may be a legal responsibility.[18] By definition, the death of an identified victim will be known and blame may be easily attributed to decision makers, whereas the deaths of anonymous individuals may go unnoticed and may be more difficult to attribute to particular decisions. Physicians and risk managers routinely set limits on the risks to which individuals may be exposed, often focusing on absolute risk levels (e.g., safety norms or standards). This practice may lead to diverting resources from protecting individuals with average exposure to those who are highly exposed and thus toward identifiable individuals. Notice that identification need not be restricted to those exposed to high risk. Suppose that a target group (e.g., a minority or low-income group) has been disadvantaged for reasons other than risk, such as poor education. Providing this group with more protective risk regulations is a way to compensate them for their disadvantaged status.[19] Decision-makers may believe they have a duty to help such identified

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[14] A QALY represents a year of life adjusted by an index of quality of life or health (e.g., Gold et al., 1996; Hammitt, 2002). Simpler forms of CEA evaluate changes in mortality risk by the expected number of lives or life years saved.

[15] Empirical evidence suggests that QALYs are not consistent with individual preferences. See, e.g., Pliskin et al. (1980), McNeil et al. (1981), and Bleichrodt and Johannesson (1994).

[16] Richardson and McKie (2003) give as an example that "*dental caps for pulp or near pulp exposure were assigned a higher priority than surgical treatment for ectopic pregnancy*." Miller et al. (2006) evaluate the implications of QALYs for allocating risk reduction in a population.

[17] Fernandez and Rodrik (1991) show that individual-specific uncertainty may change the identity of the median voter, and hence the projects that will be selected by majority vote. We do not address how this effect might be influenced by information about heterogeneity of risk.

[18] Richardson and McKie (2003), quoting Fried (1969, p. 1418), indicate that the director of a mining company refusing to spend money to save a trapped man may be civilly and criminally liable, even though she has invested large sums of money to prevent such a catastrophe. Similar legal responsibilities may exist in hospitals, e.g., to care for terminally ill patients.

[19] This practice is discussed by Viscusi (2000). Notice that the standard model of public provision of safety based on Samuelson (1954) actually predicts quite an opposite result (Bergstrom, 1982). According to this model, it is optimal to devote more resources to prevent risks faced by the sub-population of, say, richer people.

groups. Empathy and vividness may also contribute. Decision-makers may be more willing to endorse humane and caring policies, for both personal and political reasons. In contrast, they may be less willing to adopt policies that are perceived as unfair or unethical toward particular groups. This behavior is consistent with the concept of environmental justice (Tietenberg, 1996).

Second, one may view the society as composed of different groups of people, or lobbies, sharing common interests. Participants in small lobbies may have more intense interests and free-riding may be less pronounced. As a result, they may have disproportionate political influence (Olson, 1971). A policy that favors concentrated interests may be more likely to be adopted than a policy that profits the mass but has a negative impact on a few people. Moreover, consider a group that is particularly visible, e.g., through media exposure. This visibility may constitute a threat to a politician, or a firm, with reputational concerns. Visibility of a group may also be used to inform, or to manipulate, the public. This practice may exert an indirect pressure on decision-makers through the ensuing changes in public beliefs (Kuran and Sunstein, 1999).

The last remark leads us to a third political factor that we may want to consider separately, demagogy of politicians. Politicians might adopt policies that the public *believes* are good even when those policies are not necessarily good for the public. The hypothesis is that policies that reduce risks to identified people are more likely to be perceived as beneficial by the public than those that reduce risks to statistical lives. There may be some justification for this hypothesis. Altruistic individuals may feel more compassion toward identified than toward statistical victims. This may in turn stimulate a stronger emotional response through an identifiable victim effect (Jenni and Lowenstein, 1997). Moreover, the observation of identified victims of a particular risk may make that risk more salient and increase concern about one's own exposure to it. By the availability heuristic (Tversky and Kahneman, 1974), this may increase one's perceived probability of exposure and induce a higher demand for mitigation (Sunstein, 2005). This aspect may be aggravated because individuals often misperceive the (marginal) costs of government services, and the way they think about how governments should allocate resources likely depends on ethical heuristics like the principle of equality (Kemp, 2003).

Overall, benefit-cost analysis using the standard value-per-statistical-life approach to valuing changes in mortality risk may not yield the same results as maximization of social welfare, defined as the aggregation of individual expected utilities. In particular, whereas social welfare may be unaffected by information about heterogeneity of baseline risk and the magnitudes of policy-induced changes in risk, monetary-equivalent measures of the risk change depend on baseline risk and risk change and so the value of a policy-induced risk change may depend on information about risk heterogeneity. In contrast, the results of a cost-effectiveness analysis, which quantifies the effects of changes in mortality risk using quality-adjusted life years, lives saved, or other metrics, may be unaffected by information about risk heterogeneity. Hence if the effectiveness measure used in CEA is consistent with individuals' preferences, the results of the analysis may be consistent with social-welfare maximization.[20] A systematic premium for identified lives is not consistent with either BCA or CEA, but may

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Such a practice is efficient since it rests on the assumption that the government is also able to implement lump-sum transfers to redistribute income and finance the safety provision across the population. In other words, richer people will be at the same time taxed more heavily to compensate poorer people so that, at the optimum, marginal utilities are equal.

[20] Note, however, that it seems unlikely that QALYs are consistent with individual preferences (Hammitt, 2002).

be explained by political and other factors. Whether disproportionate allocation of resources toward programs that save identified lives is socially desirable depends in part on the moral legitimacy of these political factors and on the magnitudes of the efficiency costs and distributional benefits.

## References

Armantier, Olivier, and Nicolas Treich, 2004, Social willingness-to-pay, mortality risks and contingent valuation, *Journal of Risk and Uncertainty* 29, 7-19.

Arrow, Kenneth J., and Robert Lind, 1970, Uncertainty and the evaluation of public investment decisions, *American Economic Review* 1, 364-78.

Bergstrom, Theodore, 1982, When is a man's life worth more than his human capital? *The Value of Life and Safety* (M. Jones-Lee, ed.), 3-26, North-Holland, Amsterdam.

Bergstrom, Theodore, 2005, Benefit-cost in a benevolent society, mimeo, University of California Santa Barbara. Forthcoming, *American Economic Review*.

Blackorby, Charles, and David Donaldson, 1990, A review article: the case against the use of the sum of compensating variations in benefit-cost analysis, *Canadian Journal of Economics* 23, 471-94.

Bleichrodt, Han, and Magnus Johannesson, 1996, The validity of QALYs: an experimental test of constant proportional tradeoff and utility independence, *Medical Decision Making* 17, 21-32.

Broome, John, 1978, Trying to value a life, *Journal of Public Economics* 9, 91-100.

Buchanan, James M., and Roger L. Faith, 1979, Trying again to value a life, *Journal of Public Economics* 10, 245-48.

Corso, Phaedra S., James K. Hammitt, John D. Graham, Richard C. Dicker, and Sue J. Goldie, 2002 Assessing preferences for prevention versus treatment using willingness to pay, *Medical Decision Making* 22, S92-S101.

Drèze, Jacques, 1962, L'utilité sociale d'une vie humaine, *Revue Française de Recherche Opérationnelle* 6, 93-118.

Fernandez, Raquel, and Dani Rodrik, 1991, Resistance to reform: status quo bias in the presence of individual-specific uncertainty, *American Economic Review* 81, 1146-55.

Fried, Charles, 1969, The value of life, *Harvard Law Review* 82, 1415-37.

Gold, Marthe R., Joanne E. Siegel, Louise B. Russell, and Milton C. Weinstein, 1996, *Cost-Effectiveness in Health and Medicine*, Oxford University Press, Oxford.

Hadorn David C., 1996, The Oregon-priority-setting exercise: cost-effectiveness and the rule of rescue revisited, *Medical Decision Making* 16, 117-19.

Hammitt, James K., 2002, QALYs versus WTP, *Risk Analysis* 22, 985-1001.

Hammitt, James K., and John D. Graham, 1999, Willingness to pay for health protection: inadequate sensitivity to probability, *Journal of Risk and Uncertainty* 3, 33-62.

Heinzerling, Lisa, 2000, The rights of statistical people, *Harvard Environmental Law Review* 24, 189-207.

Jenni, Karen E., and George Loewenstein, 1997, Explaining the “identifiable victim effect”, *Journal of Risk and Uncertainty* 14, 235-257.

Johansson, Per-Olov, 1998, Does the choice of numéraire matter in benefit-cost analysis? *Journal of Public Economics* 70, 489-93.

Jones-Lee, Michael W., 1974, The value of changes in the probability of death or injury, *Journal of Political Economy* 99, 835-849.

Jones-Lee, Michael W., 1979, Trying to value a life: why Broome does not sweep clean, *Journal of Public Economics* 10, 249-56.

Jones-Lee, Michael W., 1992, Paternalistic altruism and the value of statistical life, *Economic Journal* 102, 80-90.

Keeney, Ralph L., 1995, Understanding life-threatening risks, *Risk Analysis* 15, 627-637.

Kemp, Simon, 2003, *Public Goods and Private Wants: A Psychological Approach to Government Spending*, Edward Edgar, Northampton, Massachusetts.

Kuran, Timor, and Cass R. Sunstein, 1999, Availability cascades and risk regulation, *Stanford Law Review* 51, 683-768.

Lamm, Richard D., 2001, Compassion for unidentified lives, *Healthplan* 42, May/June.

McNeil, Barbara J., Ralph Weichselbaum, and Steven G. Pauker, 1981, Speech and survival: tradeoffs between quantity and quality of life in laryngeal cancer, *New England Journal of Medicine* 305, 982-987.

Miller, Wilhelmine, Lisa A. Robinson, and Robert S. Lawrence (eds.), 2006, *Valuing Health for Regulatory Cost-Effectiveness Analysis*, Institute of Medicine, National Academies Press, Washington, D.C.

Olson, Mancur, 1971, *The Logic of Collective Action: Public Goods and the Theory of Groups*, Harvard University Press, Cambridge.

Pliskin, Joseph S., Donald S. Shepard, and Milton C. Weinstein, 1980, Utility functions for life years and health status, *Operations Research* 28, 206-224.

Pratt, John W., and Richard J. Zeckhauser, 1996, Willingness to pay and the distribution of risk and wealth, *Journal of Political Economy* 104, 747-63.

Richardson, Jeff, and John McKie, 2003, The rule of rescue, *Social Science and Medicine* 56, 2407-2419.

Samuelson, Paul A., 1954, The theory of pure provision of public expenditures, *Review of Economics and Statistics* 36, 387-389.

Schelling, Thomas, 1968, The life you save may be your own, *Problems in Public Expenditure Analysis* (S.B. Chase, Jr., ed.), Brookings Institution, Washington, D.C.

Small, Deborah A., and George Lowenstein, 2003, Helping *a* victim or helping *the* victim: altruism and identifiability, *Journal of Risk and Uncertainty* 26, 5-16.

Sunstein, Cass R., 2005, *The Laws of Fear: Beyond the Precautionary Principle*, Cambridge University Press, Cambridge.

Tietenberg, Tom, 1996, Environmental justice, *Environmental and Natural Resource Economics*, Chapter 20, Harper Collins College Publishers, New York.

Tversky, Amos, and Daniel Kahneman, 1974, Judgment under uncertainty: heuristics and biases, *Science* 185, 1124-1131.

Ulph, Alistair, 1982, The role of ex ante and ex post decisions in the valuation of life, *Journal of Public Economics* 18, 265-76.

Viscusi, W. Kip, 1992, Strategic and ethical issues in the valuation of life, *Fatal Tradeoffs: Public and Private Responsibilities for Risk*, Chapter 2, Oxford University Press, Oxford .

Viscusi, W. Kip, 2000, Risk equity, *Journal of Legal Studies* 29, 843-71.

Viscusi, W. Kip, and Joseph E. Aldy, 2003, The value of a statistical life: a critical review of market estimates throughout the world, *Journal of Risk and Uncertainty* 27, 5-76.

Weinstein, Milton C., Donald S. Shepard, and Joseph S. Pliskin, 1980, The economic value of changing mortality probabilities: a decision-theoretic approach, *Quarterly Journal of Economics* 94, 373-96.

Williams, Alan, 1979, A note on trying to value a life, *Journal of Public Economics* 10, 257-58.

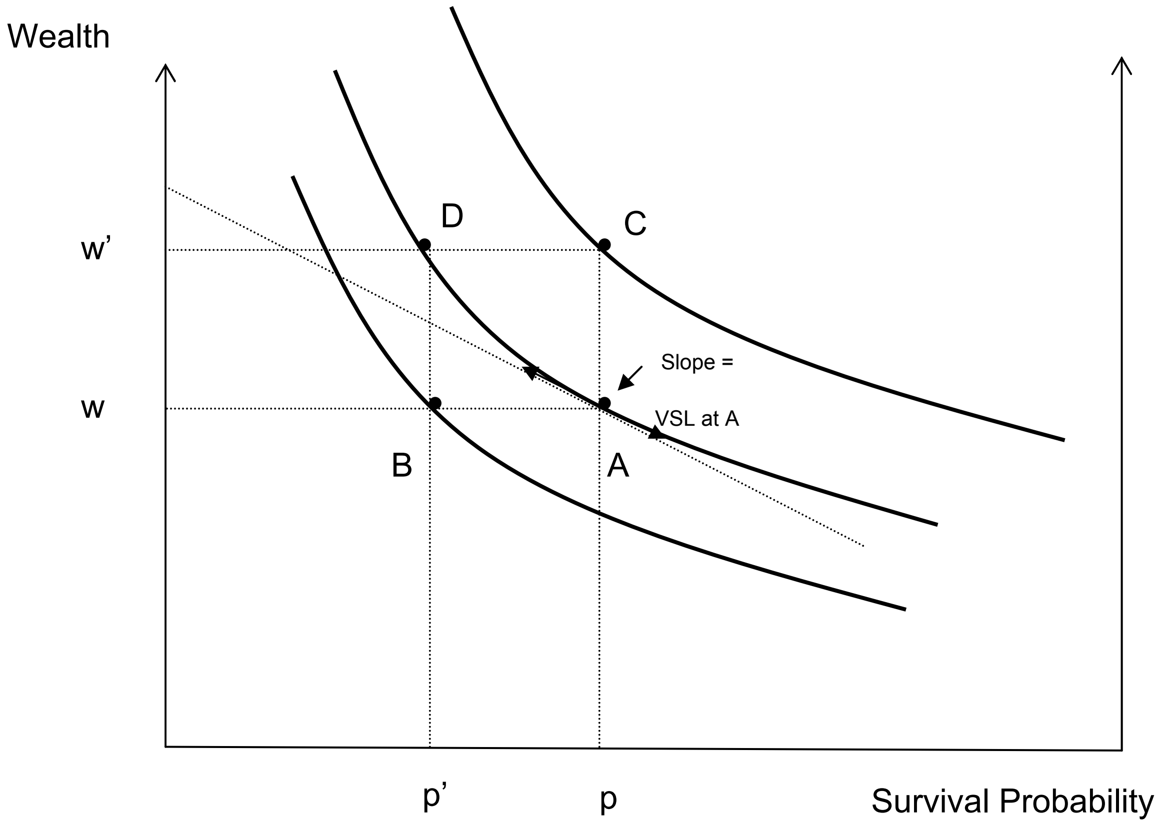


Figure 1: Indifference curves, VSL, the dead-anyway and the wealth effect.

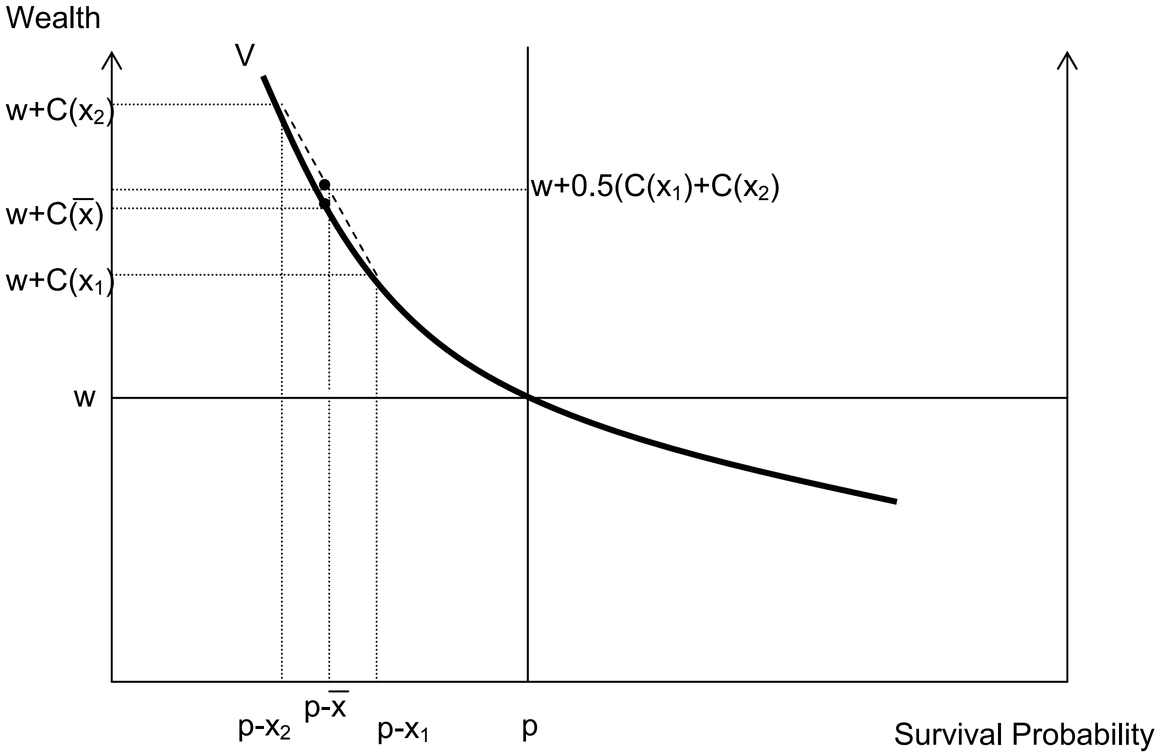
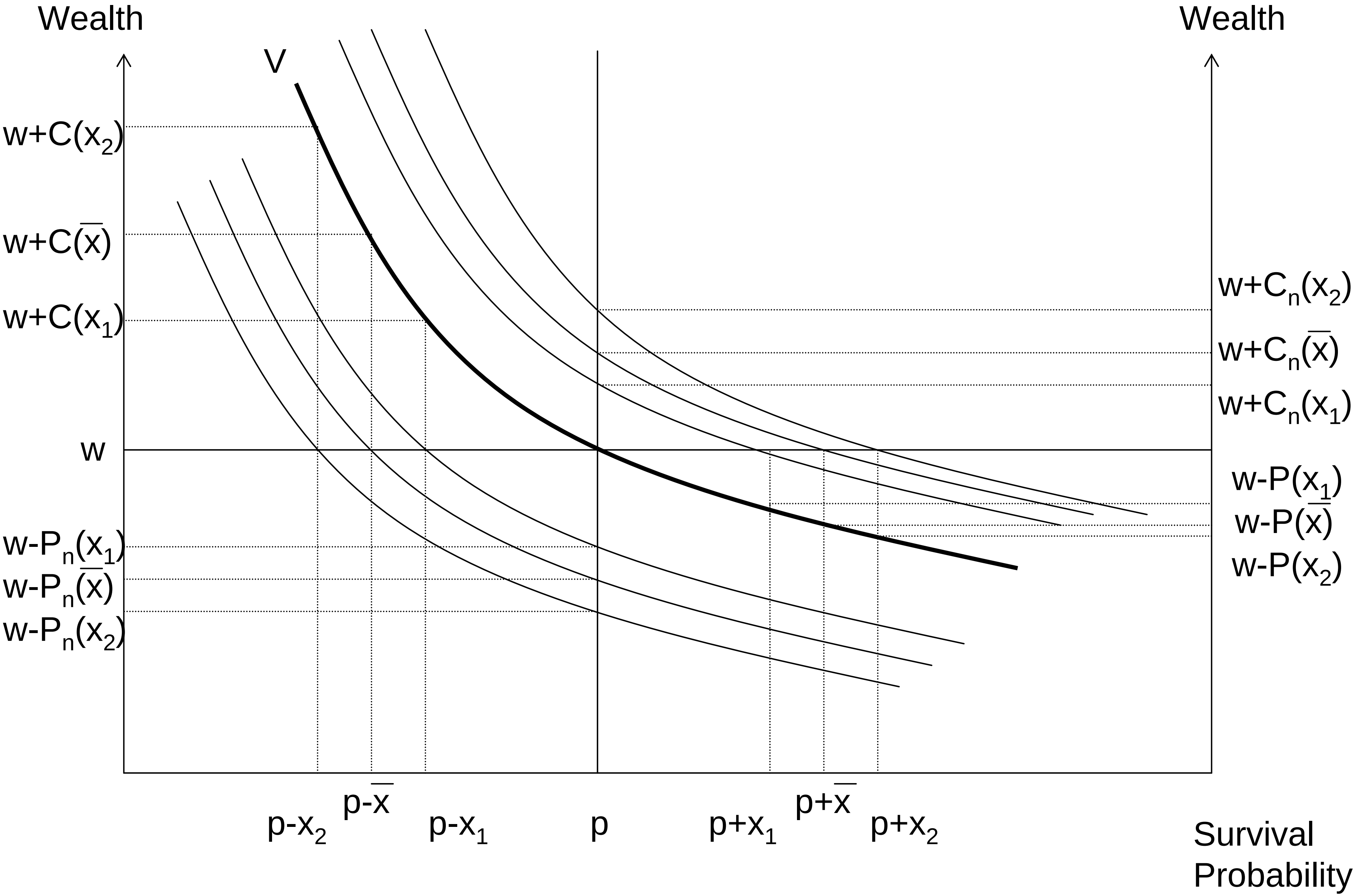


Figure 2: Individual-specific information about risk change increases the average WTA.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