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When people face the risk of death, and when they ascribe no value to their wealth post-death, they over-invest in precautions in order to reduce that risk. There are two main reasons for such over-investment. First, people under risk of death discount their risk-reduction costs by the probability of death following precautions. Second, people facing the risk of death consider the consumption of their wealth when alive to be part of their benefit from risk-reduction. From a social perspective, people's wealth does not cease to exist after death. Therefore, discounting costs by the probability of death and taking into account the benefit of wealth-consumption are socially inefficient.

But more interestingly, even from the perspective of the individual facing the risk of death, the investment in risk reduction is only optimal as a second-best alternative. We show that if people could contract with "reverse insurers", who would inherit their assets upon death while paying them a sum of money during their lifetimes, such contracts would make the insured individuals better off and, more importantly, would align the private and the social incentives to invest in risk reduction. Furthermore, we show how the insights developed in the paper should significantly change the application of "Willingness to Pay" (WTP) as a criterion for valuing life. In particular, we suggest that the WTP be discounted by the ex-post probability of death and that the value of life be determined irrespective of wealth. Finally, we argue that the results derived from traditional tort models for both unilateral and bilateral accidents should be substantially revised when applied to fatal accidents. In particular, we show that in bilateral accidents, contrary to conventional wisdom, negligence and strict liability rules lead to the same inefficient equilibrium. We also demonstrate how liability rules could be modified to increase efficiency.

Introduction

People with no family often do not leave much wealth behind them after their deaths. People *with* family leave, on average, much more.[1] This might seem odd: people without family would be expected to spend less on living expenses than people with family and therefore to leave more wealth. But in fact, it is not strange at all: there is no reason for someone to leave anything after his death, if, as is often the case, the value he ascribes to his wealth after death is less than the value he ascribes to it while alive.[2] Should this bother us? Maybe not. After all, individuals without family choose how much to work and how much to spend, and if they leave no wealth behind after their deaths, this presumably indicates that they planned their lives wisely. In economics terms, they fully internalized all the costs and benefits of their lives and therefore lived efficiently from both private and social perspectives.

But sometimes, when people are subject to risk of death and, in particular, to substantial risk of death, the fact that they ascribe much less value to their wealth after they die than when alive should bother us. In this paper we discuss two reasons why it should bother us. Both relate to investment in reducing the risk of death.[3] The first reason is that people discount the costs of reducing their risk of death by the probability that they will die anyway. We call this the "discounting costs effect". The second reason is that people ascribe a high value to their lives not only because they highly value their lives *as such*, but also because they value the consumption of their wealth while they are alive. That latter value, however, is not necessarily a social value, because other people could consume this wealth as well, once the particular individual under risk dies. Therefore, people ascribe a higher value to their lives than

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[1]   *See* for example Wilhelm (1996) "Hundreds of billions of dollars per year are bequeathed by people in the United States, and about two thirds of this passes from parents to children". Another form of this observation is that people with family often carry life insurance while people without family do not.

[2]   Empirical evidence indicates that the value individuals place on bequests is less than the value they place on consumption during their lives. *See* Viscusi & Moore (1989).

[3]   Analogical arguments can be made with respect to the consumption of goods and services, which are not risk-reducing, under risk of death. We do not pursue these arguments here, since they raise many other concerns which are beyond the scope of this paper.

the social value. We call this the "inflating benefits effect". For the sake of simplicity we will assume throughout the paper that people ascribe no value to their wealth after death, but, as we will explain, our arguments are equally valid in the more general case.[4]

To illustrate and better understand the discounting costs and inflating benefits effects, consider the following example:

> **Example 1. The Operation**. Individual A is seriously ill. He knows his chances of survival are estimated at 40%. A is a wealthy person and has no family. His wealth amounts to $4M. He ascribes no value to his wealth after his death. A decides to spend $500,000 on an operation that will increase his chances of survival to 50% (i.e., by 10%). Is such an investment efficient from a social perspective?

Conventional law and economics wisdom suggests that the answer is yes, since A bears the costs and benefits of his investment. However, upon deeper reflection, no would seem to be the correct answer. The first reason is the discounting costs effect: A's investment of $500,000 does not reflect his true private costs, and therefore it does not and cannot represent the true value A ascribes to his life. In particular, A discounts the $500,000 he is willing to spend by the probability that he will die after undergoing the operation (hereinafter: "ex-post probability of death"), because he ascribes no value to his wealth after his death. So the true private costs to A are only $250,000 ($500,000*50%). From a social perspective, however, the true social costs of A's investment is, of course, the full $500,000 (with no discount for the probability of death). The fact that A ignores the value of his wealth after his death creates a divergence between the private and social goals of maximizing welfare.

The second reason why A's spending on health is socially inefficient is the inflating benefits effect: A ascribes a higher value to his life than what society ascribes to it. Specifically, the value A ascribes to his life is composed of two components: first, the value A ascribes to his life *qua life* and, second, the value A ascribes to his ability to enjoy life *through the consumption of his wealth*. Assume, for example, that the value A ascribes to his life *qua life* is $1M, and the value he ascribes to his ability to consume his wealth is its equivalent in dollar terms, namely $4M.[5] A, who ascribes no value to his wealth after death, does not take into account the simple

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[4]   See *infra* footnote 36 and appendix B.

[5]   In other words, assume that A is risk-neutral with respect to his wealth.

fact that even if he should die and therefore cease to enjoy the consumption of his wealth, other people will consume and enjoy it. Consumption by others of A's resources has, of course, social value. Since A ignores that social value, his decision to invest resources in reducing his risk of death cannot reflect the social value of such risk-reduction. In particular, A's investment in the operation reflects the value of his life *qua life* ($1M) plus the value of his ability to consume his remaining wealth ($3.5M, which is left after spending $500,000 on the operation). But from a social perspective, A's life is worth only $1M. A's ability to consume his wealth has a private, not a social, value, since A's wealth is transferable and can be consumed by other people. Thus, there are two distortions that have induced A to invest $500,000: first, he discounted the $500,000 social costs of risk reduction by 50%, and second, he inflated the social value of his life, which is $1M, by $3.5M. If only social costs and social benefits had determined A's investment in risk reduction instead, he should have spent on the operation no more than $100,000 (10%*$1M), which is the expected social benefit of the operation.

The above two effects imply that individuals will *over*-invest in reducing the risk to their lives relative to the socially efficient level of risk reduction. This argument is distinguishable from the familiar utilitarian argument for redistribution, as we explain at length below in Part I.C. One important distinction is that individuals' overinvestment in reducing risks to their lives is also inefficient from the perspective of the individuals themselves. In particular, A who faces the risk of death would be better off if he could enter into a reverse-insurance contract, under which he would undertake to leave his assets to the reverse-insurer after his death, in return for an undertaking by the reverse-insurer to pay A the amount of the expected value of the inheritance if he survives. As we will demonstrate in Part I.D, if A were to enter into a reverse insurance contract, he would invest no more than $100,000 in reducing his risk of death. In other words, his investment in reducing his risk of death would conform to what society would like him to invest. Thus, as the potential utilization of reverse insurance indicates, A's investment in self-risk reduction in the absence of reverse insurance is not Pareto-optimal.

Should the state intervene and prohibit people from overinvestment in safety? Or should the law generally create incentives for people to behave efficiently under such circumstances? We briefly discuss these questions in Part I.D of the paper and argue that while the state should not intervene, it should facilitate people's entering

into reverse-insurance contracts if they choose to do so. We explain the difficulties in establishing a market for reverse insurance, but argue that it is nevertheless a plausible solution. We also point out that some existing market mechanisms, such as annuities and reverse-mortgage, resemble the reverse insurance contract that we propose.

In Part II of the paper, we take the discounting costs effect and the inflating benefits effect from the individual into the public arena: instead of asking how much rational people should be expected to spend on reducing the risk of death, we ask how much society should spend on reducing such risk. This question is closely related to the question concerning how society should value people's lives. In contrast to Part I, Part II has far-reaching policy implications resulting from our discussion. In particular, we show that the commonly accepted criterion for valuing people's lives, which is based on people's willingness to pay to reduce the risk of death (WTP), is flawed, because it fails to eliminate the two effects identified in Part I. We explain how WTP should be modified in order to serve as a reasonable criterion for valuing people's lives and for allocating public resources in reducing the risk of death.

In particular, we argue that due to the "discounting costs effect", people's WTP to reduce the risk of death by some small amount, say 1%, increases nonlinearly with the initial probability of risk. We therefore argue that the famous nonlinear relationship between WTP and risk does not justify employing higher values for statistical lives when the risk of death is higher, but rather calls for modifying the WTP criterion so as to eliminate the "discounting costs effect".

In addition, we argue that the fact that wealthy people's WTP is higher, on average, than poor people's WTP, which is typically due to the fact that, all else being equal, wealthy people, on average, derive greater enjoyment from life than the poor, is irrelevant to the value society should ascribe to their lives. That is so because the higher WTP of wealthy people stems from the "inflating benefits effect". Therefore, we argue, the WTP should be modified to eliminate wealth effects. We also explain that the different marginal utility of money to the poor and the wealthy does not change this conclusion. Thus, under the modified version of the WTP, the same resources should be invested in reducing the risk of death for both the wealthy and the poor. While this conclusion is commonly supported by distributive justice proponents, we are not aware of any previous support for such a claim from a law and economics perspective.

How do our arguments with respect to the adequacy of the WTP as a criterion map onto the existing literature on the value of life and safety? In the law and economics literature, there is a universal consensus that the relationship between the monetary value of life, as reflected by the WTP criterion and risk, is nonlinear and that this nonlinearity should be taken into account in different legal contexts (see below). We argue, by contrast, that nonlinearity should not matter in valuing people's lives. Additionally, there seems to be agreement in the law and economics literature that wealth should matter in valuing people's lives. Again, our view is radically different. Matters are more complex in the economics literature. There is wide agreement that the nonlinear relationship between the WTP and risk is due, at least in part, to the fact that costs are discounted by the ex-post probability of death, what is sometimes referred to as the "dead-anyway effect". Indeed, several economists have argued that the WTP criterion should be modified accordingly, in a way similar to what we propose (Linnerooth, 1982; Pratt & Zeckhauser, 1996). Many prominent economists, however, still do not seem to recognize that because of the discounting costs effect the WTP is a problematic criterion for valuing people's lives (e.g., Weinstein, Shepard and Pliskin, 1980, p. 384; Stiglitz, 2001, pp. 279-282; Tresch, 2002, pp. 776-77; Viscousi, 2007, Mishan and Quah, 2007, pp. 194-201).[6] For example, one of the main arguments in a recent paper by Philipson, Becker, Goldman and Murphy (2010) is that "existing theoretical and empirical analysis of the value of life does not apply, and often under-values, the value of life near its end and terminal care", because "several factors drive up the value of life near its end *including the low opportunity cost of medical spending near one's death*" (emphasis added).[7] In contrast to

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[6] For example, Mishan and Quah (2007), argue that since the WTP increases with the initial probability of death in increasing rates, the value of statistical life depends on the initial risk of death, and "[O]bviously, any calculated statistical life has no claim to generality and no relation whatever to the value a person places on their own life – which…is likely to be infinite."

[7] The authors conclude that "[a]lthough our analysis was mainly positive, it has important normative implications as well. In particular, it has strong implications for using traditional methods of cost-effectiveness, cost-utility, or cost-benefit criteria when making coverage decisions at private and public health plans. CE analysis has been the major method proposed to evaluate new medical inventions and has been argued to be central in managing new technologies, their adoption, and their impact on health care spending. *Such valuation schemes are often linear valuation methods, which contrasts with our claim that there is an important non-linearity in the valuation of life.*" (emphasis added).

those latter prominent economists, we argue that the "low opportunity cost of medical spending near one's death" should *not* be taken into account in valuing one's life.

More importantly, to the best of our knowledge, economists generally agree that wealth should matter in valuing people's lives. In particular, even Pratt and Zeckhauser (1996), who explicitly recommend that the WTP should be corrected to eliminate the dead-anyway effect, argue that the WTP should "continue to reflect that wealth enhances the utility of living."[8] Economists, therefore, have completely missed the "inflating benefits effect" which implies that wealth should not count in valuing people's lives. Our contribution, in this respect, is novel and much broader, as it runs against the wisdom of both economics and law and economics.

In Part III of the paper, we apply the insights that unfold in the preceding parts to tort law. Law and economics scholars have argued that for efficient deterrence purposes, the wrongdoer should compensate the victim or, in cases of death, his or her survivors, in the amount that the victim would have been willing to pay (or to accept) to avoid (or to incur) the wrongful risk, divided by the ex ante probability that the risk would materialize into harm (that is, compensation should be identical to the value of statistical life) (see, e.g., Posner, 1992; Posner & Landes, 1987; Arlen, 1999; Posner & Sunstein, 2005). Specifically, these prominent scholars suggest that in wrongful death cases, damages should reflect the wealth of the victim and the probability of death, since these parameters affect the WTP, so that the higher the risk of death, the higher the damages should be (see, e.g., Posner & Sunstein, 2005, pp. 587-590; Arlen, 1999, p. 709)[9], and the wealthier the victim, the higher the damages should be (see, e.g., Posner & Sunstein, 2005, pp. 567-568). In addition, law and economics scholars assume that a perfectly operating negligence system, which properly sets the standard

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[8]   The difference between our arguments and Pratt and Zeckhauser's (1996) approach stems from their implicit assumption—which we hold as wrong—that upon death, the individual's wealth is gone and does not remain in the social pool.

[9]   Furthermore, Posner (1992, p. 221) and Landes and Posner (1987, p. 189) argue that "the non-linear relationship between the risk of death and the value of life" entails that in accidental as well as intentional wrongful-death cases in which the risk of death is high, the optimal damages awards should be very high. This helps to explain, in their view, the overlap between criminal and tort law. Criminal law is required if tort law is insufficient to induce efficient behavior. Since optimal damages are very high in these cases while actual damages are lower, criminal law kicks in and non-monetary punishment is used.

of care, will create socially efficient incentives for victims who are exposed to risk of death, since they expect to bear the full costs of the accident.

Once one has accepted the discounting costs effect and inflating benefits effect identified in the paper, one understands that the conventional law and economics analysis is misguided. Thus, in sharp contrast to that analysis, we suggest that in awarding damages in wrongful death cases, ignoring the magnitude of the risk the victim was subject to as well as his wealth is consistent with efficiency. We also explain that under both strict liability and negligence rules, and in opposition to conventional law and economics wisdom, victims who are subject to risk of death will not take optimal care but rather excessive care. We suggest modifications to prevailing law to better align victims' incentives with the goal of minimizing the social costs of accidents.

The analysis and results of this paper are qualified in one important respect. We ignore any externalities, positive or negative, that may be associated with the lives of individuals. In particular, we ignore the value that other individuals, such as family members and friends, place on the life of an individual who is under risk of death. These externalities could definitely affect the results of the paper.

I. Self-Risk-Reduction

Conventional law and economics suggests that rational people take efficient precautions to reduce the risk of death to themselves, so long as this does not produce external effects on others.[10] This view is inaccurate, as we show in this Part of the paper, as long as people ascribe less value to their wealth upon death than when alive. For the purpose of simplicity and clarity, we will assume that people ascribe no value to their wealth upon death. Formal proofs of the arguments presented below in the case where precautions are continuous can be found in Appendices A and B.

A. Discounting-Costs Effect

Individual A, in Example 1, is willing to spend $500,000 on an operation that would increase his chances of survival from 40% to 50%. Under current law, A is free to do

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[10]   See Viscusi, 2007, p. 598. Compare also Posner (1992, p. 163: "When … the person taking precautions and the person who may be injured if they are not taken are the same, the optimal precautions will be achieved without legal intervention.").

so. This freedom is a manifestation of A's autonomy: he is entitled to decide how to use his resources, so long as he does not harm anybody else.

Why is A willing to spend so much money on medical care? One possibility is that since he is at risk of death, he is much more aware of the value of his life and perhaps fears death more than before. If this was the only reason for A's decision to spend $500,000 on healthcare, such spending would not give rise to any efficiency concern. But it could also be that A decided to spend $500,000 on healthcare simply because he realized that if he were to die, that $500,000 would be worthless to him. Indeed, as a rational human being, A would not spend all his resources on improving his chances of survival, since there is a non-trivial chance that he will survive in the end, and he therefore needs to leave resources for his own use should he survive.

Thus, for A, the private costs of the operation are $500,000 discounted by the ex-post probability of his death, which is 50%, that is, the private costs for A are only $250,000 ($500,000*50%). From a social perspective, however, the costs of the operation are the full $500,000, with no discount. Consequently, from a social perspective, A will have invested excessively in medical care. A divergence thus arises between the private and social goals of promoting welfare, stemming from the fact that A ascribes no value to his wealth after his death whereas society values A's wealth not only before but also after his death.

Note that the divergence between A's private goal and the social goal of reducing A's risk of death is not contingent on the magnitude of the risk A expects to reduce or on his preexisting risks. Instead, it depends on the ex-post probability of death. Thus, A would be willing to spend far less money to reduce his risk of death if his ex-post probability of death were 10% rather than 50%. Interestingly, whenever A takes precautions that are expected to reduce his risk of death to zero, he effectively bears the full social costs of his investment, and on this account, A is expected to behave efficiently also from a social perspective. Indeed, when the ex-post probability of death is zero, the discounting-costs effect completely disappears.

An analogical but more drastic situation is that of individual B, who has no family either and is just about to die. Suppose B could extend his life by a day at the cost of his entire wealth. Since the assumption is that B ascribes no value to his wealth after death, there is no reason for him not to spend his entire wealth on extending his life by one day. It is clear, however, that what B spends to live for one more day does

not reflect the true value he ascribes to living another day. Rather, it reflects the fact that wealth has no value for B once he dies.[11]

In sum, the problem of overinvestment in safety due to the discounting costs effect is acute in situations of *substantial* risk of death, such as serious illness, when a substantial risk remains even after precautions are taken to reduce it.[12] The problem is much less acute when the risk of death is minor, or even when it is substantial, but the ex-post probability of death is low. However, as we will demonstrate in the next section, there is another reason why individuals invest excessively in safety, which holds even when the ex-post probability of death is very small or even zero.

B. Inflating-Benefits Effect

Thus far, we have explained that individuals will spend too much on self-risk-reduction because the private costs of doing so are lower than the social costs. At the same time, we implicitly assumed that the value the individual ascribes to his life represents its social value. In this section, we question this assumption and show that there is another reason why individuals will spend on safety in excess of what is socially justified.

Any decision to spend on risk-reduction rests not only on the costs of the reduction, but also on its benefits. In the case of risk of death, the benefit of risk-reduction to the individual depends on the value he ascribes to his life. The value an individual ascribes to his life is comprised of two components: (1) the value of leisure (or, more generally, of consuming "goods" that have no marginal social costs), which we call the value of life *qua* life, and (2) the value of life stemming from the individual's consumption of wealth during his lifetime. From a social perspective, only the former component matters and the latter should be ignored. Accordingly, the individual will spend more on reducing his risk of death than the social value of reducing that risk. Let us clarify the difference between the two components.

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[11] The case at hand should be distinguished from that of a person who has lost his eyesight or other capacities for enjoying life and, as a result, is willing to spend much more money than previously on purchasing life-enjoyments that are still open to him. Such a person, had he known in advance that he would lose these capacities for enjoying life, would have tried to save enough money over the course of his life to purchase the life-enjoyments that remain available to him in his time of difficulty. S*ee* Viscusi (1978).

[12] There is some empirical evidence showing that spending on medical care near death is much higher than in other circumstances. *See* Philipson et al. (2010), Nadler et al. (2006).

The value of life qua life is presumably independent of wealth. This does not mean that it is universally identical for all people. Some people will value life more than others, regardless of their wealth. Therefore, people with the same wealth and same preferences with respect to other goods they consume could decide to spend different amounts of money on healthcare. This, of course, raises no efficiency concerns.[13]

The second component of the value of life for individuals is the value A ascribes to his ability to enjoy life *through the consumption of his wealth*. Wealth enhances the utility of living because it allows people to enjoy the consumption of more goods and services. Thus, wealthy people, if they ascribe no value to their wealth after death, will, on average, ascribe greater value to their lives than poor people and therefore will spend more on self-risk-reduction. But the portion of wealth spent on risk-reduction due to an individual's desire to enjoy his remaining wealth is a social waste. For once an individual has died, other people will consume and enjoy his remaining wealth. Therefore, from a social perspective, it is inefficient to spend any resources on increasing the probability that that individual rather than others will enjoy the consumption of his wealth.

To illustrate how the inflating benefits effect and the discounting costs effect work together, consider Example 1 again. A ascribes a value of $1M to his life *qua life*, and a value of $4M to his ability to consume his wealth. Accordingly, if A does not undergo the operation and remains with a 40% chance of survival, he will enjoy an expected utility of $2M (40%*($1M+$4M)). However, if A does undergo the operation, spending $500,000 for that purpose, he will increase his chances of survival to 50% but reduce his wealth to $3.5M. As explained above, the $500,000 costs are discounted by the probability that he would die anyway. As can now be seen, the benefits to A of undergoing the operation reflect not only the value of life qua life ($1M), but also the benefits of A's ability to consume his remaining wealth ($3.5M). So if A decides to undergo the operation, he will enjoy an expected utility of $2.25M (50%*($1M+$3.5M)), which is more than what he would enjoy ($2M) without the

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[13]   Usually, however, it is assumed that individuals value their lives similarly. We will adopt this assumption in our analysis. Empirical studies indicate approximately the same value of statistical life in the U.S.A., Australia and Japan. See Kniesner, Viscusi, Woock & Ziliak (2006).

operation. Therefore, from A's perspective the investment in the operation is efficient.[14]

From a social perspective, a completely different calculation applies. The operation would increase A's chances of survival by 10%, and the social value of A's life is $1M. Thus, from a social perspective the benefits of the operation are $100,000 (10%*$1M) only, and therefore this is also the maximum amount that should be spent on the operation. Note that if only the discounting costs effect had been considered, and the inflating benefits effect ignored, one should have concluded that since A was willing to spend $500,000 on the operation, spending $250,000 (the discount is 50%) would not be excessive from a social perspective. When both effects are considered, that conclusion is proven wrong.[15]

The divergence between the private and the social optimal investment in reducing the risk of death due to the inflating benefits effect merits two qualifications. First, sometimes individuals have resources, such as wedding rings, which are more valuable in their hands than in the hands of others. In the extreme case, there are resources that only the individual who possesses them really values. Under such circumstances, one can no longer argue that it is socially inefficient to invest in increasing the probability that that individual rather than others will enjoy the consumption of those resources.

Second, there could be another element that affects the value of life, which we will not discuss here, namely, *productivity*: since some people are more productive than others, they may generate more goods and services, and may derive greater enjoyment from life. Therefore, presumably, their lives should be ascribed a higher social value. Let's assume for the sake of discussion that that is correct. A possible proxy for people's productivity could be their income. Arguably, people whose

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[14]   Indeed, the maximum A would be willing to spend on the operation is $1M. That would leave him with an expected utility of $2M (50%*($1M+$3M)), exactly what he would have without the operation.

[15]   As the above analysis illustrates, the divergence between the private and the social optimal investment in reducing the risk of death due to the inflating benefits effect does not depend on the existing wealth of the individual, but on his *remaining* wealth after investing in risk reduction. Therefore, if A spends all of his wealth on risk reduction, he enjoys no more than the social benefits of risk reduction, and on that account his behavior is efficient also from a social perspective.

income is higher are, on average, more productive, and the value of their lives to society is greater than the lives of lower-income earners. Since high income is often correlated with wealth, the high value a wealthy individual ascribes to his life because of his wealth is correlated with the value society ascribes to his life because of his productivity. In other words, the behavior of the wealthy individual, who invests more in reducing the risk to his life because he has that much more wealth to consume in his lifetime, should not be considered inefficient from a social perspective, not because of his wealth, but because of his high productivity.

Without delving too deeply into the productivity argument, we note that wealth and income are not identical, and that economists who endorsed willingness to pay as a criterion for valuing people's lives employed wealth—and not high income—as the relevant factor in making such a valuation (Pratt and Zeckhauser (1996)).

C. Self Risk Reduction versus Redistribution

As we have argued above, individuals will over-invest in reducing their risk of death, since they ascribe no value to their wealth after death, although its social value is positive. We explained that since individuals ascribe no value to their wealth after death, they discount the costs of precautions by the ex-post probability of death and inflate the benefits of their living.

At first blush, our argument seems similar to the classical utilitarian argument for redistribution ("the redistribution argument"). While there is some superficial resemblance between the two, they are distinct from one another in several important respects.

As is well-known, if all individuals share the same utility function, and if that utility function exhibits a decreasing marginal utility of wealth, then maximizing social welfare (defined as the sum of utilities of individuals) calls for a redistribution of wealth from the rich to the poor. When no social costs are involved in implementing the redistribution, then under the above assumptions, full equality in the distribution of wealth is socially desirable. In reality, of course, there are always costs in redistributing wealth, and the big question in the public finance literature concerns the optimal tradeoff between equality and efficiency. The redistribution argument supports the utilization of the tax and transfer systems as redistributive tools for maximizing social welfare. These tools are needed, because self-interested individuals will not engage voluntarily in the redistribution of their wealth, since they care only

about their own utility, but not that of others. Thus, when an individual consumes his wealth he does not take into account that others could consume that same wealth and potentially derive greater utility from doing so.[16]

The first distinction between the redistribution argument and ours relates to *the utility function of individuals*. While the redistribution argument is valid under the assumption that the utility function of individuals exhibits a decreasing marginal utility of wealth,[17] our argument is valid even without that assumption. Thus even if all individuals had the same linear utility function, so that the consumption of any specific good by individual A would always entail the same social utility as the consumption of that same good by individual B, making redistribution unnecessary, our argument would still hold. The reason for this is that even if everyone had the same linear utility function, individuals would still ascribe no utility to their wealth after death and would therefore still over-invest in risk-reduction.

The second distinction between the redistribution argument and ours relates to the *optimal utilization of the tax and transfer systems*. If optimal redistribution were to be achieved through the tax and transfer systems, the redistribution argument would no longer be relevant, since further redistribution would not enhance social welfare. Indeed, once optimal redistribution has been achieved society, by definition, should no longer worry whether individual A is consuming a good that individual B has greater need of. Nevertheless, our argument still holds: the optimal redistribution of wealth does not repair the inefficiency which is triggered by the fact that individuals ascribe no value to their wealth after death. To illustrate, suppose there are no costs in redistributing wealth, so that optimal distribution is equal distribution. Individuals facing the risk of death will still invest excessively in reducing that risk, for the reasons identified in this paper.

Furthermore, and as implied by the two distinctions made above, our argument, but not the redistribution argument, *applies equally to rich and poor alike*.

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[16] Observe that if individual A derives more utility from a certain good than another individual B who owns the good, then presumably A could buy the good from B. However, this assumes that there are no wealth constraints. Redistribution aims at increasing or maximizing social welfare exactly when there are wealth constraint problems.

[17] Even if the utility function of individuals is linear, redistribution can be relevant if the social welfare function itself exhibits an aversion to inequality, that is, if social welfare is higher when *utility* is distributed more equally among individuals.

According to the redistribution argument, it is only the consumption by the rich, but not the poor, which could raise a social welfare concern. Therefore, the right direction for the redistribution of wealth is from the rich to the poor, but not vice versa. Conversely, according to our argument, both the rich and the poor over-invest in risk reduction when they are under risk of death,[18] even though the distortion is larger, on average, with the rich than with the poor.[19]

Finally, the redistribution argument calls for determining a social sub-optimal distribution of wealth in society, while our argument, as we make clear in the next Section, also calls for determining a sub-optimal allocation of resources by the individual over his lifetime. This distinction between the two arguments dictates different responses at the policy level. The response to the redistribution argument could be a compulsory redistribution of wealth, which is typically achieved through the tax and transfer systems. The reason why the transfer of wealth has to be compulsory is because redistribution benefits some people at the expense of others, and the latter will not voluntarily sign up for such a transfer. Conversely, the response to our argument, as we explain in the next Section, is to allow individuals to utilize market mechanisms in order to reduce their own incentives to excessively invest in self-risk reduction, when facing a high risk of death. The self-interest of individuals in solving that problem, which is created by both the discounting costs effect and inflating benefits effect, is one good reason why the state should not use compulsory means in order to force individuals to invest efficiently in self-risk reduction.

D. Correcting the Inefficiencies

When individual A is under risk of death, he over-invests in self-risk-reduction. This is a problem not only for society, but also for A himself (i.e., A himself may agree that he is investing too much given the circumstances). The problem stems from the fact that the marginal value of wealth to A depends on the state of the world, in particular on whether A is going to live or die. Since A ascribes no value to his wealth after death, and since he has a strong preference for living, he will invest excessively in protecting his life. Thus, in Example 1, A invested $500,000 and was actually

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[18]   A qualification to this is those individuals who are so poor they do not have enough resources to invest in risk reduction. See also appendices A and B.

[19]   The distortion is larger with the rich, since the inflating-benefits effect increases with the increase in the individual's wealth.

willing to invest up to \$1M in an operation for a 10% risk reduction, while the maximum amount that is justified from a social perspective is only \$100,000. As will be explained below, a market mechanism, which we call "reverse-insurance", would make A better off, bring down A's investment in risk reduction, and correct the social inefficiencies. Thus the "reverse insurance" mechanism shows that A's investment in self-risk reduction in the absence of reverse insurance is not Pareto-optimal. (A formal proof of these assertions can be found in Appendix C). Alternatively, if market mechanisms fail, an individual's over-investing in self-risk-reduction can be corrected by using direct steps. We do not recommend such steps.

1. Market Mechanisms

The straightforward solution for the problem of over-investment in safety is reverse-insurance (RI).[20] Under a risk of death, A would enter into a contract with the reverse-insurer, under which he would undertake to leave the reverse-insurer his wealth after his death, in return for an undertaking by the reverse-insurer to pay A, if he survives, an amount of money based on the expected value of the inheritance.

The RI contract would definitely make A better off, because A while still alive would be paid the value of his wealth after death by the reverse-insurer, something he would not have enjoyed without the RI. In addition, with the RI, A would have lesser incentive to spend on risk reduction than without it. The reason for that is because the less A spends on reducing the risk of death, the higher the expected value of the inheritance to the reverse insurer, thus the more the reverse insurer will be willing to pay A if he survives. But more importantly, the RI aligns A's incentives with the social interest. In the absence of RI, A's excessive investment in safety results from a market failure: since A ascribes no value to his wealth after death, he behaves *as if* the value of his wealth after death is zero, while in fact it has a positive value for society. The RI corrects this market failure by paying A while still alive (i.e., if A survives) the expected value of his wealth after his death. In so doing, the RI makes A ascribe to his wealth after death its full value to society. It makes A fully internalize all the costs and benefits of his investment in self-risk reduction, and provides him with efficient incentives from both a private and social perspective.

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[20]   Cf. Friedman (1982); Pratt & Zeckhauser (1996), Lee Fennell (2009).

To illustrate how the RI works, consider Example 1 again. Without the operation, A's expected utility is $2M (40%*($1M+$4M)). Since the probability of survival for A is low (40%), he does not enjoy the full value of his wealth. Indeed, the expected utility he derives from his wealth is only $1.6M (40%*$4M). However, A could enter into a contract with a reverse insurer under which he would undertake to leave the reverse insurer his wealth if he dies. This undertaking has an expected value to the reverse insurer of $2.4M (60%*$4M). Assuming the RI is actuarially fair, the reverse insurer, in return for A's undertaking to leave him his wealth, would promise to pay him $6M in the event that the risk does not materialize and A survives, which has an expected value of $2.4M (40%*$6M) for A. Thus, the RI increases A's expected utility from $2M to $4.4M, that is, by $2.4M. Together with the expected value of his wealth, which is $1.6M (40%*$4M), the RI puts A in a position to enjoy the full value of his wealth, which is $4M ($1.6M+$2.4M).

Thus, the RI removes the source of the problem that we identify in this paper, namely, the fact that A does not ascribe any value to his wealth after death. With the RI, A takes full account of the value of his wealth after death. As a result, A would not discount the costs of taking precautions nor inflate the benefits of living, and his behavior would align with the social interest. As we shall now demonstrate, if what A had to pay for the operation was exactly $100,000, which is its social value (10%*$1M), with RI, he would be indifferent whether or not to undergo the operation. That, of course, would occur only if the reverse insurer conditioned the payment to A on the expected value of the inheritance, which depends, in turn, on A's investment in risk reduction. Thus, if A underwent the operation and paid $100,000 for it, the expected amount of the inheritance for the reverse insurer would be $1.95M (50%*$3.9M). As a result, the reverse insurer would pay A if he survived $3.9M ($1.95M/50%), which has an expected value of $1.95M (50%*$3.9M). Therefore, the expected utility that A enjoys with the operation would be $4.4M (50%*($1M+$3.9M+$3.9M)), which is exactly the same expected utility he enjoys without the operation.

In sum, since the RI puts A in a position in which he ascribes to his wealth its full value regardless of whether or not he dies, the private benefit to A in increasing his chances of survival by 10% are $100,000, while the private costs of doing so are the full costs. Therefore, if the costs of the operation are lower than $100,000, A

would choose to undergo it, and if the costs of the operation are higher than $100,000, he would decline it.[21]

Note that A could enter into RI contract even at an earlier stage, before facing any risk of death. Under such an arrangement, A would promise the reverse insurer that if he finds himself at risk of death, he will invest in risk-reduction as though he attributes a given value to his wealth after his death. The reverse insurer would acquire the right to inherit A's estate and would pay him, in return, a certain amount of money, based on the expected value of the inheritance. Once again, such an arrangement would solve the problem of excessive investment in self-risk reduction, for both A and society.

When would be the optimal time for A to receive payments from the reverse insurer under the latter arrangement? Consider the scenario of Example 1 in which, at a certain point in time, A discovers that his chances of survival are low. In that case, from A's ex ante perspective, he would be better off without the RI payments; at this point in time, it would be better for A—again, from his ex ante perspective—to have less resources for risk-reduction than what he would have but for the RI payments.

If, however, A survives he is left with less wealth than what he would have had if he had not been subject to the risk of death to begin with. In these circumstances, A would have been better off receiving the RI payments to put him as close as possible to the situation he would have been in had the risk not emerged to begin with. One could say that, in a way, the anti insurer functions here as an insurer more than reverse insurer since it insures A by keeping his standard of living at the level it would be at absent the risk.

The RI mechanism is not easy to implement. The main impediment would be moral hazard. Note that under risk of death, A would have an incentive not only to

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[21]   To understand why the reverse insurance corrects not only the discounting costs effect but also the inflating benefits effect, consider an asset that is transferable from A to B, in the sense that both A and B ascribe the same value to it. Assume now that A can take costly steps to prevent the transfer. Those steps are a waste from a social perspective (assuming the transfer does not distort incentives to create the asset in the first place). But more importantly, A and B would have strong incentives to enter into a contract according to which A would not take those steps and B would compensate him for the increased likelihood that the asset would be transferred to B. In short, such a contract would create a surplus, equal to the amount of the saved costs, that A and B could share; such a contract would therefore make both A and B (weakly) better off and consequently would constitute a Pareto improvement.

over-invest in risk reduction but also to over-consume, thereby reducing the expected value of the inheritance. To avoid this obstacle, the reverse insurer and A should agree on how A will behave when he is under risk of death and afterwards if the risk disappears. If the risk does arise, the reverse insurer should be able to monitor A closely to make sure he complies with his contractual obligations. Those obligations would relate mainly to the measures of risk-reduction that A would be allowed to take when at risk of death, as well as to his consumption practices under such a risk. Alternatively, the reverse insurer and A can agree that the amount that A would get if he survives would depend on his investment in risk-reduction. The reverse insurer also needs information for pricing. Without sufficient information and with the resulting adverse selection, the RI market would unravel. RI is therefore costly, but under certain circumstances, not impossible.

In the real world there are various arrangements, which are motivated by the same concern which could trigger the emergence of RI, annuities being a major example. People pay annuities firms during their lifetimes to receive annuities until they die. The annuities are paid at a level that allows the insured individuals to consume and reduce risks of death at the level they choose. But people do not regularly use all their resources to buy annuities. Therefore, the problem of over-investment in risk-reduction (and consumption) does not disappear. Furthermore, the firm paying the annuities does not acquire inheritance rights from the individual purchasing the annuities. Theoretically, an individual could invest all of his resources in buying annuities, and those annuities would provide him with the living conditions he wants. Under such circumstances, the annuities and RI converge.

Reverse mortgage is another market mechanism that resembles RI. Under reverse mortgage, a loan, either as a lump sum or in periodical payments, is offered to a homeowner (usually a senior person), who undertakes to return the loan when he dies (or when the home is sold or when he leaves it, say, to live in a nursing home). As with RI, individuals receive resources while still alive and pay for them after death, when they ascribe no value to their wealth.

Finally, in the absence of RI, one should expect to see *mutual inheritance arrangements* between individuals. This kind of arrangement is common between spouses, but quite rare among friends or complete strangers. The potential harm of such arrangements to relationships may explain why we rarely see them among friends; but it cannot explain why they are not prevalent among strangers. Moral

hazard can hardly be the reason for the dearth of such arrangements among strangers, because two individuals who ascribe no value to their wealth after death are better off with mutual inheritance arrangements than with no arrangement at all, even if they both have good reason to spend as much wealth as they can before they die. Some jurisdictions, however, would prohibit such arrangements.[22]

2. State Intervention

Should the state intervene and regulate, or tax, the measures people are allowed to take when under substantial risk of death to reduce that risk? We believe that the answer is probably no, for reasons related to the theory of the second-best. Aside from the infringement of individual autonomy and privacy, which may be sufficient reason in itself to preclude state intervention, any intervention in people's risk-reduction measures when at risk of death would encourage them to shift resources from risk-reduction to consumption. In other words, instead of over-investing in risk-reduction, they would over-consume. This problem could theoretically be resolved if consumption were regulated, or taxed, but for both substantial and practical reasons, that is not a reasonable solution.[23]

II. Willingness to Pay and the Value of Life

In this Part of the paper, we turn from the private to the public arena. In this latter context, it is the state (or the government), not the individual, that should decide how much to invest in people's safety and accordingly needs to value people's lives. This difference could be normatively significant: while a strong argument is available against state interference in individuals' choices regarding their resource investment in their own safety, a much less compelling one can be made to oblige the state to allocate its scarce resources to people's safety according to the private, rather than the social, costs and benefits of doing so.

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[22]   *See* RESTATEMENT (THIRD) OF PROPERTY (WILLS AND OTHER DONATIVE TRANSFERS) §10.1 cmt a (2003).

[23]   In addition, if the state provides public medical care and prohibits private care, it can control the amount spent on major risk-reduction measures.

We discuss two questions, both of which relate to the adequacy of the WTP criterion for valuing people's lives.[24] First, should the discounting-costs effect be taken into account to derive the social value of people's lives from their WTP? Second, should the inflating-benefits effect be taken into account to eliminate wealth as a factor in valuing people's lives? We discuss each of these two questions in turn below.

A. Discounting-Costs Effect

> **Example 2. Reducing Risks by the State**. Suppose individual A is under a 90% risk of death, while individuals B and C are each under 30% risk of death. Suppose the state has a choice: either reduce the risk of death to individual A by 20% (from 90% to 70%) or reduce the risk of death to individuals B and C by 20% each (from 30% to 10%). All else being equal, could it make sense, from a social welfare perspective, to prefer the former over the latter?

From an ex-post perspective, the answer to this question should be no: the latter option reduces more risks to society and may be expected to yield fewer dead people than the former option. But from an ex-ante perspective, and if the WTP criterion is employed, the answer could be yes, for the following reason: As explained in Part I, individuals who ascribe no value to their wealth after death discount their costs, or in this case, their willingness to pay, by the ex-post probability of death. Thus, A discounts his costs by 70%, while B and C discount their costs by only 10%. Therefore, A's WTP would be much higher than the total of both B's and C's WTP.

The exact ratio between the WTP of A on one hand and that of B and C on the other depends not only on the ex-post probability of death, but also on the magnitude of the risk reduction and the wealth of the individual under risk.

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[24] The federal government instructed heads of executive agencies (such as the NSA, Secret Service, DEA, FBI, OSHA, FAA and more), in Circular A-4 of the Office of Management and Budget (OMB) (2003), to implement the WTP criterion for evaluating performance of the agencies. "Since agencies often design health and safety regulation to reduce risks to life, evaluation of these benefits can be key part of the analysis. A good analysis must present these benefits clearly and show their importance. Agencies may choose to monetize these benefits. *The willingness-to-pay approach is the best methodology to use if reductions in fatality risk are monetized*" (at p. 29, emphasis added).

To understand this better we develop, under simplifying assumptions, a simple formula to compute the WTP (see also in Appendix D). Let's denote the value individual A ascribes to his life qua life as L, the probability of his survival (death) as p $(1-p)$, the magnitude of the risk reduction as r $(<1-p)$, A's wealth as w, and A's (maximum) willingness to pay to reduce the risk from $1-p$ to $1-p-r$, as c.[25] The WTP, c, which reflects the "compensating variation", is given implicitly by equating A's expected utility after the risk reduction (the RHS of (1)) with A's expected utility before the risk reduction (the LHS of (1)):

(1) $p(L+w) = (p+r)(L+w-c)$

Solving for c we get:

(2) $c = \dfrac{r(L+w)}{p+r}$

We now apply this formula to Example 2. Suppose that each of the three individuals, A, B and C, values his life qua life at one million dollars ($L = \$1M$), and has two million dollars in wealth ($w = \$2M$). Recall that A's initial probability of death is 90% ($1-p = 0.9$), his initial probability of survival is therefore 10% ($p = 0.1$), and the risk reduction is 20% ($r = 0.2$). A's WTP to reduce the risk to his life from 90% to 70% is therefore (subscripts refer to the relevant individual):

$$c_A = \frac{0.2(\$1M + \$2M)}{0.1 + 0.2} = \$2M$$

Now recall that the only thing that distinguishes B and C from A is the fact that their initial probability of death is 30% ($1-p = 0.3$), and their probability of survival therefore 70% ($p = 0.7$). B's and C's WTP to reduce the risk to their lives from 30% to 10% is therefore:

$$c_{B,C} = \frac{0.2(\$1M + \$2M)}{0.7 + 0.2} = \$0.667M$$

and in total both are willing to pay \$1.33M (\$0.667 x 2).

As can be seen from the formula (2), if all three individuals have the same wealth and ascribe the same value to their lives, the ratio between their ex-post probabilities of survival is equal to the inverse of the ratio between their WTPs:

25   We allow c to be greater than w, but not more than w+L. So we ignore problems of wealth constraints.

$$(3) \quad \frac{c_A}{c_B} = \frac{p_B + r}{p_A + r}.$$

Thus, under the WTP criterion, all else being equal, society would do better to invest in reducing the risk to A, rather than to B and C, because A's willingness to pay to reduce his risk by 20% is three time higher than B's and C's willingness to pay to reduce their own risks by 20%. Needless to say, from a social perspective that would clearly be a mistake: society would be better off with a risk reduction of 40% (the total risk reduction of B and C) than with one of 20% (the risk reduction of A). The discounting-costs effect which creates the divergence between A's WTP on the one hand, and B' and C's WTP on the other, should be taken into account to derive the social value of people's lives from their WTP.

Example 2 and its analysis imply that the WTP to reduce the risk of death by a small percentage, say by 1%, is nonlinear in relation to the initial probability of death. This means not only that the higher the initial probability of death the higher is the WTP to reduce that probability by a small percentage, but also that the WTP to reduce the probability of death by a small percentage increases with the initial probability *in increasing rates* (for a formal proof see Proposition 5, Appendix D). This, however, does not imply, as some prominent law and economics scholars argue, that the WTP to avoid or eliminate risk altogether is nonlinear with respect to the risk.[26] Quite to the contrary, the discussion and the formula developed above indicate that when risks are eliminated, that is, reduced to *zero*, the discounting-costs effect disappears and, therefore, with risk neutrality and no cognitive biases, individuals' WTP rises *linearly* with the magnitude of the risk eliminated. To see this, observe that if the risk is eliminated, that is, if r is equal to $1 - p$, then (2) becomes:

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[26]   *See* Posner (*Catastrophe*, pp. 166-7), for example, who states that "In other words, the function that relates risk to the cost that one is willing to pay to avoid it is probably asymptotic, as in $v = r/(1-r)^{10}$," where v is the WTP and r is the magnitude of risk. Similarly, Posner and Sunstein (p. 589) argue that "Suppose that people would be willing to pay \$60 to eliminate a risk of 1/100,000. From this it does not follow that people would be willing to pay \$6,000 to eliminate a risk of 1/1,000, or \$60,000 to eliminate a risk of 1/100, or \$600,000 to eliminate a risk of 1/10. It is plausible to believe that people's WTP to reduce statistical risk is non-linear. As the probability approaches 100 percent, people become willing to pay an amount for risk reduction that rises nonlinearly to 100 percent…" But those scholars could have other reasons to explain the nonlinearity (such as risk aversion and cognitive biases).

(4) $c = (1-p)(w+L)$

Consequently, the WTP to eliminate a risk of death is a linear function of the probability of death. To illustrate this, consider the following example.

> **Example 3. Eliminating Risks by the State**. Suppose individual A is under a 50% risk of death, while individuals B and C are each under 30% risk of death. Suppose the state has a choice: either eliminate the risk of death to individual A or eliminate the risk of death to individuals B and C. All else being equal, could it make sense, from a social welfare perspective, to prefer the former over the latter?

Here too, as in Example 2, from an ex-post perspective, the straightforward answer is no. If, however, there was a nonlinear relation between the WTP to eliminate the risk of death and the magnitude of the risk, and the WTP criterion had been employed, the answer could have been yes. However, once risk neutrality and non-cognitive biases are assumed, the application of formula (4) indicates that the WTP to eliminate risk increases linearly with the magnitude of the risk. In particular, assuming still that $L = \$1M$ and $w = \$2M$, A's WTP to eliminate risk of death of 50% is \$1.5M ($c_A = (1-0.5)(\$1M + \$2M) = \$1.5M$) while B's and C's WTP to eliminate risk of death of 30% is \$0.9M ($c_{B,C} = (1-0.7)(\$1M + \$2M) = \$0.9M$), or in total \$1.8M. Therefore, in cases where the state is contemplating the elimination of risks, the WTP criterion, *at least from the perspective of the discounting-costs effect*, will lead to socially efficient results. The explanation for this is that the discounting-costs effect depends on the ex-post probability of death, and once the risk of death is eliminated this effect vanishes.[27][28]

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[27] The proposition that the WTP to eliminate risk is linear in relation to the initial probability of death, while the WTP to reduce risk by a small percentage is nonlinear, may appear confusing. The reader may wonder, for example, whether the WTP to reduce the risk of death by a certain percentage is additive, in the sense that the WTP to reduce the risk of death by, say, 10% is equal to the sum of the WTP to reduce the risk of death by 5% and the WTP to then reduce the risk by an additional 5%. As we show in Appendix D, that is indeed the case. The reader may also wonder whether the WTP to reduce the risk of death by a certain percentage may be higher than the WTP to eliminate the risk completely. Again, as we demonstrate in appendix D, that is impossible. The reader should realize, however, that knowing the WTP of an individual to reduce the risk of death by, say, 1% as a function of the initial probability of death does not tell us, at least not directly, that individual's WTP to reduce the risk of death by, say, 10%. That is because the WTP is a function not only of the initial probability of death, but also of wealth, and

B. Inflating-Benefits Effect

Poor people are commonly more often exposed to risk of bodily injury than wealthy people. One reason for this phenomenon is that the poor have less political power than the wealthy. But even absent this disparity, exposing poor people to risks is always cheaper—in terms of tort damages—than exposing wealthy people to the same risks. This is principally because damages for lost income comprise a major portion of the awards granted for bodily injury, and the lost income of the poor is lower, on average, than that of the wealthy. We are not considering here the question whether lost income could be a good proxy for productivity or whether society should ascribe a higher value to the lives of high-income (and, therefore, productive) individuals. Instead, we argue that wealth *per se* should not be a criterion for valuing people's lives.

Applying the WTP as a criterion for valuing people's lives would inevitably lead to the conclusion that the lives of wealthy people are worth more than those of the poor, because the former are willing to pay more than the latter to reduce the risk of death. One explanation for the fact that the WTP of the wealthy is higher than that of the poor runs parallel to the inflating-benefits explanation presented in Part I.

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as the probability of death is reduced, the wealth of the individual (assuming he covers the costs of the risk reduction) changes as well.

[28] In this paper we adopt the WTP approach which is common in the literature on the valuation of life. Sometimes, however, the literature presents the willingness to accept (WTA) criterion as the relevant criterion for valuing life. As is well established, the WTP and WTA criterions coincide if the risk imposed (or eliminated) is small, say 1%, if individuals are risk-neutral, and if wealth is properly adjusted between the two cases. However, things may change dramatically if the risk imposed (or eliminated) is not small. In particular, if we consider the imposition of risk on individuals who are under no risk to begin with, then under the WTA the risk of death will be nonlinear in relation to the magnitude of the risk imposed. The reason is that in such a case, individuals will discount the payment offered to them for assuming a risk of death by the ex-post probability of death. Therefore, the discounting-costs effect will reappear. Using a simple formula, let $1 - \bar{p}$ denote the risk of death imposed on the individual and $\bar{w}$ his wealth, then WTA, denoted $\bar{c}$, is given by: $L + \bar{w} = \bar{p}(L + \bar{w} + \bar{c})$. Solving for $\bar{c}$, we get: $\bar{c} = (L + \bar{w})\dfrac{(1 - \bar{p})}{\bar{p}}$. As is clear, the WTA increases nonlinearly in relation to the magnitude of risk.

Another explanation relates to the different marginal utilities of money for the rich and the poor, respectively. As we show below, both explanations imply that when society values people's lives, wealth should not matter.

We start with the inflating-benefits effect explanation. We have noted in Part I that wealthy people are willing to spend more than poor people on self-risk-reduction because they ascribe a higher value to their ability to consume their wealth during their lifetimes. We argued that an efficiency concern could arise here because wealthy people who don't care about their wealth after their deaths ignore the fact that if they die without having consumed all their wealth, others will consume and enjoy it. At the same time, we generally held that society should not intervene in such choices.

The situation is different, however, when it comes to society's valuing people's lives so as to decide how much to invest in safety. Here, the social, rather than the private, value of those lives should be taken into account, and any value an individual ascribes to his life that is transferable to other individuals should not count. Since wealth is transferable, and since there is no reason to assume that A would derive any more utility from his own consumption of his wealth than from its consumption by others, the social value of an individual's life should be determined regardless of wealth.[29]

Even if the WTP criterion is adjusted for the value people ascribe to the enjoyment of consuming their wealth, there is an additional reason why wealthy people might be willing to pay more than poor people to reduce the risk of death: Private costs of safety are lower for the wealthy than for the poor, assuming that individuals have the same concave utility function (so they derive decreasing marginal utility from wealth). Yet, again, since it is society and not the individual investing in safety, the particular costs to the individual are immaterial. Only the social costs of safety are of significance. Indeed, these social costs will depend in general on the mechanism society employs to raise social resources, which, in turn, may depend on the distribution of wealth in society if, for example, resources are raised in an equal

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[29] There might be instances in which the value of the resources of a particular individual will be higher in his hand than in the hands of other individuals. This may reflect, for example, sentiments attached to certain resources, such as wedding rings. In such cases, the added utility the individual derives from his own resources is not transferable, and therefore should be accounted not merely as a private loss but also as a social loss.

manner. However, even in such a case, there is no reason to assume that the relevant social resources will be raised from the particular individual at risk, and therefore there is no reason to take into account the particular cost to him.[30]

We can suggest a simple formulation to value life qua life, under some simplifying assumptions, such as that the individual is risk-neutral (see also in appendix D). Utilizing the WTP formula (2), we can solve for L to obtain: [31]

$$(5) \quad L = c \frac{p+r}{r} - w$$

III Applications to Tort Law

In this Part of the paper we apply our conclusions in Part I and Part II to tort law. In particular, we analyze the effects of different liability rules on the incentives of potential injurers and victims to take precautions in situations where the harm is the victim's death. We assume that both injurers and victims are risk-neutral with respect to wealth and strangers to one another. We further assume, as before, that victims ascribe no value to their wealth after their deaths. We analyze situations of unilateral and bilateral accidents and show that the fundamental results of the law and economics literature should be substantially revised following our analysis (formal proofs in Appendix E).

A. Unilateral Accidents

In unilateral accidents the injurer can take precautions to reduce the expected harm of his activity; by contrast, the victim can do nothing to affect the expected harm. The conventional law and economics stance maintains that in such accidents the injurer

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[30]   The issue becomes more complex once the individual at risk can take independent safety measures to supplement those taken by the state. See *infra* discussion in Part III.

[31]   In current empirical studies of the Value of Statistical Life (VSL), the WTP is widely used to reach the VSL. The results vary from $0.7M to $8.8M. (Viscusi, 2000, p. 206). One possible reason is that most researchers account wealth as part of the VSL. See, for example, Viscusi, 2000, p. 212: "Presumably there is similar variation in people's willingness to pay for risk reduction so that based on the usual benefit measures the value of life for more affluent populations should be greater. The government currently makes no such distinctions…".). According to our formulas, wealth is irrelevant for the VSL.

would take efficient precautions if the standard of care, under a negligence rule, and damages, under both negligence and strict liability rules, were to reflect social harm. In wrongful death cases, law and economics scholars (e.g., Calabresi (1970, p. 206); Ponser, 2007, pp. 197-198) argue that the social harm equals the value of the victim's life, measured by his WTP. Law and economics scholars who embrace this view argue that if the victim's risk of death, including his preexisting risk, is high, damages should be set higher than if the victim's risk of death is low, in order to reflect the nonlinear relationship between the WTP and the magnitude of the risk (Posner & Sunstein, 2005, pp. 587-590; Arlen, 1999, p. 709). Furthermore, Posner (1992, p. 221) and Landes and Posner ((1987, p. 189), building on the nonlinear relationship between WTP and risk, suggest that criminal law's resort to non-monetary sanctions is justified in intentional tort cases. In such cases, so they reason, the risk of death is high, and the optimal damages necessary to induce efficient behavior are very high, so that injurers do not have sufficient resources to pay them.

Law and economics scholars who embrace the WTP as the criterion for valuing people's lives would probably also endorse the notion that the standard of care under a negligence rule, and damages under both negligence and strict liability rules, should reflect the victim's wealth, since the victim's WTP increases with wealth.(Viscusi, 2000, pp 212-24, O'hara, 1990, p. 1715).

Prevailing tort law rejects the law and economics view and holds that damages are not dependent on either wealth or the magnitude of risk.[32] Furthermore, under prevailing tort law the injurer's standard of care doesn't depend on wealth. It does depend, however, on the magnitude of risk; the higher the risk, the higher the standard of care.

The conventional law and economics view is wrong. Let us start with damages first, and then turn to the standard of care. The law and economics view of damages is based on the premise that the WTP is the appropriate criterion for measuring a victim's harm. But as we have shown in the previous Parts of the paper, this premise is ill-founded. *First*, once the discounting-costs effect is correctly understood, the discounted WTP (i.e., the WTP adjusted for the ex-post probability of death) should serve as a criterion for valuing people's lives. With the discounted WTP, the valuation of the victim's life should not depend on the magnitude of the risk

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[32] One exception is punitive damages. *See* Sharkey (2003).

he was exposed to or his ex-post probability of death. *Second*, the inflating-benefit effect implies that even though the WTP depends on wealth, the true social value of life is independent of the victim's wealth. Therefore, damages in wrongful death cases should not be dependent on either the magnitude of the risk or the victim's wealth.

Generally, this is the stance taken by prevailing tort law. One exception, however, is the courts' inclination to allow punitive damages when the risks are high, intentional torts (risk close to 100%) being the paradigmatic case. Even though according to our analysis the magnitude of risk or the ex-post probability of death should not affect the valuation of the victim's life, other considerations, which we do not discuss here, could justify higher damages for harm caused through high-risk torts.

For similar reasons, the injurer's standard of care under a negligence rule should not be dependent on the victim's wealth: Once the victim's wealth is irrelevant to social harm, it should not be relevant to the standard of care either. The relationship between the magnitude of the risk and the standard of care, however, is a bit more complicated. The standard of care should reflect the magnitude of the risk *created by the injurer*, since the higher that risk the higher the expected harm. However, the standard of care should not depend on the preexisting risk or the ex-post probability of death

Again, this understanding of the relationship between wealth and risks on the one hand, and standard of care on the other, is compatible with prevailing tort law. Prevailing tort law, however, has been inconsistent in the way it deals with lost income. On the one hand, lost income is a central factor in awarding damages for bodily injury and for deprivation of life. On the other hand, when it comes to setting the standard of care, lost income is not a consideration for the courts, even when the potential victim is known to have a higher or lower income than the average person. Thus, courts would not set different standards of care for driving in a rich neighborhood as opposed to a poor neighborhood, just because people in the former neighborhood have, on average, a higher income than in the latter.

Should lost income, under our analysis, be a consideration in awarding damages for wrongful death cases or in setting the standard of care? If the WTP is adopted, wealth, *but not lost income*, should matter for valuing people's lives, and consequently only wealth should be a factor in both awarding damages and setting the

standard of care.[33] If, however, our argument that wealth should not matter for those purposes is accepted, the argument could still be made that lost income should matter for any valuation of the victim's life, since lost income reflects the victim's productivity. According to this argument, prevailing tort law is wrong in ignoring lost income in setting the standard of care, but right in factoring lost income into damages awards. We leave the lost income issue for further research.[34]

B. Bilateral Accidents

In contrast to unilateral accidents, in bilateral accidents both the injurer and the victim can and should take precautions to reduce the expected harm. For the sake of simplicity, we assume (as is often assumed) that precautions taken by either the injurer or the victim affect the expected harm *independently*; that is, the effectiveness of precautions taken by either the injurer or the victim to reduce the expected harm does not depend on the precautions taken by the other. The socially optimal standard of care for the injurer and the victim is defined in the law and economics literature as the standard of care for which the marginal costs are equal to the marginal reduction in expected social harm.

According to conventional law and economics, under a rule of negligence, when the standard of care is set at the socially optimal level and damages equal social harm, both the injurer and the victim take efficient precautions; but under a rule of strict liability (with no defenses), when damages equal social harm, the injurer takes efficient precautions, while the victim does not take any precautions at all. The law and economics literature is not clear about how these results are altered, if at all, if the

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[33]   But since future income has present value, it directly affects wealth, and indirectly affects WTP.

[34]   Our analysis could shed light on the question whether young people should be awarded a higher amount of damages than old people, all else being equal, and whether the injurer's standard of care should be set differently when the potential victims are either young or old, once again, all else being equal. Indeed, it is expected that young people's WTP to avoid risks of death will be higher than old people's. The reason for this is that since the formers' life expectancy is longer, the discounting-costs effect as well as the inflating-benefits effect has a greater influence on their WTP. Once the WTP is adjusted for those two effects, the WTP of young and old people draws much closer. Indeed, even after the said adjustment is made, there would still be a difference between old and young people's WTP, because their divergent life expectancies could affect the value of their lives qua life.

harm resulting from the accident is the victim's death.[35] In the following paragraphs we argue that law and economics' standard results should not apply when the harm is the victim's death. We start with strict liability and then turn to negligence.

Strict Liability

The standard results of law and economics, namely that under a rule of strict liability victims do not take any precautions, do not hold when the harm is not fully compensable, as is the case with many types of bodily injury. But the most extreme cases where harm is not compensable are wrongful death cases. In such cases, the victims—who ascribe no value to their wealth after their deaths—fully internalize the risk of harm created by the strictly liable injurer, regardless of the measure of recovery, because they cannot be compensated in case of death. That would provide them with incentives to take precautions to reduce their risks.

More interestingly, however, further to our analysis in the previous parts of the paper, under a rule of strict liability victims are expected to take socially excessive precautions to reduce the risk of death, for the reason that victims will discount the costs of precautions by the ex-post probability of death (the discounting-costs effect) and inflate the value they ascribe to their lives, and therefore to any reduction of their risk of death (the inflating-benefits effect). Occasionally, victims are exposed to risks that could materialize in various ways, some compensable and others not. In such

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[35]   For example, Arlen (1999, p. 702), who offers a thorough analysis of tort damages for death and serious physical injuries, presumably assumes that the main results of the standard law and economics analysis do not change when the harm is the victim's death. She maintains that "the present analysis examines what tort liability and damages rules governing serious permanent injuries induce injurers to undertake efficient care and activity levels,…The question of what rules will also induce victims to undertake optimal care and activity levels is addressed earlier in this chapter and in Chapter 3100". These other references mentioned by Arlen analyze the standard results. *See* also Posner and Landes, 1987, Ch. 9. In particular, Posner and Landes restrict their analysis in this chapter to "accidents in which many victims are *killed* or seriously injured" (p. 256, emphasis added) and go on to argue that "[we] need not consider explicitly the effect of different damage rules on the victim's activity level. As shown…, a potential victim will make the correct activity choice (for example, the choice between living near a nuclear reactor plant or elsewhere) only when he faces the full expected damages from an accident. Therefore, under strict liability victims will make incorrect activity choices but injurers will make correct ones, whereas under negligence victims will have incentives to make correct activity choices but injurers will not" (p, 270, n. 19).

cases the victims' inclination to take excessive precautions to reduce the risk of death would offset their inclination to take deficient precautions with respect to the risk of compensable harms. But once the risk of death is the major or only risk, the victims' incentives to take excessive precautions should not be ignored.

Thus, in contrast to the view of conventional law and economics, in wrongful death cases, under a rule of strict liability, when damages equal social harm, injurers take efficient precautions, while victims take excessive precautions. Given that victims take excessive precautions, the question arises as to whether damages should be adjusted either upwards or downwards to increase social welfare, or in other words, whether there is a second-best solution to the problem.

Changing the amount of damages *as such* would not affect victims' incentives to take precautions, because, by definition, in cases of death *victims* are not compensated. Changing the amount of damages, however, would affect the injurer's incentives to take precautions. But since the injurer's and the victim's precautions are assumed here to be *independent*, in the sense that the effectiveness of precautions taken by the victim does not depend on those taken by the injurer, a change in the level of precautions taken by the injurer *as such* would not affect the precautions taken by the victim; it would, however, change the risk of death to the victim and would therefore affect his incentives to take precautions. In particular, if damages were set higher than social harm, injurers would take more precautions. This in turn would reduce the probability of an accident and the risk to the victim's life. Such a reduction would increase the victim's marginal costs of taking precautions (i.e., decrease the impact of the discounting-costs effect), but it would not affect the victim's marginal benefit of taking precautions (i.e., not affect the inflating-benefits effect), resulting in fewer precautions taken by the victim.

Increasing damages under a rule of strict liability would induce the injurer to take more precautions and the victim to take less. Yet, for a sufficiently small increase in damages, social welfare necessarily rises, for the following reason: when damages equal social harm, the injurer takes efficient precautions, while the victim takes excessive precautions. Therefore, a slight increase in the injurer's precautions will have only a marginal effect on social welfare (since the additional social costs just equal the additional social benefits), while a slight reduction in the victim's precautions will have an infra-marginal effect on social welfare (since the additional social benefits are strictly greater than the additional social costs).

Negligence

In the conventional law and economics analysis, under a rule of negligence, the injurer takes efficient precautions, if the standard of care is set at the socially optimal level and damages equal social harm. The victim, who then bears the residual expected harm, also takes efficient precautions. However, as we have shown, if the harm resulting from an accident is the victim's death, the injurer still takes efficient precautions, while the victim takes excessive precautions.

Given that the victim takes excessive precautions, a question arises as to whether the negligence rule can be modified to reduce the distortion in the victim's incentives and thereby increase social welfare. As explained above, the victim's incentives can be indirectly controlled if the injurer takes more precautions. This, as discussed above, would reduce the probability of an accident and lessen the discounting-costs effect to the victim. As a consequence, social welfare would be promoted (note, again, that we assume that the injurer's and the victim's precautions are *independent*).

However, in contrast to strict liability, under a negligence rule, increasing the damages awarded in wrongful death cases would not decrease the victim's incentives to take excessive precautions, because if the negligence rule operates perfectly (i.e., without courts' or injurers' errors), the injurer will abide by the legal standard of care and escape liability.

An alternative second-best solution is to increase the legal standard of care. The success of this solution, however, depends on the way the causation requirement is applied under the negligence rule. Some law and economics scholars assume that if the injurer does not abide by the legal standard of care he is liable for all harms resulting from an accident, regardless of whether that specific accident or harm would have been avoided if the injurer had complied with the legal standard (see, for example, Shavell, 1987, 2004). On this view, increasing the standard of care slightly above the socially optimal level will induce the injurer to take more precautions. As a consequence, there will be a lower probability of an accident and the victim will therefore take fewer precautions. If, however, the causation requirement is accurately applied, so that a negligent injurer is liable only for the harm caused by his negligent behavior (see, for example, Grady, 1983; Kahan, 1989; Cooter, 1989; Tabbach, 2008), then raising the standard of care above the optimal level would also fail to achieve the

goal of improving the victim's incentives, for the reason that the injurer will prefer to behave efficiently (i.e., settle for an efficient level of care) and be liable for the harm caused by his deviation from the legal standard, than to abide by the higher standard and escape any liability. And once the injurer's incentives remain intact, so do the victim's.

To overcome this problem, it is possible to simultaneously increase both the standard of care and the level of damages. That would induce the injurer to take more than optimal precautions. As a result, the victim, knowing his risk of death is lower because of the additional precautions taken by the injurer, would take fewer precautions than he would have taken if the injurer's precaution were optimal. That would bring his behavior closer to its optimal level, and for the reasons explained above would increase social welfare.

C. Transaction Costs

Our analysis shows that in unilateral accident cases, efficiency mandates that damages, as well as the injurer's standard of care, should be set lower than what the WTP-based method dictates. It also shows that in bilateral accident cases, first-best efficiency cannot be achieved, but second-best efficiency dictates that the injurer's standard of care and damages (if causation is properly taken into account) should be set higher than what is required by the best solution. These results, however, are strictly correct if transaction costs between the injurer and the victim are prohibitively high, that is, if the victim and the injurer are strangers to one another, as the standard law and economics analysis assumes.

If, however, transaction costs are low, and injurers and victims are able to contract around tort law rules, the above analysis is not applicable. Thus, setting the standard of care under a negligence rule, and damages under both negligence and strict liability rules, at the efficient level would not necessarily achieve the desirable goal of maximizing social welfare. In particular, the injurer and victim would opt out of the efficient rules and regulate their behaviors in a way that maximizes their own private welfare, rather than the social welfare. Under those circumstances, setting efficient rules would just create transaction costs for the parties and would be welfare-reducing. Let us illustrate this latter point with a unilateral accident case. The same line of analysis applies to bilateral accident cases as well.

Suppose a patient, as in Example 1, is about to undergo an operation. The patient is a wealthy person, very sick, under a severe risk of death. He is therefore willing to pay a huge amount of money to induce the doctor who is performing the operation to take excessive precautions, much above the efficient level. The reason he is willing to pay so much money is because of the discounting-costs effect (his ex-post probability of death is high) and the inflating-benefits effect (he is wealthy) analyzed above. If transaction costs between the parties were prohibitively high, following our analysis, the patient's WTP should have been adjusted for the two aforementioned effects, and both damages and the doctor's standard of care would have been set lower than what the patient would have wanted.

But if transaction costs are low, those adjustments would fail to achieve their goal. The patient and the doctor would contract around tort law rules—assuming that is legally permissible—and set both the level of damages and the standard of care in accordance with the patient's WTP. The adjustments made by tort law would prove to be futile—merely burdening the parties with transaction costs.

Conclusions

When people take too few precautions to protect themselves, it is often said that they lack information about the risks to their lives or an understanding of their own good. State intervention to correct the latter problem is often labeled "paternalism." This paper is about precisely the opposite phenomenon: sometimes people who are at risk of death invest too much in protecting themselves. Arguably, this is not a problem that the law should care about: so long as people do not externalize costs to third parties and so long as they have not lost their minds, they are free to use their own resources as they see fit. Furthermore, people's over-investment in risk reduction is typically not the result of irrationality or oversight, as is usually the case with the reverse phenomenon of under-investment. Quite the contrary: it is efficient behavior from their perspective, given the circumstances they are facing. However, as we have shown here, the discounting-costs effect and inflating-benefits effect produce a discrepancy between the private and social perspectives regarding risk-of-death reduction, for the precautions taken by people at risk of death are inefficiently excessive from the social perspective. While the discounting-costs effect is significant only when the risk of death is substantial, the inflating-benefits effect is relevant even when the risk of death is small. Moreover, even from the standpoint of those

individuals at risk of death, their decisions could be improved to align with the social perspective if insurance markets were complete and they could enter into RI contracts.

What should be done about over-investment in precautions to reduce the risk of death? When it is just about people's choices regarding their lives, we believe the state should not intervene, except to facilitate the creation of complete markets and enable people to enter into RI contracts if they so desire. Direct intervention is not recommended since it may cause people to inefficiently shift resources to consumption. But when the state is required to invest in precautions to reduce the risk of death, and must value people's lives for that purpose, their willingness to pay for risk reduction should *not* be the criterion, unless adjusted to take into account the two effects analyzed in this paper. In particular, the fact that people with a high ex-post probability of death are willing to pay more than people with a low ex-post probability is irrelevant for valuing their lives. Likewise, and no less importantly: all else being equal, the lives of the wealthy and the poor are of identical value.

Throughout the paper we have assumed, for the sake of simplicity, that individuals under risk of death ascribe no value to their wealth after death. Our conclusions would not change in substance if we relaxed this assumption and assumed instead that those individuals ascribe value to their wealth after death, *but that that value is lower both in absolute and marginal terms than the value they ascribe to it while they are still alive.*[36] As long as these conditions hold, both the discounting-costs effect and the inflating-benefits effect are operative. Furthermore, the conclusions of the paper can be extended to other situations in which individuals face risks other than the risk of death, *as long as the materialization of those risks would reduce their marginal utility of money*. We leave this particular extension for further research.

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[36]   If individuals ascribe value to their wealth after death because they are altruistic towards their near relatives, say, children, then in a strict sense the divergence between the private and the social perspective is unchanged. The reason is that from a social perspective altruistic behavior creates double benefit: the benefit to the benefactor from his altruistic behavior, and the benefit derived by the beneficiaries of the altruistic behavior. This latter utility, unfortunately, is not accounted for by the altruistic individual. *Cf.* Friedman (1988). If this argument is adopted, then our arguments in the paper are literally applicable to all cases, regardless of the value that the individual under risk of death ascribes to his wealth after death (Formal proof of this argument can be found in Appendix B).

Finally, the arguments made in this paper can be applied in many legal fields. Here, we have applied our arguments to tort law, since the economic analysis of tort law has largely overlooked the point that reducing the risk of death is substantially different from reducing other risks. If our arguments are valid, the economic analysis of accidents that entail risk of death should be substantially revised in light of our analysis and recommendations.

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Appendix A

Model of Risky Behavior

Consider an individual who has initial wealth w and faces a probability p^0 of surviving a single period. Following Linnerooth (1982), we assume that his utility depends on the state of the world: if the individual dies he will enjoy no utility. If the individual survives, he will enjoy a utility from leisure (i.e., "consumption" of resources that have no marginal social cost) and from consumption of his wealth. For simplicity, we assume that the utility from leisure and consumption are additive. We further assume that the individual is either risk-averse or risk-neutral with respect to wealth, so that $u'(w) > 0$ and $u''(w) \leq 0$. Later on we will simplify the analysis and focus only on risk neutrality, so we could write $u(w) = w$. Thus the individual expected utility v can be written as:

$$v = p^0[L + u(w)] \tag{A1}$$

Investment in risk reduction

Suppose that the individual can invest his wealth $x \in [0, w]$ in precautions so as to increase the probability of survival. Assume that the probability of survival $p(p^0, x)$ is concave in x for all p^0, so that $p_x > 0$ and $p_{xx} < 0$. Assume also, for simplicity, that p_x is independent of p^0.[1] The problem for the individual is to choose x to maximize his expected utility:

$$v(x) = p(p^0, x)[L + u(w - x)] \tag{A2}$$

The optimal private care, assuming an interior solution, denoted $\tilde{x}$, satisfies the following FOC:[2]

$$p_x(p^0, x)[L + u(w - x)] = p(p^0, x)u'(w - x) \tag{A3}$$

The LHS of (A3) is the marginal benefit from spending the last dollar on care in terms of increasing the probability of survival and the resulting enjoyment of leisure and

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[1]This, however, cannot be strictly true, because for $p^0 = 0$, $p(0, x) = 0$ for all x. We ignore these possibilities.

[2]It is easy to check that the second order condition is satisfied $v_{xx}(x) < 0$.

consumption. The RHS of (A3) reflects the marginal cost of spending the last dollar on care. These marginal costs equal the marginal utility of income *discounted by the ex-post probability of death.* This reflects the fact that if the individual dies, he will not enjoy the last dollar anyway. At the optimum, these marginal benefits and costs should be equal.[3]

Comparative statics

To analyze how care taken by the individual changes with the initial probability of survival p^0 and with wealth w, we simply use the implicit function theorem and immediately obtain that:

$$\frac{d\tilde{x}}{dp^0} = -\frac{v_{xp^0}}{v_{xx}} = \frac{p_{p^0} u'(w-x)}{v_{xx}} < 0 \iff \frac{d\tilde{x}}{d(1-p^0)} > 0 \qquad (A4)$$

and

$$\frac{d\tilde{x}}{dw} = -\frac{v_{xw}}{v_{xx}} = \frac{p u''(w-x) - p_x u'(w-x)}{v_{xx}} > 0 \qquad (A5)$$

The explanations for these results are simple. (A4) Since the initial probability of survival is higher, the marginal cost of spending the last dollar for the individual, $p(p^0, x)u'(\cdot)$, for any x, is higher, while the marginal benefit is unchanged; that is, since the initial probability of death is higher, it is more likely that the costs of care will come from the state of the world in which wealth is worthless to the individual. This reflects the "discounting costs effect" or what Pratt and Zeckhauser (1996) call "the dead anyway effect". Therefore, the individual will invest less in precautions. (A5) Since the individual has more wealth, the marginal benefits from life (i.e., leisure and consumption) are higher and, at the same time, the marginal costs of investing in precautions (if the individual is risk averse) are lower. Therefore, as wealth increases the individual invests more in precautions. To summarize:

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[3]The problem the individual faces need not have an interior solution $x \in (0, w)$. The individual may decide to spend his entire wealth on care, $\tilde{x} = w$. That will happen if $p'(p^0, w)L > p(p^0, w)u'(0)$. Thus, the budget constraint w may be effective in the sense that the individual will benefit from investing more in precautions, but he simply does not have any wealth left.

Proposition 1 *The level of care taken by an individual who faces risk to his own life increases with the initial probability of death and with wealth (even though the effectiveness of care is independent of these parameters).*

Appendix B

The social perspective

Consider now the problem of investing in risk reduction from the perspective of a social planner whose aim is to maximize social welfare. From a social perspective, the death of an individual results in the loss of his life and therefore the loss of his enjoyment of life (i.e., leisure). However, the death of an individual does not result in the loss of his wealth (i.e., resources). These resources can and will be used by other individuals. Assuming that all individuals have the same (linear) utility functions, the social problem is to choose $x \in [0, W]$, where W reflects aggregate social resources, to maximize social welfare:

$$SW = p(p^0, x)(L + w - x) + (1 - p(p^0, x))(w - x) = p(p^0, x)L + w - x \qquad \text{(B1)}$$

There are several differences between the social and the individual maximization problems: (1) *Cost of care*: from the social perspective the costs of care are the full costs of care, while from the individual perspective the costs of care are discounted by the ex-post probability of death. (2) *Benefit of care*: for the individual, the benefits from care include the utility he derives from leisure and consumption of his wealth discounted by the probability of death, while from the social perspective the utility from consumption of wealth can be ignored, since others will enjoy consuming that wealth. (3) *Budget constraint*: for the individual the budget constraint is his wealth, while from the social point of view the budget constraint is presumably the aggregate social wealth. These differences lead to a divergence between the social and the individual optimal choice of care.

From the social perspective, optimal care x^* is implicitly defined by:

$$p_x(p^0, x)L = 1 \qquad \text{(B2)}$$

The RHS of (B2) is the marginal costs of the last dollar spent on care, which is 1. The LHS of (B2) reflects the marginal benefits from this last dollar stemming from the increased probability of survival and the value of life to the individual. At the optimum, these marginal costs and benefits should be equal. Inspection of (B2) immediately reveals the following proposition:

Proposition 2 *The socially optimal level of care is independent of the initial probability of death and wealth.*[4]

Moreover, a comparison of Propositions (1) and (2) leads to the following conclusions:

Proposition 3 *(1) An individual who faces a risk to his life will take more than the socially optimal care level* [5] *(2) The difference between care taken by the individual and the socially optimal care increases with the initial probability of death and with wealth.*

If the initial probability of survival (death) is very high (low), there will be a small divergence between care taken by the individual and socially optimal care. This is due to the fact that since the probability of survival (death) is very high (low), the individual internalizes almost all of the (marginal) costs of taking care, and so the "discounting costs effect" is negligible. However, even in this situation, there will still be a divergence, may be even a large one, between the private and the social optimal care level, because of the "inflating benefits effect". Therefore, individuals with a significant amount of resources may still invest inefficiently high in risk-reduction.

Altruistic Individuals

We have demonstrated that an individual who ascribes no value to his wealth upon death will take excessive precautions. Comparing marginal costs and benefits reveals that the difference between the social and the private marginal costs is $(1 - p(x))$ and the difference between the private and the social marginal benefits is $p'(x)[W - x]$.

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[4]Clearly, this assumes an interior solution. If p^0 is sufficiently small, society may choose to spend less or even to spend nothing on risk reduction.

[5]This is strictly true if the individual has no wealth constraints. Otherwise he might take more or less than the socially optimal care level.

In this part we examine the consequences of our analysis, assuming that the individual is *altruistic* towards his heirs so that he values his wealth upon death by a factor $\mu \in [0, 1]$. If $\mu = 0$ then the individual ascribes no value to his wealth upon death. If $\mu = 1$ then the individual ascribes the same value to his wealth regardless of whether he survives or not. We will prove the following proposition.

Proposition 4 *If individuals are altruistic towards their heirs, there is still a divergence between the private and the social incentives to take precautions to reduce the risk of death. Moreover, the difference between the private and social marginal costs and benefits of taking care is independent of whether individuals are altruistic or not or the degree of their altruism.*

Proof. If an individual discounts the value he ascribes to his wealth upon death by μ, his expected utility becomes: ∎

$$EU = p(x)[L + (1 - \mu)(w - x)] + \mu(w - x) \tag{B3}$$

Private care, $\tilde{x}$, assuming an interior solution, should satisfy:

$$p'(x)[L + (1 - \mu)(w - x)] = p(x)(1 - \mu) + \mu$$

The social problem is to choose x to maximize:

$$SW = p(x)[L + -\mu(w - x)] + (w - x)(1 + \mu)$$

The socially optimal care, x^*, assuming an interior solution, should satisfy:

$$p'(x)[L - \mu)(w - x)] = -\mu p(x) + 1 + \mu$$

Now the difference between the marginal social costs and the marginal private costs of care is:

$$\triangle_c = -\mu p(x) + 1 + \mu - p(x)(1 - \mu) - \mu = 1 - p(x)$$

And the difference between the marginal private benefits and the marginal social benefits is:

$$\triangle_b = p'(x)[L + (1 - \mu)(W - x)] - p'(x)[L - \mu(W - x)] = p'(x)(W - x)$$

Appendix C

Solving the problem - complete markets

Thus far we have analyzed the behavior of an individual who faces a risk to his life and demonstrated that he behaves inefficiently. This might seem to be only a social problem. However, as prior writers have identified, the problem arises because markets are incomplete in the sense that the individual cannot transfer wealth between the two states of the world: life and death. If a complete, fair contingent claims market exists then the individual will be made better off and will behave efficiently (compare Pratt and Zeckhauser, 1996). To illustrate that in the present context, observe that with a complete, fair contingent claims market, the individual can sell his bequest for its expected value. In particular, the individual can enter into a contract with a reverse-insurer under which he pays to the reverse-insurer an amount equal to $(w - x)$ if he dies, in return for a payment I to be received from the reverse-insurer if he survives. If the terms of this contract are actuarially fair, then I should satisfy:

$$p(p^0, x)I = (1 - p(p^0, x))(w - x) \Leftrightarrow I(x) = \frac{1 - p(p^0, x)}{p(p^0, x)}(w - x) \qquad \text{(C1)}$$

Observe that I depends on x. This reflects the fact that care taken by the individual will affect expected payment by the reverse-insurer in two ways: it will reduce both the amount of wealth that is left upon death, and the probability of death itself. Therefore, making I dependent on x is necessary to overcome these "moral hazard" problems. Observe also that $I(x)$ is positive for all $x < w$. Therefore, the possibility of "reverse insurance" necessarily improves the individual's expected utility and make this a Pareto improvement for him. In addition, observe that:

$$I'(x) = -\frac{1 - p(p^0, x)}{p(p^0, x)} - \frac{p_x(p^0, x)}{p(p^0, x)^2}(w - x) < 0 \qquad \text{(C3)}$$

so the amount of "reverse insurance" declines with care.

With reverse insurance the problem an individual faces is to choose $x \in [0, w]$ to maximize his expected payoff, given by:

$$v = p(p^0, x)(L + w - x + I(x)) = p(p^0, x)L + w - x \tag{C4}$$

Inspection of (C4) and (B1) reveals that the private and the social problems are identical. Therefore, their optimal (interior) solutions are the same and so are the comparative statics with respect to the initial probability of survival and wealth. That is, with a complete, fair contingent market, the individual behaves efficiently, and his care level is independent of the initial probability of survival or wealth.[6]

Appendix D:

Willingness to pay for risk reduction and risk elimination

In Appendix A we derived the level of private care an individual takes to save his own life. In this part we consider a similar but slightly different question: what is the maximum amount of wealth a risk neutral individual is willing to pay (WTP) to increase his probability of survival p by r. This amount, c, which reflects the "compensating variation", is given implicitly by equating expected utility after the risk has been reduced and with payment with the expected utility before the risk has been reduced and without payment:

$$(p + r)[L + w - c] = p[L + w] \tag{D1}$$

Rearrangement of (D1) yields:

$$(p + r)c = r(L + w) \tag{D2}$$

WTP is such that the benefits to the individual of increasing the probability of survival by r stemming from the enjoyment of leisure and consumption (the RHS of (D2)) are

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[6]However, for this result to strictly hold, it is necessary that there will be no wealth constraint on the part of the "insurer", because as the probability of survival approaches zero, the amount of "reverse insurance" approaches infinity. $\lim_{p->0} \frac{1-p}{p} w = \infty$

equal to the costs to the individual of increasing the probability of survival (the LHS of (D2)). As before, these costs are discounted by the ex-post probability of death.

From (D2) it follows immediately that:

$$c = \frac{r[L+w]}{p+r} \tag{D3}$$

From (D3) it follows that the WTP for risk reduction depends, among other things, on the initial probability of survival and on wealth. Thus, we can write $c = c(p, w)$, and show that:[7]

$$c_p(p, w) = -\frac{r[L+w]}{(p+r)^2} < 0 \text{ and } c_{pp}(p, w) = \frac{2r[L+w]}{(p+r)^3} > 0 \tag{D4}$$

$$c_w(p, w) = \frac{r}{p+r} > 0 \text{ and } c_{ww} = 0 \tag{D5}$$

Thus we have the following proposition.

Proposition 5 *The WTP to reduce the risk of death by a small amount (a) increases with the initial probability of death in increasing rates and (b) increases linearly with wealth.*

(D3) leads immediately to the following result.

Corollary 1 *The ratio of the WTP of two individuals who differ only by their initial probability of survival is equal to the inverse of the ratio of ex-post probabilities of death.*

The ratio of the WTP of individuals A and B is given by:

$$\frac{c_A}{c_B} = \frac{r[L+w]}{p_B+r} \frac{p_B+r}{r[L+w]} = \frac{p_B+r}{p_A+r} \tag{D6}$$

The RHS (D6) is the inverse ratio of the ex-post probabilities of death.

D(5) implies that the WTP to reduce risk by some small amount, say 1%, is nonlinear with the initial probability of death, and therefore has the 'regular' convex shape.[8]

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[7]Denoting the initial probability of death $q = 1-p$, (D3) and (D4) become: $c(q, w) = \frac{r[L+w]}{1-q+r}$, $c_q(q, w) = \frac{r[L+w]}{(1-q+r)^2} > 0$ and $c_{qq}(q, w) = \frac{2r[L+w]}{(1-q+r)^3} > 0$

[8]Observe, however, that the WTP in the graph captures the notion of how much an individual with given wealth is willing to pay to reduce the risk of death by say 1%, if he were subject to a different magnitude of risks. The graph is derived from $c = \frac{100}{1.01-p}$.
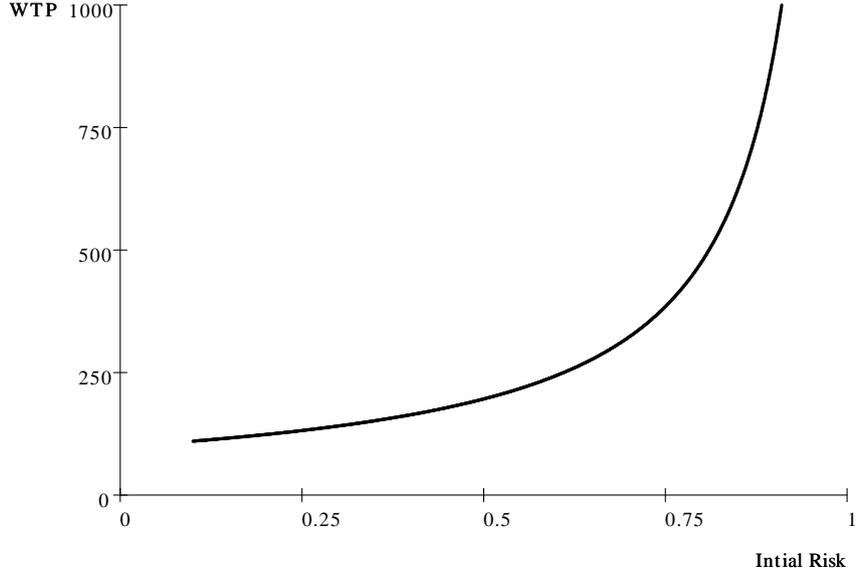
Figure 1: WTP to reduce risk by 1% as initial risk changes

However, it does not follow from D(3), D(5) or from Figure 1 that the WTP to eliminate risks of different magnitude is nonlinear. Quite to the contrary, in the case of risk elimination, we have that $r = 1 - p$, and therefore, (D3) becomes:

$$c = (1 - p)(L + w) \tag{D7}$$

From (D7) it is clear that the WTP to eliminate risks of death is linear with the magnitude of risk to be eliminated.

Proposition 6 *Willingness to pay to completely eliminate the risk of death increases linearly with the magnitude of the risk of death.*

Moreover, we can verify that for all $r < 1 - p$ (i.e., for all risk reduction that does not eliminate risk completely), (D7) is greater than (D3), that is, $(L + w)(1 - p) > \frac{r[w+L]}{p+r}$. Intuitively what that means is that an individual always has a greater WTP for eliminating risk than for only reducing it. Furthermore, we can show that the WTP to reduce risk is additive in the sense that an individual's WTP to reduce risk by r is equal to the sum of his WTP to reduce the risk successively by r_1 and then by r_2 where $r_1 + r_2 = r$. This implies that WTP is path-independent.

Proof. WTP depends on p, r, and w. Denote the WTP to reduce risk of death by r as $c(p, r, w) = \frac{r(w+L)}{p+r}$.

49

WTP to reduce risk of death by r_1 is $c(p, r_1, w) = \frac{r_1(w+L)}{p+r_1}$. After the risk has been reduced by r_1 and the individual paid $c(p, r_1, w)$, the WTP to reduce risk of death by an additional r_2 is $c(p + r_1, r_2, w - c(p, r_1, w)) = \frac{r_2(w+L-\frac{r_1(w+L)}{p+r_1})}{p+r_1+r_2}$. Assuming that $r = r_1 + r_2$, we can show that $c(p, r_1, w) + c(p + r_1, r_2, w - c(p, r_1, w)) = c(p, r, w)$, that is, $\frac{r_1(w+L)}{p+r_1} + \frac{r_2(w+L-\frac{r_1(w+L)}{p+r_1})}{p+r_1+r_2} = \frac{r(w+L)}{(p+r)}$.[9] ∎

Observe, however, that in this analysis the WTP to reduce risk of death by r cannot be computed from the function displayed in Figure 1. That is, the WTP to reduce the risk of death from say q^0 to $q^0 - r$ (i.e., from $1 - p$ to $1 - p - r$) is not equal to $\int_{q^0-r}^{q^0} WTP(q)dq$. The explanation is that the function displayed in Figure 1 gives the WTP as a function of q for a given w, while wealth itself, as can be seen from the proof, changes when the individual actually pays for consecutive risk reductions.

Appendix E:

Applications: Tort Liability

Unilateral Accidents

Standard unilateral care models assume that the injurer undertakes a dangerous activity and chooses care $y \in R_0^+$. Subsequently, with a probability of $1 - p(y)$, there is an accident and the victim suffers harm. The victim on his part can do nothing to affect the probability of an accident. We assume that the harm is the loss of the victim's life. Therefore, the social problem is to choose y to minimize the social costs of accidents:

$$SC = y + [1 - p(y)]L \tag{E1}$$

The optimal care level should satisfy

$$p'(y)L = 1 \tag{E2}$$

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[9]**Proof.** $\frac{r_1(w+L)}{p+r_1} + \frac{r_2(w+L-\frac{r_1(w+L)}{p+r_1})}{p+r_1+r_2} =$

$= \frac{r_1(w+L)}{p+r_1} + \frac{r_2(w+L-\frac{r_1(w+L)}{p+r_1})}{p+r} =$

$= \frac{r_1(w+L)}{p+r_1} + \frac{pr_2(w+L)}{(p+r)(p+r_1)} = \frac{(r_1p+r_1r+pr_2)(w+L)}{(p+r)(p+r_1)} =$

$= \frac{(p(r_1+r_2)+r_1r)(w+L)}{(p+r)(p+r_1)} = \frac{(pr+r_1r)(w+L)}{(p+r)(p+r_1)} =$

$= \frac{r(p+r_1)(w+L)}{(p+r)(p+r_1)} = \frac{r(w+L)}{(p+r)}$ ∎

In unilateral care models there is no problem with the behavior of the victim, since, by assumption, he cannot do anything to affect the likelihood of an accident. To induce optimal care by the injurer, it is necessary that damages, under a strict liability rule, and due care, under a negligence rule, will be set in accordance with the social perspective. This means that damages D should equal L and that due care, $\bar{y}$, will be set equal to y^* (implicitly defined by (E2)).

Bilateral care models

Bilateral care models differ from unilateral care models in assuming that it is optimal for both the injurer and the victim to take care. Denoting the victim's and the injurer's care by x and y respectively, and the probability of death by $1 - p(x, y)$, the social problem becomes choosing x and y to minimize:

$$SC = x + y + [1 - p(x, y)]L \tag{E3}$$

The socially optimal care levels, assuming an interior solution, x^* and y^*, should satisfy the following FOCs:

$$p_x L = p_y L = 1 \tag{E4}$$

No liability

Absent institutional arrangements, the injurer will take no care. In contrast to standard analysis, however, the victim, because he is not compensated, will take excessive rather than efficient care, given the care taken by the injurer.

Strict liability

Under strict liability the injurer is liable to pay damages to the victim in case of an accident. In contrast to monetary losses, the victim cannot be compensated, since compensation is paid only if the victim dies, and, by assumption, the victim derives no utility upon death. Therefore the injurer faces the problem of choosing y to minimize (the subscript s denotes a strict liability regime):

$$u^S = y + (1 - p(x, y))L \tag{E5}$$

while the victim faces the problem of choosing x to minimize (note the change of signs in the square brackets):

$$v^S = p(x, y)[x - w - L] \tag{E6}$$

We assume that both players, the injurer and the victim, choose care without observing the other player's care, and so the solution concept to their interaction is Nash Equilibrium. To find the NE we construct the best response curves of both players.

The injurer's best response function, $y_{br}(x)$, is the injurer's optimal care as a function of the victim's care. Given the victim's care x, the injurer will choose y to maximize (E5). The injurer's optimal choice is implicitly given by the FOC:

$$p_y(x, y)L = 1 \tag{E7}$$

Implicitly differentiating $u_y^s = 0$, with respect to x, and rearranging yields:

$$\frac{dy_{br}(x)}{dx} = -\frac{p_{xy}(x, y)}{p_{xx}(x, y)} \tag{E8}$$

Since $p_{xx}(x, y) < 0$, it follows that:

$$\frac{dy_{br}(x)}{dx} \geq\leq 0 \Longleftrightarrow p_{xy}(x, y) \geq\leq 0 \tag{E9}$$

The sign of $p_{xy}(x, y)$ reflects the interaction between the technology of care of the injurer and the victim. For simplicity, but without losing the essentials of the interaction between both players, we will assume that $p_{xy}(x, y) = 0$, that is, the effectiveness of care of each player is independent of care taken by the other player. Thus, the best response function of the injurer does not depend on the care taken by the victim. This implies that from the perspective of the injurer, this is a game with *strategic independents*.

Similarly, the victim's best response function, $x_{br}(y)$, is the victim's optimal care as a function of the injurer's care. Given the injurer's care y, the victim will choose x to maximize (E6).The optimal choice is implicitly defined by the FOC:

$$p_x(x,y)[L + w - x] = p(x,y) \tag{E10}$$

Implicitly differentiating $v_x^s = 0$, with respect to y, and rearranging yields:

$$\frac{dx_{br}(y)}{dy} = -\frac{p_{xy}(x,y)[L + w - x] - p_y(x,y)}{p_{xx}(x,y)[L + w - x] - 2p_x(x,y)} \tag{E11}$$

The sign of $\frac{dx_{br}(y)}{dy}$ depends on the sign of the numerator in (E11). Since we assume that $p_{xy}(x,y) = 0$, (E11) reduces to:

$$\frac{dx_{br}(y)}{dy} = \frac{p_y(x,y)}{p_{xx}(x,y)[L + w - x] - 2p_x(x,y)} < 0 \tag{E12}$$

This implies that the victim's best response function decreases with care taken by the injurer, which reflects the notion that from the perspective of the victim this is a game with *strategic substitutes.*

Finally, by the envelope theorem:

$$\frac{dv^s}{dx} = \frac{\partial v^s}{\partial x} > 0 \tag{E13}$$

and

$$\frac{du^s}{dy} = \frac{\partial u^s}{\partial y} > 0 \tag{E14}$$

That is, both players' expected payoffs increase along their best response curves (i.e., as the other player's strategy increases). This reflects the notion that this is a game of cooperation.

The following observation summarizes the essential features of the interaction between the injurer and the victim.

Remark 1 *The game between an injurer and a victim in a bilateral care model governed by strict liability is a game of cooperation in which the players' strategies are substitutes from the perspective of the victim and independent from the perspective of the injurer.*

Having constructed the best response functions of the injurer and the victim, the NE occurs at their intersection. Thus, the NE solution of this game is y^{s*} and x^{s*}, satisfying

conditions (E7) and (E10). It is straightforward that x^{*s} is inefficiently high, while y^{s*} is efficient. To summarize:

Proposition 7 *Strict liability: In a bilateral care model with independent care, the injurer takes efficient care if damages are set equal to the social harm, while the victim takes excessive care.*

Second-best optimum

Thus far we have analyzed strict liability if damages were set equal to the social harm. We now demonstrate the following proposition.

Proposition 8 *In a second-best world in which the victim's behavior cannot be directly controlled, optimal damages under strict liability are more than social harm.*

Proof. The proof is by contradiction. Suppose that optimal damages were equal to social harm $D^* = L$. Then the social costs of accidents is: ∎

$$x^{s*} + y^{s*} + [1 - p(x^{s*}, y^{s*})]L \tag{E15}$$

Consider now a slight increase in D (i.e., L). This will change the NE. The social costs of accidents will change by:

$$\Delta = \frac{dx^{s*}}{dy^{s*}}\frac{dy^{s*}}{dL} + \frac{dy^{s*}}{dL} - \frac{dp^{s*}}{dx^{s*}}\frac{dx^{s*}}{dy^{s*}}\frac{dy^{s*}}{dL}L - \frac{dp^{s*}}{dy^{s*}}\frac{dy^{s*}}{dL}L \tag{E16}$$

or equivalently by:

$$\Delta = \frac{dx^{s*}}{dy^{s*}}\frac{dy^{s*}}{dL}[1 - p_x(x^{s*}, y^{s*})L] + \frac{dy^{s*}}{dL}[1 - p_y(x^{s*}, y^{s*})L] \tag{E17}$$

By (E7), it follows that $1 - p_y(x^{s*}, y^{s*})L$, so (E17) reduces to:

$$\Delta = \frac{dx^{s*}}{dy^{s*}}\frac{dy^{s*}}{dL}[1 - p_x(x^{s*}, y^{s*})L] \tag{E18}$$

Now, $\frac{dx^{s*}}{dy^{s*}} < 0$ (from E12) and, by the implicit function theorem, $\frac{dy^{s*}}{dL} > 0$. In addition, since $x^{s*} > x^*$, it follows that $1 - p_x(x^{s*}, y^{s*})L < 0$ (see E4 and E10). Therefore, $\Delta > 0$, which contradicts the optimality of $D^* = L$.[10] This completes the proof.

Negligence

Under negligence, the injurer is liable for damages in the event of an accident if and only if he took less than due care. Assuming full liability, i.e., ignoring the legal requirement of causation, the injurer faces the problem of minimizing:

$$u^N = \begin{cases} y & \text{if } y \geq \bar{y} \\ y + (1 - p(x, y))L & \text{if } y < \bar{y} \end{cases} . \quad \text{(E19)}$$

where $\bar{y}$ is due care assumed to be set at optimal care, that is, $\bar{y} = y^*$.

Since the victim cannot be compensated, even if compensation is paid by the injurer, the victim still faces the problem in (E6). Therefore, the best response function for the victim $x_{br}(y)$ is the same as under strict liability. In addition, since by assumption $p_{xy}(x, y) = 0$, it follows that $y^* < y^* + (1 - p(x, y^*))L < y + (1 - p(x, y))L$ for all y, and therefore, the injurer's best response function is independent of x and is also the same as under strict liability (i.e., $y_{br}(x) = \bar{y} = y^*$). Therefore, the NE under negligence is identical to the NE under strict liability. To summarize:

Proposition 9 *In a bilateral care model, strict liability and negligence induce the same behavior from the injurer and the victim. In particular, under negligence with independent care, the injurer abides by due care and takes efficient care, while the victim takes excessive care.*

Proposition (8) should be contrasted with standard results in the law and economics literature concerning pecuniary losses. In bilateral care models, a negligence rule induces

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[10]The explanation is as follows. The injurer behaves efficiently given that the victim takes too much care. However, the victim does not behave efficiently given the care taken by the injurer. Therefore, if damages are increased slightly, the injurer will increase his care, but that would have no significant effect on social welfare. However, since the injurer increases his care, the victim would *decrease* his care, because from his perspective this is a game with strategic substitues. The victim decreases his care not because his care becomes less effective as the injurer takes more care. This possibility is ruled out by the assumption that $p_{xy}(x, y) = 0$. Rather, it is becasue more care taken by the injurer increases the probability that the victim will survive, and therefore the victim's marginal costs of taking care are higher (see Proposition 1). Now, the reduction in care taken by the victim will increase social welfare, because his care level is inefficiently high given the care taken by the injurer.

the injurer to take efficient care by the threat of liability, and since the victim is not compensated, the victim bears the residual harm and therefore takes efficient care as well. Under strict liability, on the other hand, the victim is compensated, and therefore he does not take care at all. If, however, the risk is to the victim's life and not to his property, as we explained above, the victim is not compensated, even if compensation is paid. In addition, as we have explained, the lack of compensation implies that the victim takes excessive care relative to the social optimum because of the discounting costs and inflating benefits effects.

Second-best optimum

Thus far, we have analyzed the negligence rule assuming that due care is set at the socially optimal level. This, however, is not socially optimal given that the victim does not take efficient care. Instead, as we will now explain, social welfare can be increased by setting due care higher than optimal care.[11]

The proof is again by contradiction. Suppose that due care is set at the socially optimal care level, $\bar{y} = y^*$. Then the social costs of accidents are given in (E15). Consider now a slight increase in due care. This will change the NE. The social costs of accidents will change by:

$$\Delta = \frac{dx^{s*}}{dy^{s*}}\frac{dy^{s*}}{d\bar{y}} + \frac{dy^{s*}}{d\bar{y}} - \frac{dp^{s*}}{dx^{s*}}\frac{dx^{s*}}{dy^{s*}}\frac{dy^{s*}}{d\bar{y}}L - \frac{dp^{s*}}{dy^{s*}}\frac{dy^{s*}}{d\bar{y}}L \tag{E20}$$

or equivalently by:

$$\Delta = \frac{dx^{s*}}{dy^{s*}}\frac{dy^{s*}}{d\bar{y}}[1 - p_x(x^{s*}, y^{s*})L] + \frac{dy^{s*}}{d\bar{y}}[1 - p_y(x^{s*}, y^{s*})L] \tag{E21}$$

By (E7), it follows that $1 - p_y(x^{s*}, y^{s*})L$, so (E17) reduces to:

$$\Delta = \frac{dx^{s*}}{dy^{s*}}\frac{dy^{s*}}{d\bar{y}}[1 - p_x(x^{s*}, y^{s*})L] \tag{1}$$

---

[11] This, however, depends on the assumption that negligence does not account for causation and insteads takes the form of full liability. If causation is taken into account, then increasing due care will not alter the behavior of the injurer (see Kahan, 1989). However, social welafre can be increased by simultaneuously increasing the standard of care and damages.

Now, $\frac{dx^{s*}}{dy^{s*}} < 0$ (from E12) and, if the increase in $\bar{y}$ is sufficiently small,$\frac{dy^{s*}}{d\bar{y}} > 0$. In addition, since $x^{s*} > x^*$, it follows that $1 - p_x(x^{s*}, y^{s*})L < 0$ (see E4 and E10). Therefore, $\Delta > 0$, which contradicts the optimality of $\bar{y} = y^*$. This completes the proof.

If due care is set slightly above optimal care, the injurer will abide by due care and, for similar reasons discussed in the previous section, the victim will decrease his care. Social welfare will increase because the injurer takes efficient care given that the victim takes too much care, while the victim takes too much care given the care level taken by the injurer. Indeed, due care should be set at exactly the level of care induced by a strict liability rule with optimal damages awards.[12] Indeed, optimal negligence and a strict liability rule induce the same behavior from injurers and victims.

The above analysis is summarized in the following proposition.

Proposition 10 *Negligence: in a bilateral care model, due care should be set above optimal care. In particular, due care should equal the level of care induced by strict liability with optimal damages awards. Moreover, optimal negligence and strict liability rules induce the same behavior by injurers and victims.*

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[12]The qualification is that this care level may be sufficiently high so that the injurer will prefer to act negligently. However, this problem can be remedied if damages under negligence are increased to guarantee that the increased due care will be respected.

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