Mad Cows, Terrorism and Junk Food: Should Public Policy Reflect Subjective or Objective Risks?

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Abstract

Empirical evidence suggests that people's risk-perceptions are often systematically biased. This paper develops a simple framework to analyse public policy when this is the case. Expected utility (well-being) is shown to depend on both objective and subjective risks. The latter are important because of the mental suffering associated with the risk and as a basis for corrective taxation and second-best adjustments. Optimality rules for public provision of risk-reducing investments, "internality-correcting" taxation and provision of (costly) information to reduce people's risk-perception bias are presented.

Key words: Subjective risk, risk management, risk regulation**,** risk perception bias, terrorism, fat taxes, internalities, cost-benefit analysis, corrective taxation, paternalism

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I. Introduction

Public policies concerning health care, education, transportation, energy, agriculture, national security and military defence, the environment, and virtually all public policy areas in a modern society have to deal with risks. For example, how should we deal with natural catastrophes, genetically engineered food, terrorism, airplane safety, gun control and toxic substances in food? While risk has been incorporated into mainstream economic theory for a long time, there are many problems with applying the conventional approach in practice. In this paper we focus on the observed fact that the general public's risk perception is often very different from that of the experts, contrary to the assumption in conventional theory. [2] The issue to be analysed here is whether public policy in such situations should be based on the general public's risk perceptions or that of the experts or, if neither of these, what other criteria should we base our policy on?

Examples of risk perception biases have been identified in many areas including air pollution, food, smoking and terrorism. It is for example typically found that people severely overestimate risks associated with outdoor air pollution compared to indoor pollution (Breyer 1993, Margolis 1996). Many European smokers were recently found to be much more afraid of eating beef due to the BSE (Bovine Spongiform Encephalopathy, often referred to as the Mad Cow Disease) crisis (Abbot, 2001), than they were of smoking, even though virtually all experts considered the individual risk of BSE negligible when compared with smoking (cf. Aldhous, 2000). Similarly, given equal actual risk, most people (including the author) seem to feel much more unsafe when travelling by airplane than they do when travelling by car (cf.

[2] Biased risk perceptions are of course not the only possible explanation for people's behaviour differing from the behaviour of the conventionally assumed expected-utility maximising Homo Economicus; see for example Frederick et al. (2002) and Starmer (2000) for good overviews of time inconsistent behaviour and non-expected utility models, respectively.

Carlsson et al. 2003). Other obvious examples include the fear of eating genetically modified food, despite the fact that most experts appears to be in agreement that the objective risk is very small, for example compared with a diet that is too high in calories (see e.g. Noussair et al. 2004); and people's perceived risk of terrorist attacks, despite the fact that almost everywhere this risk is much smaller than the risk of a serious traffic accident (e.g. Sunstein 2003, 2005).[3]

Although there are large bodies of literature on both risk perception (see e.g. Slovic 2000) and risk regulation (Hahn 1996; Viscusi 1992a, 1998), systematic analysis based on the combination of the two appears to be an almost empty field, which is somewhat surprising given its obvious policy relevance. For example, should the government apply a higher value for a statistical life for outdoor air pollution compared with indoor air pollution, for consumption of meat or genetically modified food compared with fatty foods, and for air transport (and terrorist attacks) compared with other transport modes? Or should the same valuation per safety unit be used, irrespective of the subjective risk perception?

Salanie and Treich (2005), written independently from this paper, constitute an important exception in the literature. In their paper, a regulator can either be paternalistic or what they denote populistic, meaning that others' preferences are respected even if they are based on erroneous risk beliefs. They then compare the outcome based on an explicit functional form of the utility function.[4] Despite the basic similarities, the model and the contribution of the current paper is quite different.

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[3] Why and how risk misperceptions are formed and prevail is beyond the scope of this paper, but there are many reasons of which the media attention given to certain spectacular risks appears to be an important one (Slovic 1986, Pidgeon et al. 2004). Moreover, research in psychology indicates that people have large problems to deal with probabilities when strong feelings are involved (e.g. Lowenstein et al. 2001).

[4] Other notable exceptions are Hammond (1981) and Sandmo (1983), who analysed risk misperceptions in the framework of ex-ante versus ex-post welfare economics.

The main purpose of this paper is twofold: 1. To provide a simplified but practically useful and quite general framework for policy analysis when people have biased risk perceptions. The normative criterion in this framework is standard welfaristic, so that it is solely well-being that counts intrinsically; the policy instruments analyzed include direct public investments to reduce the risk, corrective taxation to counteract people's misperceptions, as well as (costly) information provision to reduce people's risk-perception biases. 2. To derive explicit normative policy conclusions, of which some may be surprising and perhaps counter-intuitive. For example, if people over-estimate a certain risk one may guess that the government should take this fact into account by spending less on reducing this risk, compared to what the first-best cost-efficiency rule would suggest. However, it is shown that this conclusion is premature, and that it may in fact be optimal to spend more than according to the first-best rule. It is also shown that providing a consumer with more information may in some cases induce choices that causes lower well-being, rather than the opposite.

Section II presents the most basic first-best model where the subjective risk does not affect individual well-being directly (i.e. there is no suffering from believing that something is dangerous). However, recalling the air travel example, it appears natural to think that passengers' mental sufferings associated with the (subjective) risk are just as real as other kinds of suffering. The benefit of reducing such suffering is therefore included in the more general model developed in Section III. Further, most risky decisions are made by individuals themselves, and are thus outside the direct control of the government. Nevertheless, if differentiated commodity taxation can be used to correct for people's (or a representative individual's) risk misperception, the government may still obtain a first-best solution. Unhealthy food is a possible target for such taxes, if people underestimate the risks of such food. The extent to which such perfect tax instruments are feasible can be discussed, however.

Section IV therefore analyses a second-best model where no differentiated commodity taxation is possible.

In addition to direct safety investments and pricing, the government may directly try to decrease the discrepancy between the objective and the subjective risk by providing more and better information. Indeed, perhaps the most natural thing to do when people are misinformed is to provide people with better information, instead of modelling what to do when they behave irrationally. However, as has recently been emphasized in the industrial organization literature, communication is typically costly (e.g. Dewatripont and Tirole, 2005). Indeed, there are many examples that show that even after very large and costly information campaigns, many misperceptions prevail (e.g. Pidgeon et al. 2003).[5] Rules for the optimal amount of information provision are therefore also derived, both in first-best and second-best models. Section V summarises and discusses the policy implications more generally.

II. The basic model: levels versus marginal risk changes

The issue of whose risk perceptions should ultimately count in public policy is not new; see e.g. Portney (1992) and Pollak (1998) for previous discussions. While both appear to be quite undecided on this issue, according to Pollak (1998), most analysts would agree with Breyer (1993) that such discrepancies do not reflect differences in *values* but in *understanding* of the risk-related facts, and that public policy should be based on these facts rather than on people's (mis)perceptions. For example, Viscusi (2000) strongly argues in favour of using the objective risks, according to the best available scientific evidence, rather than using people's biased risk perceptions. According to him, to spend scarce resources on reducing illusory fears, rather than real risks, "is a form of statistical murder in which lives are sacrificed." (p.

[5] Indeed, Carillo and Mariotti (2000) demonstrate that individuals who are aware of their own limitations may even sometimes prefer to be uninformed also when the information is costless to them.

867) Harsanyi (1982, 1995, 1997) has also repeatedly argued that what should matter in social decision making is *informed* or *true* preferences, i.e., the preferences a rational individual equipped with perfect information would have. It is difficult to argue against this standpoint when it is obvious that people simply make mistakes due to limited information or cognitive capacity. Indeed, since people know that they make mistakes for various reasons they often delegate their rights to choose to others, or they may vote to support systems where official experts make many choices for them. There is also evidence that people sometimes deliberately choose to reduce their own future freedom by crating commitments such as deadlines, presumably because the "current self" does not trust their "future self." Therefore, following e.g. Broome (1998), Ng (1999), Johansson-Stenman (2002) and O´Donoghue and Rabin (2005), we assume throughout in this paper that what matters intrinsically is well-being rather than choice. Or, using the terminology of Kahneman et al. (1997), we are intrinsically interested in *experienced* utility rather than *choice* utility. This implies that the model allows for paternalism following a small but rapidly growing literature that takes people's documented irrationality in various ways (notably time inconsistency) into account (e.g. Camerer et al. 2003, Gruber and Köszegi 2002, 2003, O'Donoghue and Rabin 2003, Thaler and Sunstein 2003). [6] In other respects the model is conventional.

Assume that a representative consumer's strictly quasi-concave expected utility function (reflecting expected well-being) is given by

$$U = u(x, r), \tag{1}$$

[6] Such a view can of course still be criticized. One can for example argue that individual choices should be given moral significance *per se*, i.e. independent of people's well-being; see e.g. Sugden (2004). Still, it is not difficult to modify the standard welfaristic approach adopted here by assuming that people get increased well-being from choosing for themselves.

where x is (net) private income and r is the objective risk (probability) of an accident, and where $u_x > 0, u_r < 0$ (subscripts denote partial derivatives). The risk can be reduced by a public investment G, so that $r = r(G)$, where $r_G < 0$ and $r_{GG} > 0$. Hence, we assume here for simplicity that the risk is independent of individual actions (since there are no individual actions in the model).[7]

The objective for the government is to maximise (1), which is assumed as known to the government, even when people's behaviour or expressed preferences would not imply the maximization of (1). Thus, the model implies that we know with certainty that the experts and policy-makers (who have access to the experts' views) are right, and correspondingly, that the general public is wrong, when the risk perceptions differ. This is of course not a strictly accurate assumption, since the real risk is often difficult to estimate even for experts. Moreover, both experts and policy makers are of course also to some extent affected by perception biases, as discussed by Viscusi (1995) and Viscusi and Hamilton (1999). Nevertheless, the assumption made here, that experts' risk perceptions are unbiased, constitutes a natural and important benchmark case. Throughout the paper it will also be assumed that there are no possibilities for private firms to 'internalize' people's risk misperceptions, e.g. by offering corresponding insurances or lotteries.[8]

[7] This simplifying assumption may be justified in cases where individual actions are likely to be independent of the public investment, but see the subsequent sections for generalizations.

[8] This may appear to be a strong assumption. For example, the popularity of some lotteries may depend on their possibility to induce people to think that their winning prospects are better than in reality. Nevertheless, it is clear that in many areas where risk misperceptions are large and prevail, there are still no insurances or lotteries offered. This may have several reasons, such as large transactions costs or market failures caused by moral hazard or adverse selection; see Russel and Thaler (1985) and Shleifer and Vishny (1997) for evidence that irrationalities may prevail also in highly competitive markets.

Efficient public safety investments

Maximising (1) subject to a budget restriction $M = x + p^G G$, where p^G is the per-unit price of G in terms of x and M is the available public budget, implies the standard condition for a Pareto efficient investment in G as follows:

$$WTP_r^{informed}(-r_G) = p^G , \qquad (2)$$

where $WTP_r^{informed} = -\frac{u_r}{u_x}(x,r)$ reflects an informed individual's marginal willingness to pay (*WTP*) for a risk reduction (i.e. without any risk perception bias),[9] and where $-r_G$ is the risk reduction caused per unit of G. Eq. (2) then simply reflects the conventional efficiency rule, corresponding to the Samuelson rule in the many individuals case, where the left hand side is equal to the individual benefit in terms of the *WTP* for the risk reduction caused by an additional dollar spent on G, and the right hand side reflects the marginal cost of G (or the marginal rate of transformation between G and x). This, of course, is not very surprising, since as long as the benefits from the last dollar spent on G are larger than the benefits from private consumption, it is optimal to invest more. In this paper we will not go further into the technical relationship between G and r; we will instead focus exclusively on people's perception of the risk r and the corresponding *WTP* to reduce this risk.

Efficiency with biased risk-perceptions

One of the most consistent and well-researched conclusions in the psychological literature on economic decision making is that people's responses to risk tend to deviate systematically

[9] Possible biases related to the elicitation method *per se* are neglected throughout the paper. In practice it is far from straightforward to quantify such preferences, perhaps particularly for stated-preference methods; see e.g. Beatty et al. (1998) and Kahneman et al. (1999).

from what is predicted by the conventional rationality assumptions in economics (Kahneman et al. 1982, Kahneman and Tversky 2000, Gilovich et al. 2002).[10]

In order to formally handle systematic risk misperceptions, let *s* denote the subjective risk, which may deviate from the objective risk *r*. We will assume that *s* depends on *r*, i.e. $s = s(r)$, where $s_r > 0$. For example, people know that travelling by car is risky, but not how risky it is. If the objective risk increases, e.g. through a speed increase, their subjective risk will also increase, and vice versa. Assume that the government uses some method (e.g. a revealed-preference method; cf. Viscusi and Aldy, 2003) to elicit individual preferences for a small risk-reduction. The *observed* individual marginal willingness to pay for a reduction in the risk *r*, at the perceived risk level *s*, is then given by

$$WTP_r^{observed} = s_r \left(-\frac{u_r}{u_x}(x,s) \right) = WTP_r^{informed} / \Omega . \tag{3}$$

where the correction factor $\Omega = \frac{WTP_r^{informed}}{WTP_r^{observed}} = \frac{1}{s_r} \frac{u_r / u_x (x,r)}{u_r / u_x (x,s)}$. By combining (2) and (3) we can write the efficiency condition in terms of observed *WTP*:

$$-r_G \, WTP_r^{observed} \Omega = p^G \tag{4}$$

Consequently, *G* should be over-provided compared with the efficiency rule in terms of observed individual *WTP* if $\Omega > 1$, i.e. $WTP_r^{observed} < WTP_r^{informed}$, and vice versa. To be able to say more about the likelihood for when this is the case, let us look closer on the relationship between the subjective and the objective risk. Consider Figure 1:

[10] It is sometimes argued that the observed differences in risk perceptions may not, at least not solely, reflect risk misperceptions by the general public. Instead, it may in part reflect differences in values and priorities between experts and people in general (e.g. Krupnick et al. 1993; Morgan 1992). Sunstein (2003), in a careful assessment of this proposition, nonetheless concludes that different priorities and values can only explain the large discrepancies typically obtained to a small extent, and that people's risk misperceptions are the main reasons behind them.

[Figure 1 about here]

In case *A*, the subjective risk *s* is simply a proportional amplification of the actual risk *r*, clearly implying that $s_r > 1$ so that a change in the real risk implies a larger subjective (or perceived) risk change. Similarly in case *B*, reflecting a case where people always systematically underestimate the risk, we have that $s_r < 1$. However, there is much evidence that people tend to systematically overestimate small risks and underestimate large ones (e.g. Viscusi 1992a, 1998). In case *C*, which is often seen as the standard picture of risk perception (e.g. Viscusi 1992a, p. 117) we have a linear relation between subjective and objective risk, clearly implying that the slope $s_r < 1$. If so, an objective risk increase (or decrease) will always imply a smaller subjective risk increase (or decrease). Note that this is also the case when the subjective risk is larger than the objective one i.e., to the left of the crossing point in the diagram. Thus, people may perceive a subjective risk to be much larger than the actual risk, but at the same time perceive the size of the risk *change* to be smaller than the true risk change.

It is often argued and found, however, that a relationship as in case *D*,[11] as proposed e.g. by Tversky and Kahneman (1992), is more realistic. In this case we have that $s_r > 1$ for sufficiently small risk levels and that $s_r < 1$ for larger ones. Taken together, we can note that the following pattern holds everywhere for each of the four diagrams:

Assumption 1. $s_{rr} \leq 0,\ s(r = 0) \geq 0$.

This implies a single-crossing property such that if $s < r$ then we have that $s_r < 1$, whereas the opposite does not hold, i.e. $s > r$ does not imply that $s_r > 1$.[12] In other words, if people

[11] There are of course many functional forms consistent with this pattern; see e.g. Gonzales and Wu (1999) for a good overview.

[12] The cumulative prospect theory actually implies that the subjective risk function would be convex in the real risk *r* for a sufficiently large *r* (close to 1), so that we would have an inverse s-shaped curve, implying that

underestimate the subjective risk, they will also underestimate the risk change (caused by an objective risk change), but if they overestimate the subjective risk they will not necessarily overestimate the subjective risk change.

Consider now the other factor of Ω: Strict quasi-concavity of *u* implies that the *WTP* increases in the initial baseline risk level,[13] implying that $-\frac{u_r}{u_x}(x,s) > -\frac{u_r}{u_x}(x,r)$ for *s* > *r* and vice versa. Combining this with the assumed pattern for s_r we have that that if *s* < *r* then $WTP_r^{observed} < WTP_r^{informed}$, but we cannot say whether the observed *WTP* exceeds the informed one if *s* > *r*. Combining this with (4) we have:

> ***Proposition 1.*** *If people underestimate the risk (s < r) then the optimal provision of G exceeds the basic efficiency rule in terms of observed WTP for a risk decrease. However, if people overestimate the risk (s < r) it is ambiguous whether or not the optimal provision of G exceeds the level obtained by the basic efficiency rule.*

III. Decentralisation, mental suffering, pricing and information provision

In the real world most risky decisions are made by people themselves, such as what to eat, drink, whether or not to smoke and if so what to smoke, how to travel etc. Therefore, in this section we model a decentralised market economy where people choose themselves how

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$s_r > 1$ would again hold for sufficiently high risk levels (not shown in the graph). However, this risk interval is not relevant here, since risk regulation typically deal with much smaller risks. Moreover, the value function in prospect theory need not be based on cognitive risk misperceptions, it is sufficient that people behave *as if* they have risk misperceptions. The same applies here. It is thus sufficient that people behave as if they have risk misperceptions.

[13] Although strict quasi-concavity is not self-evident, the implication that *WTP* for a given risk reduction increases in the initial risk level is often assumed, implicitly or explicitly; see e.g. Jones-Lee (1974) and Pratt and Zeckhauser (1999).

much to buy of a risky and a non-risky good, respectively. Furthermore, if the consumers acted perfectly rationally, in the sense of maximising their own expected well-being, and if there were no externalities associated with consumption, a regulator concerned with efficiency would have no reason to do so. But when people make systematic mistakes it is possible to obtain an efficiency improvement by adjusting prices of goods through corrective taxation. Therefore, we allow for the possibility of using consumption taxes, where the revenues can be distributed back in a lump-sum manner.

Further, it has so far been assumed that expected utility (well-being) is solely a function of consumption and actual risk, even if this risk may be misperceived. However, this is clearly quite restrictive and it is possible that the perceived risk affects individual utility directly, i.e. independent of the actual risk. Obvious examples include fear related to a perceived risk while flying, or health-risk anxiety due to the use of certain chemicals in food or terrorism, even though the actual risks might be fairly low. Given that we care intrinsically about people's well-being, rather than their choices, it is hard to see why such mental suffering should count less than other determinants of individual well-being. Thus, it is included in the utility function, as in Becker and Rubinstein (2004).[14]

Moreover, one may argue that when the discrepancy between objective and subjective risk is due to imperfect information, the appropriate task for the government is to provide information in order to eliminate, or at least reduce, this discrepancy, rather than to try to correct for possible misperceptions. Although this argument may seem convincing, it has often been found that large differences persist even after intensive public information campaigns, sometimes partly due to a limited governmental credibility; see e.g. Pidgeon et al. (2003). Further, providing information is typically costly and can therefore not be seen as a

[14] They model fear in a slightly different way. They let fear depend on the objective risk, the degree of salient, and a possible fixed investment that the consumer may pay in order to eliminate the fear.

free lunch. The following model is generalised to encompass these aspects. Expected utility for the representative consumer can now be written as:

$$U = u(x, y, r, m(s)), \qquad (5)$$

where *x* is a composite risk-free good, *y* is a risky good, *r* is the objective risk, and *m* is the mental suffering (or fear) associated with the subjective risk *s*. Assume further that *u* is strictly quasi-concave in its arguments (to ensure a unique perceived optimum for the consumers, as well as an actual expected utility optimum), $u_x > 0, u_y > 0, u_r < 0, u_m < 0$, $m_s > 0$, and $m_{ss} < 0$. Thus, for a given objective risk, expected utility decreases with the subjective risk. For analytical convenience, we also make the following assumption:

> ***Assumption 2:*** *It is possible to write the utility function as weakly separable in the objective risk, as follows:* $U = v(f(x, y, m), r(\cdot))$.

This implies that the marginal rates of substitution between *x*, *y* and *m*, respectively, are independent of the objective risk *per se*.[15] In other words, the relative value of *x*, *y* and *m* are independent of the objective risk *r*. This assumption does not seem overly restrictive and, although it is not essential for the main conclusions, it simplifies the subsequent analysis and the optimality expressions. The objective risk *r* is now a function both of the consumption of the risky good *y* and of public investments to reduce the risk *G*:

$$r = r(y, G), \qquad (6)$$

where $r_y > 0, r_{yy} < 0, r_G < 0$ and $r_{GG} > 0$. The subjective risk is now a function of both the objective risk and of publicly provided information *I*, aimed at reducing the discrepancy between the subjective and objective risks. Thus, we have:

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[15] That is, for a constant subjective risk. The mental suffering in itself is a function of the subjective risk, which in turn depends on the objective risk. Moreover, since *r* depends on *y*, the consumer choice between *x* and *y* will therefore still be affected by exogenous changes in *r*.

$$s = s(r(y,G), I) \,, \tag{7}$$

where $s_r > 0$ and where $s_I < 0$ for $s > r$ and vice versa, where the latter condition simply means that the risk misperceptions decrease monotonically in *I*. Moreover, we assume that the *marginal* risk perception bias decreases with the information provided, i.e. $\frac{\partial s_r}{\partial I} < 0$ for $s_r > 1$ and vice versa. Let us for simplicity also assume a linear budget restriction such that

$$M = x + y + p^G G + p^I I \,, \tag{8}$$

where p^I is the per-unit price of public information *I*, and where the prices of *x* and *y* without loss of generality are normalised to one. Substituting (6)-(8) into (5) we can write individual expected utility as:

$$U = u(M - p^y y - p^G G - p^I I, y, r(y,G), m(s(r(y,G), I))) \,. \tag{9}$$

Optimal safety investments

The first order optimum condition is obtained by differentiating (9) with respect to the public safety investment *G*:

$$WTP_r^{informed}(-r_G) + WTP_m m_s s_r(-r_G) = p^G \,. \tag{10}$$

where $WTP_m = -\frac{u_m}{u_x}$ is the marginal willingness to pay per unit of mental suffering reduction in terms of *x*. Note that since we are in a first-best world, this expression would be identical in the case with no risk misperceptions. The terms on the left-hand side reflect components of the marginal benefits of *G*, which is based on the objective risk, whereas the term on the right-hand side reflects the marginal cost (the per unit price) of *G* in terms of the numeraire good *x*. The first term on the left-hand side is identical to the one in Section 2, and it has the same straightforward interpretation here. The second term reflects the *WTP* for the correspondingly decreased mental suffering from a slight increase in the safety-enhancing investment *G* (and hence a decrease in *r* and *s*).

The *WTP* for the risk decrease associated with an incremental increase in *G* for an individual with risk misperception is instead given by $WTP_r^{observed}(-r_G) + WTP_m m_s s_r(-r_G)$. Thus, the condition for when the optimal provision of *G* exceeds the level obtained by the conventional efficiency rule is the same as in the previous section, and depends on whether $WTP_r^{observed} > WTP_r^{informed}$, i.e. whether the observed *WTP* for a risk decrease exceeds the informed *WTP* or not; thus, *Proposition 1* holds here as well. The intuitive reason behind the fact that mental suffering does not affect this condition is that there is no discrepancy between the effects on choice utility and experienced utility here. People simply feel what they feel, and no one feeling is more or less correct than another.

Optimal pricing

We now turn to the pricing issue. The optimal tax *t* on the risky good *y* is obtained by comparing the social optimum condition with respect to *y* with the corresponding private optimum condition, where a consumer faces the budget constraint

$$M + \tau = x + y(1+t), \tag{11}$$

where τ is a lump-sum transfer from the government. It can be shown (see appendix) that an optimal tax *t* on the risky good can then be written as the following straightforward expression:

$$t = r_y(WTP_r^{informed} - WTP_r^{observed}) \tag{12}$$

Thus, the tax equals the difference between what an informed individual on the margin would have been willing to pay per unit of *y* if she had perceived the risk accurately, and her actual willingness to pay. In the absence of any perception bias, i.e. when *s* = *r*, the optimal tax *t* is clearly zero. This is not surprising at all, since it just reflects the first theorem of welfare economics, i.e. that an undistorted market equilibrium is Pareto efficient.

Suppose, for example, that people underestimate the risk of eating potato chips by 50% at the margin.[16] This would imply that their *WTP* to avoid the risk of an additional potato chip (holding the mental suffering of the risk constant) would be reduced by more than 50%, if *WTP* increases with the perceived initial risk. Suppose it is reduced by 60%. Denote the first term of (12) by α, implying that the second term is equal to $(1-0.6)\alpha$ or 0.4α. Thus, the optimal tax would be 60% of the *WTP* that they would have been willing to pay for this risk reduction without risk misperceptions, or, expressed alternatively, 1.5 times the *WTP* they actually have for the risk reduction (once again holding mental suffering constant).

Now consider the case where we only know that people misperceive the overall risk of consuming *y*, and in what direction this risk perception is, but that we have no direct information regarding the perception of a marginal change. Since we have as before that when $s < r$ it follows that $WTP_r^{observed} < WTP_r^{informed}$, but not vice versa, we have, analogous to *Proposition 1*:

Proposition 2. *If people underestimate the risk associated with consuming the good (s < r) then a first-best optimal tax on the risky good y is strictly positive. However, if people overestimate the risk (s > r) the sign of the tax is ambiguous.*

Note that the basis for this corrective taxation is not externalities, i.e. costs imposed on others, but what Herrnstein et al. (1993) denote *internalities*, i.e. individuals hurt themselves by making bad decisions. There are of course other sources for internalities in private consumption besides risk misperceptions. For example, Gruber and Köszegi (2002, 2003), argue in favour of high cigarette taxes based on individual irrationalities, but not based on risk

[16] Lomborg (2001), and many others, argue that people on average tend to underestimate the risks associated with fatty food in particular and unhealthy food more generally.

misperceptions but on limited self-control resulting in time inconsistent behaviour. The tax derived here is then similar to the tax proposed by Gruber and Köszegi in that it is motivated by internalities, even though the reasons behind the irrationalities are different.

Optimal information provision

Let us first assume an interior solution with respect to the optimal amount of information provided by the authorities, then briefly discuss the possibility of a lower corner solution with no information provision. The socially optimum condition is obtained by differentiating (9) by I implying:

$$WTP_m m_s(-s_I) = p^I . \tag{13}$$

Thus, the *WTP* that an informed individual would have for the decreased mental suffering associated with the decreased perceived risk due to a unit increase in public information I, should at optimum equal the per-unit cost of information. Note in particular that there is no benefit from the fact that people can make better choices when they are better informed in the optimum condition. This is due to the fact that the possibility of adjusting the relative prices *per se* implies that consumer choices are efficient. (Welfare effects of better consumer choices are analysed in the next section.)

Therefore, the existence of an interior solution is far from obvious here. Note in particular that when $s < r$ the left-hand-side term is actually negative, implying that it is never optimal to provide more information in this case. This reflects the fact that in a first-best world, when the consumption of x, y and I is optimal, providing better information about the actual risk would reduce expected utility. This is because the only difference that this information would make would be an increase in the mental suffering associated with the subjective risk. Hence, if the authorities can ensure that consumers make an optimal consumption choice, e.g. through taxes, their well-being would actually be decreased if they were informed about the (higher) true risks. Whether information provision would be part of the optimum condition when $s > r$ is not obvious either, but depends on whether the benefit of providing a small amount of information reduces the risk misperception, and hence the mental suffering, sufficiently to warrant the costs in a situation where optimal safety investments and relative price adjustments are made anyway. Formally, it is optimal to provide a non-zero amount of information if (and only if)

$$\left(WTP_m m_s(-s_I)\right)_{I=0} > p^I \tag{14}$$

Thus we have:

Proposition 3*. If people underestimate the risk (s < r) in a first-best economy, it is never optimal to provide the consumers with better information, as long as the price of information is non-negative. However, if people overestimate the risk (s > r), it is optimal to provide a positive amount of information, provided that the per-unit price of information is sufficiently low.*

IV. When differentiated taxes are not possible: A second-best model

In Section 3 it was assumed that the government could use differentiated consumption taxes in order to correct for people's risk misperceptions. Even if these results are important as benchmark cases, one can question whether such taxes are feasible in reality, e.g. due to administrative and legal reasons. Moreover, with heterogeneous individuals with differing risk misperceptions we would need personalised taxes to obtain efficiency, and such taxes are clearly unfeasible in practice. Another natural benchmark case is therefore to assume that no differentiated taxes are possible. In such a situation it is in general not possible to obtain a first-best solution, implying that our objective here is to derive second-best optimality rules.

Let us assume an identical model to that in Section 3 with the only difference being that we cannot use differentiated taxation any more, implying that we cannot affect the relative prices. Expected utility is thus, as before, given by the strictly quasi-concave function $U = u(x, y, r, m(s))$ which fulfils the weak separability property in *r* (*Assumption 2*), and where $r = r(y, G)$ and $s = s(r(y, G), I)$; the budget requirement is also given by $M = x + y + p^G G + p^I I$ as before. Now, however, due to the impossibility of adjusting relative prices, the consumer choice between *x* and *y* will in general not be optimal anymore. The only way the government can affect this choice is through its choice of *G* and *I*. It is straightforward to show (see appendix) that the optimal provision of *G* is given as follows:

$$WTP_r^{informed}(-r_G) + WTP_m m_s s_r(-r_G) + (WTP_r^{observed} - WTP_r^{informed}) r_y y_G = p^G . \quad (15)$$

The terms on the left-hand side reflect components of the marginal benefits, and the term on the right-hand side reflects the marginal costs (the per unit price) of *G* in terms of the numeraire *x*, as before. The first two terms on the left-hand side are identical to the ones in a first-best world, as shown in Section 3, eq. (10), and they have the same straightforward interpretation here, whereas the third term reflects second-best welfare effects. The interpretation of this term is also straightforward: Assume that people underestimate a marginal risk change, so that $WTP_r^{observed} < WTP_r^{informed}$. Then people will consume too much of *y*, implying that it is a social benefit if the consumption of *y* is reduced. The size of this benefit is exactly equal to the difference between the perceived and the informed value of the risk change, times how much the risk is reduced on the margin (through reduced consumption *y*) per unit of *G*.

The consumers perceived optimum condition is given by:

$$WTP_r^{observed}(-r_G) + WTP_m m_s s_r(-r_G) = p^G \quad (16)$$

Consequently, combining (15) and (16) we find that *G* should be over-provided compared with the conventional efficiency rule if $(WTP_r^{informed} - WTP_r^{observed})((-r_G) - r_y y_G) > 0$, and vice versa.

In order to determine the sign of this expression, let us start with the sign of y_G. There is ample evidence that public safety investments are partly crowded out by people making more risky individual choices themselves. For example, Peltzman (1975) in a classic study showed that mandatory seat-belt laws implied more risky driving behaviour; see Keeler (1994), Peterson et al. (1995) and Merrel et al. (1999) for additional evidence. Moreover, from this literature it is also typically found that people do not over-compensate. This implies that there is generally a positive net effect of the safety measure taken, albeit a smaller one than without compensatory behaviour.[17] Following this empirical evidence, we have:

Assumption 3. $y_G > 0$; $(-r_G) > r_y y_G$.

Consider now the case where *s* < *r* implying from Section 2 that $s_r < 1$ and that $WTP_r^{informed} > WTP_r^{observed}$. From Assumption 3 we clearly have that $(-r_G) - r_y y_G > 0$. Hence, *s* < *r* implies that *G* should be over-provided compared to the basic efficiency rule. When *s* > *r* on the other hand, we have the same ambiguity as previously, since we cannot say whether $WTP_r^{informed} > WTP_r^{observed}$ or not. Thus, conditional on *Assumption 3*, *Proposition 1* holds also in this second-best context.

In order to illustrate these second-best results, consider the recent European experience of many people being afraid of eating beef due to the Mad Cow Disease, even though most leading medical experts considered the risks to be negligible compared with many other risks that we cannot (or do not want to) avoid in our daily life. Applying the subjective risk would presumably imply far-reaching import restrictions on beef, whereas applying the objective

[17] Although this relationship appears quite reasonable in most cases, in a slightly different model where increased publicly provided safety increases private costs, it is less obvious. For example, as mentioned by Sunstein (2003), increased air-travel safety standards that imply that the costs of flying increase, may cause travellers to choose to go by car instead, which increases the risk. Indeed, recent empirical estimates by Blalock et al. (2005) suggest that this effect may be substantial.

(assuming that the experts were right in their judgements) would not.[18] The results from this paper suggest that no restrictions should have been imposed unless one would have expected non-negligible mental suffering from the risk, or unless people would have largely adjusted their behaviour. In reality, we know that many people were indeed very scared, and there were quite large consumer adjustments too. Therefore, the import-restrictions actually undertaken may after all have been well-motivated in a second-best perspective, since both the mental suffering and the welfare loss of poor consumer choices may have been much larger otherwise.

Similarly, consider the US investments in safety after 9/11. Even if we only consider domestic investments, it is obvious that the cost per potential life saved must be enormous, and that many more lives could have been saved if some of these money would have been spent on, say, improved road safety instead; cf. Sandler (2004). On the other hand, this is also a case where the mental suffering costs are clearly non-trivial, and where people themselves might have made even more irrational decisions (e.g. reduced their air-travels even more, cf. Blalock et al. 2005) without these large investments. Of course, this does not imply the large measures taken are justified, only that the naïve standard model is inappropriate here.

For analytic simplicity, the theoretical model was based on choices between two consumer goods, but it is straightforward to extend the model to many goods, and also so that it encompasses private risk-reducing investments. Public policy, then, needs to take into account the indirect welfare effects of private safety investments that it induces. It is easy to think of relevant examples here as well. Consider the case when people are irrationally afraid of poor drinking water, and they therefore invest large amounts of money to improve the

[18] It is implicitly assumed that higher subjective risk also increases the *WTP* for a risk *change*, which seems reasonable here since the objective risk is close to zero. Note also that we only discuss import restrictions on *beef*; there was a much stronger case for stringent import restrictions on *cattle*.

quality. Should the authorities improve the water quality despite the fact that, based on the objective risk, the measure is cost-ineffective? Well, maybe if the public investment would crowd-out much of the private investments. Of course, if the government could provide information to eliminate the risk misperception at a modest cost, this would be preferable. In reality, though, this is unlikely. Hence we need to think of criteria that should guide decisions about how much information to provide in a second-best world. This is the issue we turn to next.

Second-best information provision

It appears to be a more obvious role for information provision in this second-best world, since increased information will help people making better decisions. Hence, there is a trade-off between the gains through better consumer choices that could be achieved by providing more information in a second-best world, and the corresponding costs. Therefore, also the existence of an interior optimal solution appears more likely in this case. However, as will be shown, it is actually possible that more information will imply poorer individual consumption choices.

Assuming the existence of an interior optimum we can write (see appendix) the optimal information provision condition as follows:

$$WTP_m m_s(-s_I) + r_y y_I (WTP_r^{observed} - WTP_r^{informed}) = p^I \ . \tag{17}$$

The first term of (17) is identical to the first-best model, eq. (13), and it has the same straightforward interpretation, i.e. the *WTP* that the individual would have for the decreased mental suffering associated with a unit increase in public information *I*. In practice, from a policy perspective, however, the most important motive for providing better information is presumably that consumers would be able to make better-informed decisions relating to risky activities, and such effects are reflected in the second term. This term can be interpreted as the additional (expected) welfare, in monetary terms, that one unit of *I* causes through better consumer choices, provided that the term is positive. In order to determine the sign of this term, let us make the following reasonable assumptions:

Assumption 4. *i. The consumption of the risky goods decreases with the perceived risk of consuming one more unit of the good, i.e.* $\frac{\partial y}{\partial (s_r r_y)} < 0$. *ii. The consumption of the risky goods decreases with the perceived absolute magnitude of the risk, i.e.* $\frac{\partial y}{\partial s} < 0$.

Then we find that when people underestimate the risk, so that $s < r$, $y_I < 0$ implying that more information induces people to consume less of the risky good, since $s_r < 1$. Moreover, since $WTP_r^{observed} < WTP_r^{informed}$ we clearly find that the sign of the second term of (17) is positive, which follows intuition. On the other hand, when $s > r$ *Assumption 4* is not sufficient to say that the sign is positive, and we have instead:

Proposition 4. *The second-best welfare effects due to changed consumer choices (the second term of eq. 17) are negative when s > r and* $s_r < 1$, *and the following condition holds: If* $\frac{\partial y}{\partial s}\frac{\partial |s-r|}{\partial I} < (>) \frac{\partial y}{\partial (s_r r_y)}\frac{\partial |s_r - 1|}{\partial I}$ *then* $WTP_r^{observed} < (>) WTP_r^{informed}$. *For all other cases, these welfare effects are non-negative.*

Proof: See appendix. Intuitively, one may expect that consumers with biased risk perceptions would make better choices between risky and non-risky goods if they get more information, since it is assumed that both their absolute and the marginal degree of risk misperception decrease with the amount of public information provided. In most cases this is also the case, but when people simultaneously overestimate the overall risk and underestimate a risk change, it is ambiguous whether more information will induce more or less risky behaviour, and then whether the welfare effects are positive or negative.

Consider an example with tobacco smoking, and assume that an individual overestimates the overall risk of smoking (see e.g. Viscusi 1992b for some empirical evidence for this) and that he simultaneously underestimates the marginal risk associated with smoking one additional cigarette. Also assume that the net effect in this case is that he smokes too much for his own interest, in terms of expected experienced utility. More publicly provided information about the true risk of smoking will in this case have two effects. 1. The risk-perception bias in terms of absolute risk level will decrease. This effect will induce the individual to smoke more. 2. The marginal risk-perception bias will also decrease. This effect will induce the individual to smoke less. Thus, if the first effect dominates the latter, more information will hurt the individual, so that he will make even worse choices (in this case smoke more) than before the additional information.

However, even when the second term of (17) is positive, it does not follow that it is optimal to provide any information at all. In the first case, where people underestimate the overall risk, there is an increased mental suffering component from providing more information that one should take into account, and in both cases the marginal benefit of more information must of course outweigh the marginal cost, or the per unit price, of providing the information.

V. Discussion and Conclusions

This paper has analysed normative implications of biased risk perceptions, for which there is ample empirical evidence. It was shown that the fact that people overestimate a certain risk does *not* imply that they, correspondingly, would overestimate a risk *change*, either as a result of their own actions or of measures taken by others (such as the authorities). Nor does it imply that their *WTP* for a risk change would be overestimated compared with what they would have been willing to pay had they had perfect information. Indeed, empirical evidence of the opposite, from the risk literature, was presented. However, the result is asymmetric and it was shown that if people underestimate the risk, they would also underestimate risk *changes* and their *WTP* for a risk change would be lower than with an unbiased risk perception. Consequently, the optimal level of public safety investments was shown to exceed the level implied by the conventional efficiency rule in terms of *WTP* when people underestimate the risk; however, the result is ambiguous when people overestimate the risk. This asymmetry was shown to hold, conditional on some additional fairly weak assumptions, also for the more general models with decentralised market, where people choose between risky and non-risky alternatives, where they suffer mentally due to the subjective risk, and where the government can provide (costly) information that reduces people's risk misperceptions.

In a first-best world optimum internality-correcting taxes, such as "fat-taxes" when people underestimate the risk of eating unhealthy food, were shown to equal the *WTP* that the individual would have based on an accurate risk perception for the risk minus the actual *WTP* that the individual has for this risk reduction (where the subjective suffering is held constant). In a second-best world, when such differential commodity taxation is considered unfeasible, the optimum conditions for optimal safety investments as well as information provision include terms that reflect whether such measures on the margin improve the consumer choices, or not, relative to what the consumer would have chosen with correct misperception. One may expect that more information that reduces the risk misperceptions would improve the consumer choices. This is also the fact in most cases, but cases where the opposite holds were also identified.

Finally, it is of course important to bear possible *instrumental* considerations in mind when discussing policy recommendations based on paternalism. Since we have indeed seen terrible consequences of *excessive* paternalistic decision-making in many countries in the past "we should not replace welfare agnosticism with a "promiscuous paternalism"" O'Donoghue and Rabin (2001, 31). Still, this does not imply that we should refrain from welfare-based policy analysis in situations where people make systematic and important mistakes; cf. e.g. O'Donoghue and Rabin (2003). Furthermore, when people's behaviour can be characterised by what O'Donoghue and Rabin (1999) denote sophisticated irrationality, meaning that they are well aware of their own imperfections such as their self-control problems, people may vote for paternalistic policies based on pure self-interest. Indeed, in virtually all Western democratic countries, we have a system of representative democracy, meaning that we voluntarily vote for candidates that will make many decisions for us. As noted by Thaler and Sunstein (2003), paternalistic policies are sometimes simply inevitable.

As far as the author knows, the current paper provides the first attempt (together with Salanie and Treich, 2005) to theoretically analyse normative policy implications of risk misperceptions. A possible extension would be to model macro economic consequences of risk misperceptions through what Kuran and Sunstein (1999) denote *availability cascades*, i.e that an expressed perception triggers a chain reaction and starts a self-reinforcing process of collective belief formation. For example, although direct monetary costs of terror attacks, such as 9/11 in the US, are in general quite modest from a country perspective, indirect effects through increased fear may be substantial (Abadie and Gardeazabal, 2003, 2005; Becker and Rubinstein 2004); according to Krugman (2001) "Truly, the only thing we have to fear is fear itself." In any case, the main conclusion regarding the question posed in the title of this paper seems fairly robust: policy-makers cannot simply choose between being concerned with the subjective or the objective risk; they need to be concerned with both.

APPENDIX

Proof of equation (12):

The social first order condition with respect to consumption of the risky good *y* is obtained by differentiating (9) with respect to *y*:

$$\frac{u_y}{u_x}(x,y,m)+\frac{u_r}{u_x}(x,y,r,m)r_y+\frac{u_m}{u_x}(x,y,m)m_s s_r r_y=1, \tag{A1}$$

The left-hand side of (A1) reflects the social marginal rate of substitution between the risky and the risk-free good, whereas the right-hand side reflects the marginal rate of transformation between them (which equals the relative production price, which in turn is normalised to one). The reason we can write the first and the third marginal rates of substitution as functions independent of *r* is because of the separability structure (*Assumption 2*).

From individual expected utility maximisation, we find that consuming one more unit of the risky good *y* must give the same utility as consuming one more unit of the risk-free good *x* and that a rational individual would also take into account the mental suffering associated with the action. Given the standard competitive assumption, each consumer's contribution to the overall tax revenues is small, implying that the lump-sum transfer τ is treated as exogenous to each consumer. Substituting (6), (7) and (11) into (5) implies that individuals will maximise the following function:

$$U=u(M+\tau-y(1+t),y,s(r(y,G)),m(s(r(y,G)))). \tag{A2}$$

When consumers perceive the true risk *r* as *s*, we can obtain the first order condition for the consumer decision by differentiating (A2) by *y*, implying:

$$\frac{u_y}{u_x}(x,y,m)+s_r r_y\frac{u_r}{u_x}(x,y,s,m)+\frac{u_m}{u_x}(x,y,m)m_s s_r r_y=1+t \tag{A3}$$

where we can again write the first and the third marginal rates of substitution as functions without the objective risk due to *Assumption 2*. We can then obtain the optimal tax by combining the individual optimum condition (A3) with the social optimum condition (A1), implying:

$$t = r_y\left(-\frac{u_r}{u_x}(x,y,r,m) - \left(-\frac{u_r}{u_x}(x,y,s,m)s_r\right)\right) = r_y\,(WTP_r^{informed} - MWTP_r^{observed})\ . \qquad \text{(A4)}$$

Proof of equation (15):

Here we are only interested in the net effect in equilibrium, and not in the specific mechanisms. Hence, we can work with a reduced form of the relationship between the choice of *y* (and hence implicitly also of *x*) and *G* and *I*, as follows:

$$y = y(G,I)\ . \qquad \text{(A5)}$$

Substituting (6)-(8) and (A5) into (5) implies that we can then write individual expected utility as:

$$U = u(M - y(G,I) - p^G G - p^I I, y(G,I), r(y(G,I),G), m(s(r(y(G,I),G),I)))\ . \qquad \text{(A6)}$$

Differentiating (A6) with respect to *G* gives the regulator's first-order conditions for an interior second-best optimal solution with respect to *G*

$$-u_x p^G - u_x y_G + u_y y_G + u_r r_y y_G + u_r r_G + u_m m_s s_r r_y y_G + u_m m_s s_r r_G = 0\,, \qquad \text{(A7)}$$

where y_G is thus the overall marginal effects on consumption of *y* from an increase in public investment *G*, including indirect effects from changes in safety and income. Re-arranging (A7) gives:

$$\begin{aligned}&\left(\frac{u_r}{u_x}(x,y,r,m) + \frac{u_m}{u_x}(x,y,m)m_s s_r\right)r_G \\ &+ y_G\left(-1 + \frac{u_y}{u_x}(x,y,m) + \frac{u_r}{u_x}(x,y,r,m)r_y + \frac{u_m}{u_x}(x,y,m)m_s s_r r_y\right) = p^G\end{aligned}\ . \qquad \text{(A8)}$$

An individual that attempts to maximise his expected utility, when misperceiving *r* as *s*, would consume the risky good *y* until the perceived marginal utility of doing so equals the utility from consuming one more unit of the risk-free good *x*, and the optimality condition for doing so is the same as in the first-best case in Section 3 (eq. A3), except for the fact that we have no corrective tax here. Given the weak separability assumption we then have

$$\frac{u_y}{u_x}(x,y,m) + s_r r_y \frac{u_r}{u_x}(x,y,s,m) + \frac{u_m}{u_x}(x,y,m) m_s s_r r_y = 1. \tag{A9}$$

Combining the social and individual optimum conditions, i.e. (A8) and (A9), implies:

$$\begin{aligned} &\frac{u_r}{u_x}(x,y,r,m) r_G + \frac{u_m}{u_x}(x,y,m) m_s s_r r_G + r_y y_G \left(-s_r \frac{u_r}{u_x}(x,y,s,m) - \left(-\frac{u_r}{u_x}(x,y,r,m)\right)\right) \\ &= WTP_r^{informed}(-r_G) + WTP_m m_s s_r (-r_G) + r_y y_G \left(WTP_r^{observed} - WTP_r^{informed} \right) = p^G \end{aligned}. \tag{A10}$$

Proof of equation (17):

The first order condition for an optimal amount of information provision is obtained by differentiating (A6) with respect to *I*:

$$-u_x p^I - u_x y_I + u_y y_I + u_r r_y y_I + u_m m_s s_r r_y y_I + u_m m_s s_I = 0, \tag{A11}$$

where y_I is the overall marginal effect in equilibrium on consumption of *y* from an increase in public investment *G*, including various indirect effects. Re-arranging (A11) gives:

$$\begin{aligned} &\frac{u_m}{u_x}(x,y,m) m_s s_I \\ &+ y_I \left(-1 + \frac{u_y}{u_x}(x,y,m) + \frac{u_r}{u_x}(x,y,r,m) r_y + \frac{u_m}{u_x}(x,y,m) m_s s_r r_y \right) = p^I \end{aligned}. \tag{A12}$$

The individual optimum condition is given by (A9). (A12) and (A9) imply:

$$\begin{aligned} &\frac{u_m}{u_x} m_s s_I + r_y y_I \left(\frac{u_r}{u_x}(x,y,s,m) s_r - \left(-\frac{u_r}{u_x}(x,y,r,m)\right)\right) \\ &= WTP_m m_s(-s_I) + r_y y_I (MWTP^{observed} - MWTP^{informed}) = p^I \end{aligned}. \tag{A13}$$

Proof of proposition 4:

The case when $s < r$ is already shown. When $s > r$ and $s_r > 1$ we have directly that $y_I > 0$. Then we have from (17) that the sign is positive if $MWTP^{observed} > MWTP^{informed}$. This, in turn, is the case if $\frac{MWTP^{observed}}{MWTP^{\inf ormed}} = s_r \frac{u_r / u_x (x,y,s,m)}{u_r / u_x (x,y,r,m)}$>1, which holds since $\frac{u_r / u_x (x,y,s,m)}{u_r / u_x (x,y,r,m)} > 1$.

The remaining case is when $s > r$ and $s_r < 1$. Then the sign is negative if $y_I > 0$ and $MWTP^{observed} < MWTP^{informed}$, or if $y_I < 0$ and $MWTP^{observed} > MWTP^{informed}$. Thus, the sign of the second term of (17) is negative if and only if $\left(\frac{\partial y}{\partial s} \frac{\partial |s-r|}{\partial I} - \frac{\partial y}{\partial (s_r r_y)} \frac{\partial |s_r - 1|}{\partial I} \right) \left(MWTP^{observed} - MWTP^{informed} \right) < 0$, which is equivalent to *Proposition 4*.

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Figure 1. Possible relations between subjective and objective risk.