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Mad cows, terrorism and junk food: Should public policy reflect perceived 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 perceived risks (beliefs). The latter are important because of the fear 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 (e.g. fat taxes) and provision of costly information to reduce people's risk-perception bias are presented.

JEL classification: D81; H4; I1

Keywords: Risk regulation; Risk perception bias; Internalities; Cost-benefit analysis; Paternalism

1. Introduction

Virtually all public policy areas in a modern society have to deal with risks. For example, how should we deal with possible negative side effects of medicine, natural catastrophes, genetically engineered food, terrorism, airplane safety, gun control and toxic substances in food? And similarly, how should we deal with uncertain positive impacts from sport activities and healthy foods? While risk has been incorporated into mainstream economic theory for a long time, there are many problems with applying the conventional approach in practice. This paper focuses 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. Should public policy in such situations be based on the general public's risk perceptions or that of the experts? If neither, what other criteria should be employed?

The main purpose of this paper is twofold: (1) to provide a simplified but general and practically useful framework for policy analysis when people have biased risk perceptions, and (2) to derive explicit normative policy conclusions based on this framework, where the policy instruments analysed 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.

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Examples of risk perception biases have been identified in many areas including health care, 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 Bovine Spongiform Encephalopathy (BSE), known as the ‘mad cow disease’ crisis, than they were of smoking, even though virtually all experts considered the individual risk of BSE negligible when compared with smoking; cf. Pennings et al. (2002) and Setbon et al. (2005). Similarly, most people (including the author) seem to feel safer when travelling by car rather than by using a commercial airline (cf. Carlsson et al., 2004). Other obvious examples include the fear of eating genetically modified food, despite the fact that most experts appear to agree that the objective risk is very small compared with for example 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 experiencing a serious traffic accident (e.g. Sunstein, 2003, 2005).[1]

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 has not attracted much attention, which is surprising given its obvious policy relevance.[2] For example, should the government apply a higher value of 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?[3] Or should the same valuation per safety unit be used, irrespective of risk beliefs?

Section 2 presents the basic model where the objective risk can be reduced by public safety investments. Section 3 presents a more general model that includes fear from risk beliefs and where people can consume both risky and risk-free goods. The policy instruments, in addition to safety investments, include information provision in order to reduce the risk misperception as well as differentiated commodity taxation. Section 4 analyses a second-best model similar to the one in Section 3, but where no differentiated commodity taxation is possible. Section 5 summarises and concludes the paper.

2. 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 the *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. 867). Harsanyi (1995, 1997) similarly argues 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, people know that they make mistakes for various reasons and they often vote for systems where experts make many choices for them. Therefore, following e.g. Broome (1999), Ng (1999), Johansson-Stenman (2002) and O’Donoghue and Rabin (2006), we assume throughout 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 *decision* utility. This implies that the model allows for paternalism following a small but rapidly

[1] Why and how risk misperceptions are formed and prevail is beyond the scope of this paper. The media attention given to certain spectacular risks appears to be an important reason (Slovic, 1986; Pidgeon et al., 2003). Moreover, research in psychology indicates that people have large difficulties dealing with probabilities when strong feelings are involved (e.g. Lowenstein et al., 2001).

[2] Salanie and Treich (2005) constitutes an important exception, where a regulator can either be paternalistic or populistic in the sense that preferences based on erroneous beliefs are respected as well. Other notable exceptions are Hammond (1981) and Sandmo (1983), who analysed risk misperceptions in the framework of ex-ante versus ex-post welfare economics. Smith and Desvousges (1987) and Gegax et al. (1991) measure people’s willingness to pay for reductions of the perceived, rather than the real, risk.

[3] In conventional models with no risk misperception, where the aim is to maximise the safety benefits in terms of saved lives for a given budget, it is of course optimal to apply the same value per saved life across contexts.

growing literature that takes people's documented irrationality (notably time inconsistency) into account (e.g. Camerer et al., 2003; Gruber and Köszegi, 2002, 2004; O'Donoghue and Rabin, 2003, 2006; Thaler and Sunstein, 2003).[4]

Assume that a representative consumer's strictly quasi-concave expected utility function, which reflects expected well-being, is given by

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

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 $r_{GG} > 0$.

The objective for the government is to maximise (1), which is assumed as known to the government. Thus, the model implies that the experts and policy-makers (who have access to the expert 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. The real risk is often difficult to estimate even for experts, and both experts and policy-makers are also to some extent affected by perception biases (Viscusi, 1995; Viscusi and Hamilton, 1999). Nevertheless, the assumption made here constitutes a natural and important benchmark case.

2.1. *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:

$$\mathrm{WTP}_r^{\mathrm{informed}}(-r_G) = p^G, \tag{2}$$

where $\mathrm{WTP}_r^{\mathrm{informed}} = -(\frac{u_r}{u_x})(x, r)$ reflects an informed individual's marginal willingness to pay (WTP) for a risk reduction (i.e. without any risk perception bias),[5] and where $-r_G$ is the risk reduction caused per unit of G. Eq. (2) then simply reflects the conventional efficiency rule where the left hand side consists of the marginal benefit associated with the risk reduction of increased G, whereas the right hand side reflects the corresponding marginal cost. 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.

2.2. *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 from what is predicted by conventional economic theory (Kahneman et al., 1982; Kahneman and Tversky, 2000; Gilovich et al., 2002).[6]

In order to formally handle systematic risk misperceptions, let s denote beliefs about the objective risk (i.e. the perceived or the subjective risk), which may deviate from the objective risk r. We 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 risk belief will also increase, and vice versa. Assume that the government uses some method (e.g. a stated-preference method) 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

[4] One can of course argue that individual choices should be given moral significance *per se* 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.

[5] Possible biases related to the elicitation method *per se* are disregarded throughout the paper, although they will be touched upon in the concluding section.

[6] It is sometimes argued that the observed differences in risk perceptions may not, at least not solely, reflect risk misperceptions by the public. Instead, they may reflect differences in values and priorities between experts and people in general (e.g. Krupnick et al., 1993; Morgan, 1992). Sunstein (2002), in a careful assessment of this claim, nonetheless concludes that different priorities and values can only explain a small extent of the large discrepancies typically obtained, and that people's risk misperceptions are the main reasons behind them. See also Hammitt (2000) for a balanced discussion on these issues.

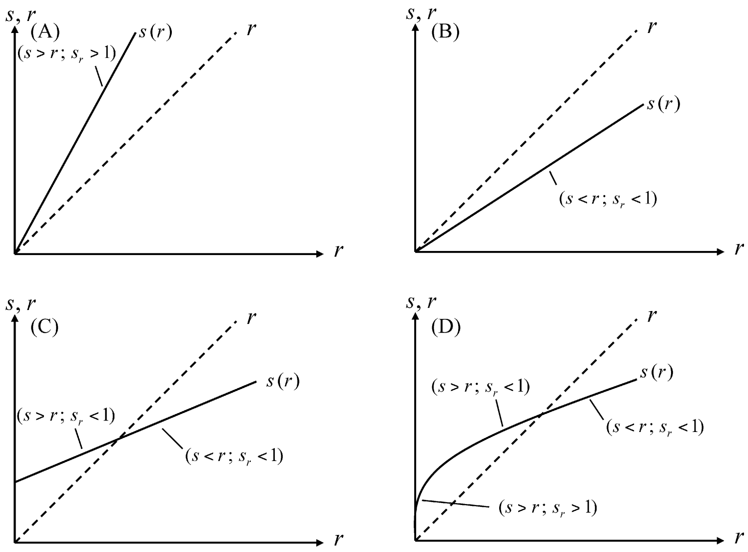

Fig. 1. Possible relations between the subjective and the objective risk.

by

$$\mathrm{WTP}_r^{\mathrm{observed}} = s_r\left(-\frac{u_r}{u_x}(x, s)\right) = \frac{\mathrm{WTP}_r^{\mathrm{informed}}}{\Omega}, \tag{3}$$

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

$$-r_G \mathrm{WTP}_r^{\mathrm{observed}}\Omega = p^G. \tag{4}$$

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

In case A, the risk belief 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 perceived risk change. Similarly, we have that $s_r < 1$ in case B where people always underestimate the risk. However, there is much evidence that people systematically overestimate small risks and underestimate large ones as in case C (e.g. Viscusi, 1992a, p. 117), so that $s_r < 1$ generally. Then an objective risk increase (or decrease) will always imply a smaller perceived risk increase (or decrease), irrespective of the level of the risk misperception. Thus, people's risk belief may be much larger than the actual risk, but at the same time they perceive the size of the risk *change* to be smaller than the true risk change.

However, it is sometimes argued that a relationship as in case D is more realistic; see e.g. Tversky and Kahneman (1992) or Gonzalez and Wu (1999), and Bleichrodt and Pinto (2000) for a health application. 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 observe 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 $s_r < 1$, whereas the opposite does not hold, i.e. $s > r$ does not imply that $s_r > 1$.[7] In other words, if people underestimate the risk, they will also underestimate the risk change, but if they overestimate the risk they will not necessarily overestimate the risk change.

[7] Cumulative prospect theory implies an inverse s-shaped curve where $s_r > 1$ holds for a sufficiently large r (close to 1). This interval is ignored here because risk regulations 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.

Consider now the other factor of Ω: Strict quasi-concavity of u implies that the WTP increases in the initial baseline risk level,[8] 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 if $s < r$ then $\text{WTP}_r^{\text{observed}} < \text{WTP}_r^{\text{informed}}$, 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.*

3. Decentralisation, fear, pricing and information provision

In the real world, most risky decisions are made by people themselves (such as what to eat, drink, how to travel, whether or not to smoke and if so what to smoke, etc.). Therefore, in this section we model a decentralised market economy where people choose themselves how much to buy of a risky and a non-risky good, respectively. We also allow for the possibility of using differentiated consumption taxes, where the revenues are distributed back in a lump-sum manner.

Following Akerlof and Dickens (1982), Akerlof (1989) and Becker and Rubinstein (2004), we include the fear associated with risk directly in the utility function.[9] Obvious examples include fear related to a perceived risk of flying, health-risk anxiety due to the use of certain chemicals in food, and 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 fear, or anxiety or mental suffering more generally, should count less than other determinants of individual well-being.

However, one may argue that when the discrepancy between objective and perceived 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; see e.g. Pidgeon et al. (2003). A novelty in the model here is that information provision is costly, and is hence no free lunch. The following model is generalised to encompass these aspects. Expected utility for the representative consumer is then given by

$$U = u(x, y, r, m(s)), \tag{5}$$

where x is a composite risk-free good, y a risky good, r the objective risk, and m is the fear (or mental suffering) associated with the risk belief s. Assume further that u is strictly quasi-concave in its arguments (to ensure a unique perceived optimum for the consumers and an actual expected utility optimum), $u_x > 0$, $u_y > 0$, $u_z < 0$, $u_m < 0$, $m_s > 0$, $m_{ss} > 0$ and $\partial(u_m/u_x)/\partial m < 0$. Thus, for a given objective risk, expected utility decreases with the risk belief and the marginal WTP to reduce fear increases with the amount of fear. 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 r *per se*.[10] 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:

$$r = r(y, G), \tag{6}$$

[8] 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; see e.g. Jones-Lee (1974) and Pratt and Zeckhauser (1996).

[9] Other papers have modelled utility as depending on when information is updated, including Kreps and Porteus (1978) and Caplin and Leahy (2001, 2004); for health applications see Köszegi (2003) and Hoel et al. (2006).

[10] That is, for a constant perceived risk. The fear in itself is a function of the perceived risk, which in turn depends on the objective risk. Moreover, because r depends on y, the consumer choice between x and y will therefore still be affected by exogenous changes in r.

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

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

where $s_r > 0$ and where $s_I < 0$, $s_{II} > 0$ for $s > r$, and $s_I > 0$, $s_{II} < 0$ for $s < r$. Thus, it is assumed that the risk misperception decreases monotonically in I, and also that it decreases at a decreasing rate. Moreover, we also similarly assume that the *marginal* risk perception bias decreases at a decreasing rate with the information provided, i.e. $\partial s_r/\partial I < 0$, $\partial^2 s_r/\partial I^2 > 0$ for $s_r > 1$, and $\partial s_r/\partial I > 0$, $\partial^2 s_r/\partial I^2 < 0$ for $s_r < 1$. 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

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

3.1. Optimal safety investments

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

$$\mathrm{WTP}_r^{\mathrm{informed}}(-r_G) + \mathrm{WTP}_m m_s s_r(-r_G) = p^G, \tag{10}$$

where $\mathrm{WTP}_m = -u_m/u_x$ is the marginal willingness to pay per unit of fear reduction in terms of x. Note that because 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 has the same straightforward interpretation. The second term reflects the WTP for the correspondingly decreased fear 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 $\mathrm{WTP}_r^{\mathrm{observed}}(-r_G) + \mathrm{WTP}_m m_s s_r(-r_G)$. 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 $\mathrm{WTP}_r^{\mathrm{observed}} > \mathrm{WTP}_r^{\mathrm{informed}}$. Consequently, we have:

Corollary 1. *If, in the given framework, 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.*

The intuitive reason behind the fact that fear does not affect this condition is that there is no discrepancy between the effects on decision utility and experienced utility here. People simply feel what they feel, and a feeling is from a hedonic perspective equally important when it is based on an illusory risk.

3.2. 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 A) that an optimal tax t on the risky good can then be written as the following straightforward expression:

$$t = r_y(\mathrm{WTP}_r^{\mathrm{informed}} - \mathrm{WTP}_r^{\mathrm{observed}}). \tag{12}$$

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, which simply reflects the first theorem of welfare economics, i.e. that an undistorted market equilibrium is Pareto efficient.

Suppose that people underestimate the risk of eating potato chips by 50% at the margin. This implies that their WTP to avoid the risk of an additional potato chip (holding the fear of the risk constant) is reduced by more than 50% if the 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 fear constant).

Now consider the case where we know that people misperceive the overall risk of consuming y, and know the direction of this risk perception, but where we have no direct information regarding the perception of a marginal change. Because we have as before that when $s < r$ it follows that $\mathrm{WTP}_r^{\mathrm{observed}} < \mathrm{WTP}_r^{\mathrm{informed}}$, 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,* where individuals hurt themselves by making bad decisions.[11]

3.3. Optimal information provision

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

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

Thus, the marginal benefit should at optimum equal the per-unit cost of increased information. Note that there is no benefit from improved consumer choices due to more information in the optimum condition. This is because the regulator can always obtain efficient consumer choices by adjusting the relative prices (welfare effects of better consumer choices are analysed in the next section). The existence of an interior solution is therefore far from obvious here. Note in particular that when $s < r$ the benefit term is actually negative, implying that it is never optimal to provide more information in this case. This reflects that in a first-best world when the consumption of x and y is optimal, the only welfare difference that better information about the true higher risk would make is to increase the fear associated with the risk belief.

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 fear) 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,[12] the net marginal benefit is positive when no information is provided:

$$(\mathrm{WTP}_m m_s(-s_I))_{I=0} > p^I. \tag{14}$$

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 costly information*. *However*, *if people overestimate the risk* ($s > r$), *it is optimal to provide costly information provided that the per-unit price of information is sufficiently low*.

[11] There are of course other sources for internalities besides risk misperceptions. For example, O'Donoghue and Rabin (2006) and Gruber and Köszegi (2002, 2004) argue in favour of higher taxes on unhealthy food and cigarettes, respectively, based on self control problems. The tax derived here is then similar in that it is motivated by internalities, even though the underlying reasons differ.

[12] The "if" part is obvious and the "only if" part follows because the benefit term increases at a decreasing rate in I, which in turn follows because the marginal WTP to reduce fear increases with the amount of fear, together with the assumed curvature of m and s (in s and I, respectively).

4. 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.[13] More fundamentally, many important activities from a health perspective, such as sexual behaviour (and the implications for HIV/AIDS), drug compliance, and hospital avoidance due to fear of MRSA (methicillin-resistant *Staphylococcus aureus*), are not market transactions at all, and where there is no tax levels that *can* be varied. The same applies to sports and other healthy activities. 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.

Consider a model similar to the one in Section 3 with the only difference being that we cannot use differentiated taxation, implying that we cannot affect the relative prices.[14] 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 $s=s(r(y, G), I)$. In order to be able to interpret the results also for non-market goods and activities such as sexual activity, the budget restriction (8) may alternatively be interpreted more broadly e.g. in terms of the alternative cost of time.

4.1. Second-best safety investments

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 A) that the optimal provision of G is given as follows:

$$\mathrm{WTP}_r^{\text{informed}}(-r_G) + \mathrm{WTP}_m m_s s_r(-r_G) + (\mathrm{WTP}_r^{\text{observed}} - \mathrm{WTP}_r^{\text{informed}}) r_y y_G = p^G. \tag{15}$$

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 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, 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 $\mathrm{WTP}_r^{\text{observed}} < \mathrm{WTP}_r^{\text{informed}}$. Then people will on the margin consume too much of y, implying that it is beneficial 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

$$\mathrm{WTP}_r^{\text{observed}}(-r_G) + \mathrm{WTP}_m m_s s_r(-r_G) = p^G. \tag{16}$$

Consequently, combining (15) and (16) we find that G should be over-provided compared with the conventional efficiency rule if $(\mathrm{WTP}_r^{\text{informed}} - \mathrm{WTP}_r^{\text{observed}})((-r_G) - r_y y_G) > 0$, 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. 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 Merrell et al. (1999) for additional evidence. However, from this literature it is also typically found that people do not over-compensate. This implies that there is indeed a positive net effect of the safety measure taken, albeit a smaller one than without compensatory behaviour. Following this empirical evidence, we have:

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

[13] Moreover, in reality people are of course heterogeneous with varying risk misperceptions, so we would need personalised taxes to obtain efficiency; such taxes are clearly unfeasible in practice.

[14] It is straightforward to generalise the model in many ways such as to increase the number of goods and allow for private risk-reducing investments.

Consider now the case where $s<r$, implying from Section 2 that $s_r<1$ and that $\text{WTP}_r^{\text{informed}} > \text{WTP}_r^{\text{observed}}$. 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. On the other hand, when $s>r$ we have the same ambiguity as previously, because we cannot say whether $\text{WTP}_r^{\text{informed}} > \text{WTP}_r^{\text{observed}}$ or not. Then, conditional on Assumption 3, we have:

Corollary 2. *If, in the given framework, 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.*

In order to illustrate these second-best results, consider the recent European experience where many people were afraid to eat beef due to the mad cow disease, despite the fact that most leading medical experts considered the risks to be negligible compared with many other risks. Applying the risk belief would then imply far-reaching import restrictions on beef, whereas applying the objective risk would not (given that the experts were right).[15] The results from this paper suggest that no restrictions should have been imposed unless one would have expected large fear effects from the risk, or unless people would have adjusted their behaviour to a large extent. In reality, we know that many people were indeed very scared, and that there were large fear-induced consumption changes. Therefore, the import restrictions actually undertaken may have been well motivated after all. Similar arguments can be made regarding the US investments in safety after 9 November 2001, where presumably many more lives could have been saved if instead some of the money would have been spent on, say, improved road safety; cf. Sandler (2004). On the other hand, without these large investments perhaps people would have made even more irrational decisions, such as replacing air travel with more dangerous car travel to an even larger degree (cf. Blalock et al., in press); see Frey et al. (2007) for a survey of the overall economic consequences of terrorism. There are also important health economic examples, including some people's excessive fear of MRSA that may make them hesitate visiting the hospital when they are ill. Such indirect health effects may in fact be larger than the direct ones, which highlights the importance of including indirect effects in cost benefit analysis of MRSA preventing measures.

4.2. Second-best information provision

The role for information provision appears more obvious in this second-best world, where increased information can help people make better decisions. Assuming the existence of an interior optimum, we can write (see Appendix A) the optimal information provision condition as follows:

$$\text{WTP}_m m_s(-s_I) + r_y y_I(\text{WTP}_r^{\text{observed}} - \text{WTP}_r^{\text{informed}}) = p^I. \quad (17)$$

The first term of (17) is identical to the first-best model, Eq. (13), and has the same straightforward interpretation, i.e. the WTP that the individual would have for the decreased fear associated with a unit increase in public information I. However, from a policy perspective the most important motive for providing better information is presumably that consumers would be able to make better-informed decisions regarding the risky activities; 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. For example, studies have shown that a majority of women with a family history of breast cancer have exaggerated perceptions of their own risk of this disease and experience excessive anxiety, and that their risk misperception and anxiety can be reduced with better information (Lerman et al., 1995). In order to determine the sign of the second term, let us first 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. $\partial y/\partial(s_r r_y)<0$. (ii) The consumption of the risky goods decreases with the perceived absolute magnitude of the risk, i.e. $\partial y/\partial s<0$.

[15] It is implicitly assumed that higher perceived risk also increases the WTP for a risk *change*, which seems reasonable here because 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*.

Then it follows that when people underestimate the risk, so that $s < r$ and $s_r < 1$, we have that $y_I < 0$, meaning that more information induces people to consume less of the risky good. Moreover, because $\text{WTP}_r^{\text{observed}} < \text{WTP}_r^{\text{informed}}$, we clearly find that the sign of the second term of (17) is positive, which follows intuition. On the other hand, when $s > r$, then 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 from more information (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* $\text{WTP}_r^{\text{observed}} < (>) \text{WTP}_r^{\text{informed}}$. *For all other cases, these welfare effects are non-negative.*

For proof, see Appendix A. Intuitively, one may expect that consumers with biased risk perceptions would make better choices between risky and non-risky goods with more information, because it is assumed that both their absolute and marginal degrees 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 Viscusi, 1992b) and that he simultaneously underestimates the marginal risk associated with smoking one additional cigarette (see Hammar and Johansson-Stenman, 2004). 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, then more information will hurt the individual by making him make even worse choices (in this case smoke more) than before the additional information.[16]

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 fear 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.

Clearly, a sufficient condition[17] for positive information provision is that the left hand terms of (17) exceed p^I, at zero amount of provided information, i.e.

$$(\text{WTP}_m m_s(-s_I) + r_y y_I(\text{WTP}_r^{\text{observed}} - \text{WTP}_r^{\text{informed}}))_{I=0} > p^I. \tag{18}$$

Thus we have:

Proposition 5. *If people underestimate the risk ($s < r$) in the second-best economy, it is optimal to provide costly information if the second-best welfare effects from changed choices are sufficiently large compared to the increased fear effect and the per-unit price of information. If people overestimate the risk ($s > r$), it is optimal to provide costly information if the per-unit price of information is sufficiently low compared to the decreased fear and second-best effects (whose sign is undecided).*

5. Summary and conclusion

This paper has analysed normative implications for optimal public safety investments, internality correcting taxation and costly information provision as a result of biased risk perceptions, for which there is ample empirical evidence. For example, it was shown that the optimal level of public safety investments quite generally exceeds the level implied by the conventional efficiency rule, in terms of individual WTP, when people underestimate the risk, whereas the result is ambiguous when people overestimate the risk; see Table 1 for a summary of the main results.

[16] This is in contrast to Carbone et al. (2005), where more information always reduces smoking. However, that paper provides other interesting insights regarding the *timing* of smoking reduction.

[17] This is also a necessary condition if the left hand side of (18) is never larger than at $I = 0$. The conditions for this, in turn, are however quite complex.

Table 1
Summary of the main results

Basic model		First best general model with differentiated commodity taxation		Second best general model without differentiated commodity taxation	
Subjective risk lower than objective risk $s < r$	Subjective risk higher than objective risk $s > r$	Subjective risk lower than objective risk $s < r$	Subjective risk higher than objective risk $s > r$	Subjective risk lower than objective risk $s < r$	Subjective risk higher than objective risk $s > r$
Public safety investments					
Optimal provision beyond the conventional cost-benefit rule	Ambiguous whether the optimal provision exceeds the conventional cost-benefit rule	Optimal provision beyond the conventional cost-benefit rule	Ambiguous whether the optimal provision exceeds the conventional cost-benefit rule	Optimal provision beyond the conventional cost-benefit rule	Ambiguous whether the optimal provision exceeds the conventional cost-benefit rule
Differentiated commodity taxation					
Not applicable	Not applicable	Efficient tax on the risky good strictly positive	Ambiguous whether an efficient tax on the risky good is positive or negative	Not applicable	Not applicable
Public information provision					
Not applicable	Not applicable	Never optimal to provide costly information	Optimal to provide information provided that the information cost is sufficiently low	Positive welfare effects from changed consumer choices due to increased information. Optimal to provide information provided that the information cost and the fear increase due to increased information are sufficiently small	Ambiguous welfare effects from changed consumer choices due to increased information. Optimal to provide information if the per unit information cost is lower than the net marginal welfare effects of changed consumer choices and the fear decrease

The results in this paper can be compared to the on-going discussion in health economics of stated preference (SP) methods to estimate consumer health costs of illnesses and benefits of treatments. In that discussion, the main concerns have been to what extent, and under what conditions, hypothetical SP methods reflect people's real-money WTP; see e.g. Blumenschein et al. (2001, in press).[18] The results in this paper, on the contrary, suggest that SP methods may sometimes provide misleading benefit and cost measures when there is no hypothetical bias at all. In other words, people's real-money WTPs may be poor measures of their underlying expected welfare effects. Although the risk misperceptions are presumably in general difficult to quantify, which is an issue that is beyond the scope of the current paper, it is nevertheless important to understand the normative implications of such misperceptions. Sometimes one may be able to provide an informed guess about the range of possible misperceptions, or maybe about the sign, and sometimes the implications can provide reasons for obtaining better information about possible misperceptions, or for including such values in sensitivity analysis.

Finally, it is inevitable that the results in this paper, as in all theoretical analysis, depend on the simplifying assumptions made. More work in this relatively under-researched area is encouraged, where the robustness of the findings can be tested with alternative assumptions. Moreover, it is of course important to bear possible *instrumental* considerations in mind when discussing policy recommendations based on paternalism. We have indeed seen terrible consequences of *excessive* paternalistic decision-making in many countries in the past and it is easy to agree with O'Donoghue and Rabin (2001, p. 31) that "we should not replace welfare agnosticism with a 'promiscuous paternalism"'. Still, this does not constitute a good reason to refrain from welfare-based policy analysis in situations where people make systematic and important mistakes. The main conclusion regarding the question posed in the title of this paper seems fairly robust, both related to the health area (Lerman et al., 1995; Bleichrodt and Pinto, 2000) and more generally: policy-makers cannot simply choose between being concerned with the perceived and the objective risk; they need to be concerned with both.

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Appendix A

Proof of Eq. (12). Differentiating (9) with respect to y implies:

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

The reason we can write the first and the third marginal rates of substitution as functions independent of r is because of Assumption 2. Substituting (6), (7) and (11) into (5), and noting that τ is treated as exogenous to each consumer, imply that individuals will maximise the following function:

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

Differentiating (A2) by y, we obtain:

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

where we in the first and the third terms have again used Assumption 2. The optimal tax is obtained by combining the individual optimum condition (A3) with the social optimum condition (A1):

$$t = r_y\left(-\frac{u_r}{u_x}(x, y, r, m) - \left(-\frac{u_r}{u_x}(x, y, s, m)s_r\right)\right) = r_y(\mathrm{WTP}_r^{\mathrm{informed}} - M\mathrm{WTP}_r^{\mathrm{observed}}). \tag{A4}$$

[18] Corso et al. (2001) study the important issue of how different risk communication formats can improve the quality of stated preference studies.

Proof of Eq. (15). Since we are only interested in the net effect in equilibrium, we can work with a reduced form of the relationship between y (and hence also of x) and G and I, as follows:

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

Substituting (6)–(8) and (A5) into (5) implies:

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

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

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

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

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

An individual who attempts to maximise 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:

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

Proof of Eq. (17). Differentiating (A6) with respect to I implies:

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

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:

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

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

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

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 $M\text{WTP}^{\text{observed}} > M\text{WTP}^{\text{informed}}$. This, in turn, is the case if $\frac{M\text{WTP}^{\text{observed}}}{M\text{WTP}^{\text{informed}}} = s_r \frac{u_r/u_x(x,y,s,m)}{u_r/u_x(x,y,r,m)} > 1$, which holds because $\frac{u_r/u_x(x,y,s,m)}{u_r/u_x(x,y,r,m)} > 1$. The remaining case is when $s > r$ and $s_r < 1$. Then the sign is negative if $y_I > 0$ and $M\text{WTP}^{\text{observed}} < M\text{WTP}^{\text{informed}}$, or if $y_I < 0$ and $M\text{WTP}^{\text{observed}} > M\text{WTP}^{\text{informed}}$. Thus, the sign of the second term of (17) is negative if and only if $\left(\frac{\partial y}{\partial s}\frac{\partial |s-r|}{\partial I} - \frac{\partial y}{\partial (s_r r_y)}\frac{\partial |s_r-1|}{\partial I}\right)(M\mathrm{WTP}^{\mathrm{observed}} - M\mathrm{WTP}^{\mathrm{informed}}) < 0$, which is equivalent to Proposition 4.

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