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On how access to an insurance market affects investments in safety measures, based on the expected utility theory

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ABSTRACT

This paper focuses on how access to an insurance market should influence investments in safety measures in accordance with the ruling paradigm for decision-making under uncertainty—the expected utility theory. We show that access to an insurance market in most situations will influence investments in safety measures. For an expected utility maximizer, an overinvestment in safety measures is likely if access to an insurance market is ignored, while an underinvestment in safety measures is likely if insurance is purchased without paying attention to the possibility for reducing the probability and/or consequences of an accidental event by safety measures.

1. Introduction

Principally, there are three alternative ways to treat risk in projects that affect safety. One can (1) take all the consequences when an accidental event occurs, (2) reduce the probability and/or the consequences of an accidental event by safety measures or (3) transfer the consequences of the occurrence to parties better able to carry them (i.e. buy insurance) [1,6].

When decisions are made with respect to resource use in safety measures and the insurance market in the risk analysis literature, it is common that the investments in safety measures are not affected by access to an insurance market [9]. As there is no theoretical justification of this practice, we will in this paper discuss whether or not access to an insurance market should influence the investments in safety measures. We use the expected utility theory as basis for our argumentation. The expected utility theory is the backbone for all economic thinking and states that the decision alternative with highest expected utility is the best alternative. We will not repeat the rationality of this principle, but it has validity under very reasonable conditions for logical and consistent behaviour; see for example [10].

We show that the investment in safety measures for an expected utility maximizer will normally be higher in situations where there is no access to an insurance market compared to a situation where such an access does exist. If access to an insurance market is not taken into consideration, this will normally lead to an overinvestment in safety measures for an expected utility maximizer. One could make an argument that is inverse too that an underinvestment in safety measures is very likely if we purchase insurance without paying attention to the fact that the probability and consequence of an accidental event can be reduced by safety measures.

Our work is closely related to the analysis of Ehrlich and Becker [6]. They also discuss the influence of insurance on safety measures with reference to the expected utility theory. Their main message to a large extent overlaps with our conclusions. However, the basis for their analysis is different from ours. In Ref. [6] all the consequences of an accidental event are transformed to one comparable unit (money). This is in strong contrast to much of the risk literature, where it is often regarded as problematic to compare the risk of fatalities with damages to property or even worse, increased consumption due to lower investments in risk reducing measures; see for example [2–4,8,9,12]. In our paper we introduce fatalities as a separate variable in the expected utility framework in addition to money. In this respect, our work expands the model of Ehrlich and Becker [6]. Thus, our model gives a basis for showing how non-economic variables interact with the economic variables and how an insurance market affects the investments in safety measures. This is of interest due to the fact that transformation of all attributes to one common comparable unit is avoided by many safety experts, and is also regarded as unethical by some [9].

The paper is organized as follows. In Section 2 an expected utility model is developed in order to show how an expected utility maximizer manages risk in situations first without and then with access to an insurance market. Then in Section 3 a short discussion about the value of a statistical life is given, seen in relation to the model developed in Section 2. Finally, in Section 4 special attention is given to the difference between optimal investments in safety

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measures for the two situations analysed in Section 2, before some conclusions are provided.

2. An economic model

In this section an economic model is developed to show how an expected utility maximizer manages risk in situations first without and then with access to an insurance market. In Section 3 special attention is given to the difference between optimal investments in safety measures for these two situations analysed in this section.

2.1. When access to an insurance market does not exist

Consider a firm that has preferences with respect to wealth y and a non-economic variable h. In the following, h is referred to as fatalities, but could in principle be all types of non-economic values such as injuries, environmental damages, etc. The preferences are represented by the utility function

$$U(y,h) \tag{1}$$

We follow the standard in the literature and assume that the utility function is increasing and concave in y, which implies that the firm's marginal utility ($\partial U/\partial y$) diminishes as the wealth increases. The firm then considers the utility of an extra dollar of wealth to be higher when it is relatively poorer than the utility of an extra dollar when it is relatively richer. We also assume that the utility function is decreasing and convex in h. The firm then considers that the disutility of one extra fatality is reduced by the number of fatalities. This implies that the disutility for the first fatality is higher than the disutility of going from 100 to 101 fatalities. To make the model tractable, we make the standard simplifying assumption that there are only two states of the world, one where there is no accidents and one where there is one. The firm's wealth and number of fatalities are respectively y_1 and h_1 ($h_1=0$) if an accidental event does not occur. The wealth reduces to a level y_2 ($y_2<y_1$) and the number of fatalities increases to a level h_2 ($h_2>0$) if an accidental event occurs. The initial number of fatalities given an accidental event and the initial wealth are h_0 and y_0, respectively. The probability of an accidental event (being in state 2) is denoted p.

Suppose that the firm may invest r (the effort) in self-protection that affects the consequences in the case of an accidental event. We assume that the cost of effort r, $c(r)$ is an increasing and convex function; $\partial c/\partial r>0$ and $\partial^2 c/\partial r^2<0$. This means that the cost increases by an increased effort by the firm, but gradually the increased effort in self-protection contributes to an increased cost by the firm, for example caused by new production technology, etc.

The magnitude of the reduction in losses in wealth (l) and the number of fatalities (v) depends on the investments in r. As a simplifying assumption we say that the reduction in losses in wealth and the reduction in the number of fatalities of the investments in self-protection are deterministic. We assume that the reduction in losses in wealth when an accident occurs due to the investment in r, $l(r)$, is increasing and convex; $\partial l/\partial r<0$ and $\partial^2 l/\partial r^2<0$. The same assumptions are also given to $v(r)$, which means that $\partial v/\partial r<0$ and $\partial^2 v/\partial r^2<0$. From these assumptions one can see that the firm's marginal utility from self-protection diminishes as the investments in self-protection increase. One can, for example, say that the utility of the first dollar spent on self-protection is higher than the utility of the last dollar spent on self-protection.

Under these assumptions, the firm's problem is to choose r to maximize

$$EU=(1-p)U(y_1,h_1)+pU(y_2,h_2) \tag{2}$$

where

$$y_1=y_0-c(r); \quad y_2=y_0-c(r)-l(r) \tag{3}$$

and

$$h_1=0; \quad h_2=h_0-v(r) \tag{4}$$

The derivative of the expected utility with respect to r is

$$\begin{aligned}\partial EU/\partial r &= (1-p)U_{1y}(-c_r)+pU_{2y}(-c_r-l_r)+pU_{2h}(-v_r)\\ &= -pU_{2h}v_r-pU_{2y}l_r-[pU_{2y}+(1-p)U_{1y}]c_r=0\end{aligned} \tag{5}$$

where U_{iy} denotes partial derivatives of U_y with respect to i, l_r is the derivative of l with respect to r, and c_r the derivative of c with respect to r.

The condition (5) means that the optimal level of self-protection is at the point where the marginal utility cost of decrease in the firm's wealth due to the cost of self-protection, $[pU_{2y}+(1-p)U_{1y}]c_r$, is equal to the marginal utility of the self-protection, $pU_{2h}v_r+pU_{2y}l_r$. This means that the firm's optimal investment in self-protection is at the point where the utility of the last dollar spent on self-protection is equal to the utility of the reduction in losses caused by the last dollar spent on self-protection. The marginal utility consists of two parts: (I) the marginal utility from an increase in the firm's wealth through reduction in losses, $pU_{2y}l_r$, and (II) the marginal utility from a decrease in the number of fatalities in the bad state, $pU_{2h}v_r$. Hence, even though the firm's wealth is not being reduced by fatalities, it will influence the firm's decisions as long as the firm cares about avoiding accidents. If this term is removed from the problem, that is the firm does not take into account the fatalities that the accidental event can cause, the firm will under-invest in risk-reducing measures. This seems to support the notion that analysis focusing only on economic factors will lead to underinvestment in safety measures, and it will if the effect of these variables are not taken into account. However, in the economic literature non-economical variables are usually not removed from the decision problem even if wealth is the only attribute included, as non-economic variables are transformed to one comparable unit, money [13]. In such cases, the difference in the safety investment will be determined by the weight given to these variables in different approaches to determining the level of safety investments.

Note that as long as a reduction of the consequences of an accidental event is costly, there will always be negative consequences for the firm if an accidental event occurs. The cost of reducing the consequences of an accidental event (or the probability) will usually increase to infinite when the consequences approach zero.

2.2. When access to an insurance market exists

Until now we have ignored the fact that for some risks the firm has an alternative method to handle risk for investment by transferring risk to parties that are better able to carry the consequences. Such mechanisms include insurance, use of derivatives and government protection. For simplicity, we will here refer to all such mechanisms as insurance as they all work in a similar manner.

Access to an insurance market gives the firm the opportunity to transfer the economic consequences of an accidental event to others by compensation, the insurance premium, s. The firm's wealth will then in the good state be reduced by s, while the wealth in the bad state will increase with the insurance payment, g. The wealth in the bad state increases when the insurance payment increases, which means that the insurance payment is an increasing function of s, $\partial g/\partial s>0$.