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Valuing life: Experimental evidence using sensitivity to rare events

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ABSTRACT

Global environmental phenomena like climate change, major extinction events or flutype pandemics can have catastrophic consequences. By properly assessing the outcomes involved – especially those concerning human life – economic theory of choice under uncertainty is expected to help people take the best decision. However, the widely used expected utility theory values life in terms of the low probability of death someone would be willing to accept in order to receive extra payment. Common sense and experimental evidence refute this way of valuing life, and here we provide experimental evidence of people's unwillingness to accept a low probability of death, contrary to expected utility predictions. This work uses new axioms of choice defined by Chichilnisky (2000), especially an axiom that allows extreme responses to extreme events, and the choice criterion that they imply. The implied decision criteria are a combination of expected utility with extreme responses, and seem more consistent with observations.

1. Introduction

Global environmental phenomena like climate change, major extinction events or flu-type pandemics share two characteristics: potential catastrophic consequences and a high degree of uncertainty. To determine the best decision to take in order to mitigate or avoid their harmful consequences, decision theorists use the choice under uncertainty framework, especially the widely-applied expected utility (EU). This then commonly assesses potential outcomes, including those affecting human life when deaths are involved. In essence, EU theory values life in terms of the low probability of death that would be acceptable in return for a given amount of money.

However, Arrow (1966) provided the following illustration of how people value their lives that puzzles decision economists: Most people would prefer 5 cents to 2 cents, and 2 cents to death. Does this mean that they would prefer 5 cents and a very low probability of death, to 2 cents? Kenneth Arrow famously commented that a positive response to this question would seem "outrageous at first blush". And yet the answer is 'Yes' according to the EU theory that Von Neumann–Morgenstern, he and others pioneered (Arrow, 1971). For instance, if we take a value of a prevented fatality (VPF) of $5.5 million (U.S. Environmental Protection Agency, 2004), the corresponding probability of death that would be acceptable for an extra 3 cents is 5.45 10^{-9} (i.e. $0.03/5.5.10^6$) according to EU.

Consequently, Arrow's comment is fully relevant, although at first glance it could be argued that the amounts at stake in his example are too small to make sense. But Arrow's famous example can be reworked within a simple experiment that provides much larger numerical values.

In February 1998, 64 subjects were invited to play a hypothetical game in which they could choose whether or not to swallow one pill among 1 billion (10^9) identical ones. Only one pill contained a lethal poison that was sure to kill, all the others being harmless. The survivors (i.e. those who swallowed one of the 999,999,999 harmless pills) received $220,000. We easily infer the value these subjects attribute to their own life according to EU predictions. Each of the 33 subjects who answered 'No', implicitly valued his/her own life at more than $ 220 trillion ($220{,}000/10^{-9}$). This VPF obviously contrasts with the $1.7–$7 million range usually obtained in the literature. The same game was played again by the same subjects as well as new subjects in January 2009, providing similar results as well as motivations for their (possible change in) answers.

This article examines the results of this experiment, and takes another look at Arrow's comment. The theory we present reveals that this puzzling result can be attributed to the failure of EU theory to provide an appropriate value for catastrophic events such as death. It is well known that EU theory has limitations and individuals have been found to violate its axioms in a variety of settings since the 1950s (historical examples are Allais', 1953, and Ellsberg's, 1961 paradoxes). Chichilnisky (2000) showed that it underestimates our responses to rare events no matter how catastrophic they may be. This insensitivity has unintended consequences. We argue that this insensitivity, and the attendant inability to explain responses to choices where catastrophic outcomes are possible, makes EU theory less appropriate to properly express rationality in these situations. A case in point is the experimental paradox presented above when

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valuing human life, since EU theory does not "fit" with the stated behavior of most of the subjects in the experiment.

This paper provides a theoretical framework by considering death as a 'catastrophe', namely a rare event with major consequences. Using the new axioms of choice introduced in Chichilnisky (2000, 2002), we derive a choice criterion that is more consistent with the experimental evidence on how people value catastrophic events such as death. We show that EU theory underestimates rare events and that this originates from the classic axiom of continuity (Monotone Continuity, defined in Arrow, 1971) which implies that rational behavior involves *insensitivity to rare events with major consequences* like death. We replace the axiom of continuity by an alternative axiom of *sensitivity to rare events*, formalizing a theory of choice under uncertainty where rare but catastrophic events (such as death) are given a treatment in symmetry with the treatment of frequent events. As a consequence, a probability can be considered low enough to make the lottery involving death acceptable; it all depends on what the other outcomes are.

This implies a different way of valuing life, one that seems more in tune with experimental evidence. First, this new way of valuing life is in keeping with evidence provided by the experiment reported below, given that age and family situation appear to affect the way subjects change their decisions about whether or not to take action impacting the value of their lives. More generally, it may explain why in some experiments people appear to give unrealistically high numerical values to life that are not consistent with the empirical evidence about how they choose occupations, for instance. Second, this new way of valuing life is in keeping with evidence provided by experimental psychologists, who observe that the brain reacts differently when making a decision involving rare situations inspiring extreme fear (LeDoux, 1996). Overall, the proposed framework suggests an alternative way to define rational behavior when catastrophic risks are involved.

The remainder of the paper proceeds as follows. Section **2** presents the experimental evidence. Section **3** recalls recent contributions in the literature on modeling risk and catastrophic events, shows how EU theory fails to appropriately value life and proposes a solution. The final Section discusses the results and draws conclusions.

2. Experimental Evidence

We present the results of an experiment (referred to below as the pill experiment) which twice asked a sample of subjects a question implying a trade-off between the risk of dying and a fixed amount of money, at an interval of 11 years.

2.1. The 1998 Initial Pill Experiment

In February 1998, the members of a Research Center in Quantitative Economics were asked by internal e-mail (in French): "Imagine that you are offered the opportunity to play a game in which you must choose and swallow one pill out of 1 billion (10^9) identical pills. Only one contains a lethal poison that is sure to kill you, all the other pills being ineffective. If you survive (i.e. you swallow one of the 999,999,999 ineffective pills), you receive a tax-free amount of €152,450.[1] Are you willing to choose one pill and to swallow it?".

The value subjects attribute to their own life can be assessed using the classic utility theory of choice under uncertainty. Indeed, state-dependent models, simple single period models, life-cycle models when the change in mortality lasts over an infinitesimally short time (Johansson, 2003) as well as wage-risk trade-off models for marginal changes in risk (see Rosen, 1988; Viscusi, 1993) rely on the EU theory and express the VPF as a marginal rate of substitution between wealth and risk of death. What happens if this approach is crudely applied to the results of the above experiment?

Before answering, it should be pointed out that studies aiming at valuing life never ask the kind of direct question we use. They generally use either data from market choices that involve an implicit trade-off between risk and money (labor or housing markets, transportation, self-protection or averting behaviors), or stated preferences elicited in more subtle ways and using unidentified victims.[2] Moreover, stated preferences suffer from limitations, both generally and in this case: the actual behavior is not observed; due to incorrect sensitivity to probabilities, smaller changes in risk tend to induce higher VPF estimates (Beattie et al., 1998); a significant gap exists between willingness to pay and willingness to accept…

Finally, the lack of monetary incentives in this experiment may puzzle the reader and is briefly justified below. A number of authors (e.g. Smith, 1976; Harrison, 1994, or Smith and Walker, 1993) emphasize the importance of paying subjects in real cash and providing appropriate monetary incentives in experiments, based on the principle that monetary incentives are needed to motivate people sufficiently when answering hypothetical questions and that this leads to better performance. On the contrary, other authors, including social (and economic) psychologists (Loewenstein, 1999; Slovic, 1969; Tversky and Kahneman, 1992), consider that subjects should be intrinsically motivated enough to answer truthfully in the experiment and that social or affective incentives may be even better motivators than monetary incentives.

This is a controversial issue among researchers, regularly raised by new experiments or meta-analyses. A case in point is Camerer and Hogarth (1999), who analyzed 74 experiments either known to them (1953–1998) or published in famous US journals from 1990 to 98. These studies all varied incentives substantially. The authors found no effect on mean performance in most of the studies (though variance is usually reduced by higher payment) and noted that "no replicated study has made rationality violations disappear purely by raising incentives". They conclude that apart from cases in which subjects are required to make a major cognitive effort and/or face an incitement to lie, monetary incentives are not mandatory.

Neither of these conditions applies to our experiment, which moreover has several characteristics suggesting that subjects were intrinsically motivated to answer truthfully: they were volunteer colleagues, with a potential reciprocity concern vis-à-vis the experimenter; they were told they would be provided with a summary of the experimental results; the topic can be considered entertaining and of intellectual interest; and the experiment was not time-consuming at all (5 min). We are therefore confident that participants answered seriously even without monetary incentives, which would have been difficult to implement in this case.

All that being said, subjects face a choice between compensation (€152,450) for accepting a change in risk of death (increase of 10^{-9}) and a status quo alternative. Subjects who answer 'Yes' clearly consider that €152,450 is enough to compensate for the increase in death risk, whereas those who answer 'No' do not. Due to the referendum-type elicitation question, the minimum amount at which subjects would accept the increase in risk is unknown. Among the 64 responses collected, 33 subjects answered 'No' and 31 answered 'Yes' (see the second column of Table 1 for details by answer type).

Do some subjects' characteristics explain such behavior? We look for dependences between the answer given and individual characteristics with contingency chi-square tests (see the second column of Table 2). No evidence of dependence is found: the *p-values* are far from the usual significant levels in use. These results are confirmed by performing an analysis of variance for main effects and crossed

[1] Note that the original wording mentioned FRF 1,000,000. In 1998, the exchange rate was 1 USD per 5.9 FRF.

[2] However, in our experiment, the victim, although identified, is only exposed to an (infinitesimal) risk change, not to certain death.