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Models-as-usual for unusual risks? On the value of catastrophic climate change

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ABSTRACT

We study the role of intertemporal preference representations in a model of economic growth, stock pollutant and endogenous risk of catastrophic collapse. We contrast two polar instances of risk-sensitive preferences: the traditional "discounted utility" model, which imposes a positive rate of pure time preference and risk neutrality with respect to intertemporal utility, and multiplicatively separable preferences, which display risk aversion in that dimension but no pure time preferences. We show that both representations of preferences can rationalize the same economy when there is no collapse risk associated with pollution. Once we introduce a collapse risk whose hazard rate depends on the pollution stock, multiplicatively separable preferences are associated with a much higher value of catastrophic risk reduction, and a more stringent policy response. A relatively high discount rate may thus be compatible with large emissions abatement in the face of a low probability large impact event, reflecting preferences for catastrophic risk reduction.

Introduction

A substantial part of the economic literature on climate change discusses climate policy as an intertemporal trade-off, where the costs of an early intervention are compared with the costs of later measures. Such an approach is for example the baseline of the prominent contributions by Stern (2007), Nordhaus (2008) and Golosov et al. (2014). This line of literature presumes that anthropogenic climate change is gradual and reversible, and that the world, as we know it, will exist for ever or, at least, that its existence may not be endangered by today's action (or inaction). However, recent literature on climate change reveals the very large uncertainty about how greenhouse gases (GHG) could affect global equilibrium temperatures (Roe and Baker, 2007; Allen and Frame, 2007), and shows an increasing concern for the risk of abrupt and irreversible changes in the climate system (e.g. Alley et al., 2003; Lenton et al., 2008; Kriegler et al., 2009).[1] There is then the possib-

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[1] The study by Lenton et al. (2008) characterizes potentially abrupt and long-lasting changes for some major elements of the climate system, such as the weakening or shut down of the North Atlantic thermohaline circulation, the melting of the Greenland and the West Antarctic ice sheets, the die-back of the Amazon rainforest and the increasing frequency and amplitude of El Niño-Southern Oscillation. Weitzman (2009) discusses how uncertainty about

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ility that preventive measures that could be taken today may no longer be available in the future, as a "collapse" might occur in-between. The relevant trade-off is no longer between present and future consumption, but between consumption and a risk of catastrophic climate change. As initially suggested by Weitzman (2009), usual models are not appropriate to inform the management of such low-probability high-impacts risks.

The aim of this paper is to study the role of social preferences for the trade-off between consumption and catastrophic risk reduction. To do so, we consider a simple setting in which output generates emissions, emissions accumulate into a stock of pollution, and the size of the pollution stock determines the probability of a catastrophic collapse. More specifically, we follow Cropper (1976) and define a catastrophic collapse as an irreversible regime shift, with post-collapse welfare independent of current actions and equivalent to some constant consumption trajectory $\underline{c}$. In this framework the key assumption is that outcomes after the regime shift are exogenous, so that it is not possible to invest towards post-collapse welfare (see also Clarke and Reed, 1994; Tsur and Zemel, 1996, 1998, 2008, 2009; Gjerde et al., 1999; Karp and Tsur, 2011, among others). While this is admittedly a drastic simplification of environmental problems in general and climate change in particular, it provides a sharp characterization of the trade-off of interest, and allows us to study a concept akin to the value of a statistical life (VSL) at the individual level, termed "the value of statistical civilization" by Weitzman (2009). We refer to this concept as the social value of catastrophic risk reduction, as measured by the inverse of the marginal rate of substitution between consumption and hazard risk of a regime shift.[2]

In the setting we consider, the time at which the regime shift occurs is a random variable that generates a risk on intertemporal utility. The use of the standard expected discounted utility model would implicitly impose a risk neutrality assumption (Bommier, 2006) that we do not see as obviously desirable. This is the main motivation for the use of an alternative representation of social preferences. To be more specific, consider the following four intertemporal plans: $c^1=(\underline{c},\overline{c},\underline{c},\overline{c},\ldots)$, $c^2=(\overline{c},\underline{c},\overline{c},\underline{c},\ldots)$, $c^3=(\overline{c},\overline{c},\overline{c},\ldots)$ and $c^4=(\underline{c},\underline{c},\underline{c},\ldots)$, where $\overline{c}>\underline{c}$, and a choice between two alternative lotteries: (L1) c^1 or c^2 with probability 1/2, and (L2) c^3 or c^4 with probability 1/2. These lotteries are deemed equivalent when evaluated with the standard *additively-separable* preferences intertemporal utility function[3]:

$$V_0^{add}=\sum_{t=0}^{\infty}(1+\theta)^{-t}E(u(c_t)), \tag{1}$$

where $u(\cdot)$ is the instantaneous utility function and $\theta>0$ is the pure rate of time preference. However, one may think that a social planner should prefer to avoid the second lottery, as it involves the possibility of a catastrophic collapse occurring now (c^4), resulting in a very low level of intertemporal utility. In other words, one may want to account for risk aversion with respect to intertemporal utility. Since the collapse risk that we consider in this paper is similar to lottery L2, as all future generations have a predetermined welfare level after collapse, introducing risk aversion with respect to intertemporal utility will increase the social value of catastrophic risk reduction.

In order to consider the role of risk aversion with respect to intertemporal utility, we rely on risk-sensitive preferences introduced by Hansen and Sargent (1995). Risk-sensitive preferences use the general framework suggested by Kreps and Porteus (1978) and are thus similar to Epstein–Zin preferences (Epstein and Zin, 1989; Weil, 1990), though based on a different certainty equivalent function.[4] These can be defined through the following recursion:

$$V_t=u(c_t)-\frac{1}{(1+\theta)\varepsilon}\log\left(E[e^{-\varepsilon V_{t+1}}]\right)$$

where $\varepsilon\geq 0$ measures the degree of absolute risk aversion with respect to intertemporal utility. In general, risk-sensitive preferences allow for non-trivial preferences for the timing of resolution of uncertainty. There are however two polar cases where indifference for the timing prevails (so that preferences are expected utilities, see Kreps and Porteus, 1978). The first one is the expected discounted utility model, namely $\theta>0$ and $\varepsilon=0$, yielding the well-known additively separable

(*footnote continued*)
non-linear feedback effects can dramatically widen the range of climate sensitivity estimates reported by Roe and Baker (2007), and illustrative calculations suggest a 1% probability that it is above 20 °C.

[2] An alternative is to consider the risk of "tipping points", where the realization of the risk reduces the stock of productive capital and it is thus possible to invest towards post-collapse welfare (see Keller et al., 2004; Lemoine and Traeger, 2015; Cai et al., 2013; Tsur and Withagen, 2013). This allows distinguishing between different possible events described in Lenton et al. (2008) and compute the associated social cost of carbon. Closer to our work, van der Ploeg and de Zeeuw (2014) formulate a model in which climate change generates a risk of an irreversible decline in total factor productivity (TFP). This implies that, after the realization of the risk, the economy converges to a less favorable steady state. They show that such risk can motivate the accumulation of a precautionary stock of capital to smooth consumption in between the two regimes. Our setup essentially abstracts from the transition between steady states, and hence does not consider precautionary capital accumulation. But like in their setting the long run welfare of the catastrophe is exogenous.

[3] This preference representation is also commonly named 'expected discounted utility'. Throughout the paper we use interchangeably the labels 'expected discounted utility' and 'additively separable preferences'.

[4] The difference is that risk-sensitive preferences use a constant absolute risk aversion certainty equivalent, whereas Epstein–Zin preferences use constant relative risk aversion certainty equivalent. As explained in Bommier and Le Grand (2014), relying on Epstein–Zin preferences involves giving up a key assumption of preference monotonicity, which makes the role of risk aversion particularly unintuitive. For example, non-monotonicity of Epstein–Zin preferences can imply that more risk averse agents display lower precautionary savings. With risk-sensitive preferences, one can benefit from the flexibility of Kreps and Porteus framework while having preferences that are monotone with respect to first-order stochastic dominance.