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Numerical analysis of non-constant pure rate of time preference: A model of climate policy

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Abstract

When current decisions affect welfare in the far-distant future, as with climate change, the use of a declining pure rate of time preference (PRTP) provides potentially important modeling flexibility. The difficulty of analyzing models with non-constant PRTP limits their application. We describe and provide software (available online) to implement an algorithm to numerically obtain a Markov perfect equilibrium for an optimal control problem with non-constant PRTP. We apply this software to a simplified version of the numerical climate change model used in the Stern Review. For our calibration, the policy recommendations are less sensitive to the PRTP than widely believed.

JEL classification: C63; Q20

Keywords: Non-constant pure rate of time preference; Hyperbolic discounting; Numerical methods; Non-renewable resources; Observational equivalence; Climate change; Stern Review

1. Introduction

The pure rate of time preference (PRTP) is a component of the discount rate, and as such plays a (potentially) important role in dynamic policy decisions. A model with non-constant pure rate of time preference (NCPRTP) is useful for reconciling observations on medium term market discount rates with ethical considerations relevant to the distant future. The optimal solution to such a model is typically time-inconsistent; a subgame perfect (and therefore time consistent) solution requires the solution to a dynamic game. Numerical methods have proven useful in many areas of economics, both to solve old problems and to suggest new ones. Numerical methods can be similarly useful in NCPRTP models. We introduce and apply a numerical package that solves a fairly general NCPRTP model.

We use the software to study an aspect of the climate change debate that has recently received a great deal of attention. The Stern Review of Climate Change [26] uses a constant 0.1% per annum pure rate of time

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preference and an elasticity of marginal utility equal to 1. Some commentators, including [4,23,29], think that these values lead to unreasonably low social discount rates, and thus call into question the Stern Review's policy recommendations. The Stern Review defends its discounting parameters on ethical grounds. It is difficult to satisfy both ethical criteria and to obtain a social discount rate that reflects medium term market rates, using a single PRTP. Karp and Tsur [18] discuss the role of NCPRTP in reconciling these two objectives in a model that focuses on low probability catastrophes.

We construct a simple model of climate change that is consistent with the orders of magnitude of costs and benefits in the integrated assessment model used in [26]. Our most surprising finding is that for this calibration, the PRTP is much less important than has previously been thought. The explanation is that a modest level of expenditures produces major gains, but much larger expenditures are worth little, and may even be counterproductive. Therefore, the optimal level of expenditures with a 3% PRTP is not much smaller than the level under a 0.1% discount rate. Of course, this result is model-specific.

The rest of this Introduction explains why NCPRTP may be an important feature in economic problems, and we explain what we mean by the "solution" to such a model. Groom et al. [12] provide a recent review of much of this literature.

The resurgence of interest in NCPRTP is due largely to behavioral economics' use of hyperbolic discounting, a particular form of NCPRTP in which the PRTP decreases. Hyperbolic discounting models have been used to explain anomalies such as apparent reversals in an individual's preferences [25]. These models use a relatively short period of time, such as the life of an individual. However, NCPRTP is also important for the study of long-lived environmental problems, such as greenhouse gasses (GHGs), where it is reasonable to use a very long or infinite horizon.

Our interest in NCPRTP arises from natural resource/environmental problems. Constant discounting at a non-negligible rate makes the possibility of extremely large damages in the far-distant future irrelevant to current actions. Constant discounting at a negligible rate causes current generations to save too much for (possibly richer) future generations (or, for example, to spend too much on GHG abatement). NCPRTP, with a discount rate that approaches a very low level, provides a balance that takes into account legitimate reasons for impatience in the near to middle term, while still giving non-negligible weight to welfare in the distant future [2,21,14].

The PRTP measures our willingness to trade utility between (for example) two successive generations. A constant rate implies that our willingness to exchange utility between the current and the next generation is the same as our willingness to exchange utility between two successive generations in the far-distant future. Introspection and survey data [3] suggest that many people do not have such preferences. We can distinguish between the current and the next generations and therefore might exhibit impatience when thinking about transferring utility between the two, leading to a positive PRTP in the near term. However, two generations in the very distant future are indistinguishable to us, suggesting that the PRTP in the distant future might be close to zero. The longest financial instruments mature within 30 or 40 years, so we cannot rely on markets to reflect a declining discount rate over long spans of time.

Two other circumstances produce models that are formally equivalent to a model with NCPRTP. In the first, there exists a "correct" constant discount rate, but the decision-maker has only a probability distribution for this parameter. Moreover, the decision-maker either obtains no information about this parameter or is unable to act on that information. If the decision-maker maximizes the expected value of a payoff, using the subjective distribution of the discount rate, the resulting maximization problem involves a discount rate that falls over time [1,6,28]. Second, if the decision-maker maximizes a convex combination of the payoffs of two or more agents with constant discount rates, the discount rate to the resulting problem falls over time [11].

Some decision problems, such as those that involve a large sunk cost, can be modeled as consisting of a single choice. Once a nuclear power plant is built, it is unlikely to be de-commissioned before its lifetime has expired. The undiscounted future costs of disposing of spent fuel may be of the same order of magnitude as the current construction costs, so the discount rate(s) are critical in determining the cost–benefit ratio of the construction project. However, once the trajectory of discount rates is chosen, the computation of the cost–benefit ratio is standard.

Other problems require a sequence of decisions, leading to a sequence of costs and rewards. Efforts to control climate change involve abatement costs and possible benefits (from reduced climate-related damages)