SOCIAL DISCOUNT RATE, INTERGENERATIONAL EQUITY AND CLIMATE CHANGE

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DISSEMINATION PAPER - 11

Centre of Excellence in Environmental Economics
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1. Introduction

The concept of social discount rate (SDR) refers to the rate used for converting future flows of costs and benefits from an investment project into the same units as current values (present values) from a social perspective. This rate is generally applied to public sector investment projects. In a without uncertainty world, when projects are independent and there are no externalities, using a given SDR, the net present value of benefit of each project can be calculated and the projects can be ranked on the basis of their net present values. The decision problem becomes choice of a project which yields the highest net present value of benefit.

In a discrete model, if i is the discount (interest) rate, the discount factor for period t is $(1+ i)^{-t.}$ When i is positive, the present value of one rupee of benefit or cost accruing at a future time t will decrease as t increases. When i= 0.02, the present value of one rupee available at t=10 (at the end of ten years) is Re 0.82 and the present value of one rupee available at t= 100 is less than Re 0.14. When i=0.15, the present value of one rupee at t=10 is less than Re 0.25 and the present value of one rupee available at t=100 is Re 0.00000085. See Table 1. A positive i implies decreasing weights for incomes accruing as time passes on. As for project selection, a high SDR would favour projects yielding immediate net benefits and only a low SDR may favour projects with net benefits accruing after long time.

Table 1: Present values of one rupee available in different periods for selected interest rates

Time	i= 0.02	i=0.05	i= 0.10	i=0.15
t=10	0.8203	0.6139	0.3855	0.2472
t=20	0.6730	0.3769	0.1486	0.0611
t=50	0.3715	0.0872	0.0085	0.0009
t=100	0.1380	0.0076	0.000073	0.00000085

It should be noted that in the standard deterministic Ramsey model of optimum economic growth, the SDR is derived endogenously from an intertemporal optimization problem. Many climate economists including Nordhaus and Stern use the standard Ramsey framework for cost benefit analysis of climate mitigation policies. There are many conceptual and measurement problems in applying the derived SDR from the Ramsey model for analysis of climate change mitigation projects. These issues arise because of the following reasons.

First, in most climate change mitigation projects costs are incurred now but the benefits occur after long time and when they do occur the benefits may be available for very long period, say one hundred years more. The current generation incurs the mitigation costs and the benefits would accrue to future generations. In conventional social cost benefit analysis of investment projects, the assumed life of project is often less than 50 years.

Second, there are both structural uncertainties and inertia in the climate system. The cascading effects of uncertainties from emissions to concentration of greenhouse gases in the atmosphere, from the concentrations to increases in the global temperature, from the increase in the temperature to the impacts on the economic system, and the extent and speed of governments' policy responses result in probability distributions for per capita consumption growth with fat tails which are difficult to analyze (Weitzman, 2009). Incorporation of non-substitutability between natural capital and man-made capital, irreversibility of some investment decisions and possibility of learning over time, and intra-generational equity considerations pose great challenges in development of an appropriate framework for analyzing climate change mitigation policies.

Third, as the atmosphere is a global common and a common concern of mankind, the issue of preserving the natural capital and the equitable sharing of it for current and future generations is a matter of global concern. The principles of intergenerational equity, sustainable development and precautionary approach in management of the commons have been endorsed by the United Nations. Some of the benefits are in the form of non-market benefits or public goods

The purpose of this dissemination paper is to highlight issues relating to choice of social discount rate and appropriateness of conventional social cost benefit analysis framework in analyzing climate change mitigation policies. Section 2 considers the standard Ramsey model of optimum economic growth which has been used as a basic framework by many economists to answer the question how much and how fast should we react to the threat of global warming. Section 3 deals with uncertainty and climate change. It reviews the contributions of Heal and Kiström (2002) and Weitzman (2007, 2009) to understand the implications of structural uncertainty for climate modeling and cost benefit analysis. Section 4 deals with other issues which are relevant for developing a satisfactory framework for analyzing climate mitigation problem within a multilateral framework. Section 5 contains concluding remarks.

2. The Social Discount Rate in the Ramsey Model

In a pioneering work, Ramsey formulated a model of economic growth in which a central decision maker desires to maximize the discounted utility of per capita consumption of an individual (generation/cohort) over an infinite horizon. Let *c(t)* denote the per capita consumption at time *t*, *U[c(t)]* denote the utility derived from consumption at time *t*, and ρ is the rate of social time preference/discount rate (the relative weight of economic welfare of different households or cohorts over time), then the discounted sum of utility can be written:

$$\int U\left[c(t)\right] e^{-\rho t}\, dt. \qquad (1)$$

The widely used utility function is constant elasticity marginal utility function of the form

$$U\left[c(t)\right] = \left[1/(1-\eta)\right] c(t)^{1-\eta},\ \eta > 0 \text{ but not equal to 1} \qquad (2)$$

$$U\left[c(t)\right] = Ln\ c(t),\ \eta = 1. \qquad (3)$$

The preferred value of η is between 0 and 4. η is interpreted as the elasticity of marginal utility of consumption, also as the coefficient of relative risk aversion.

Substituting (2) for *U[c(t)]* in (1) and then maximizing (1) subject to the constraint that consumption *c(t)* = income (*t*) [wage income *(w(t))*+ return on capital *r(t) k(t)]* - net investment, yields the Ramsey equation[1]

$$r = \rho + \eta g \tag{4}$$

where, *r*, the social discount rate (real return on capital) depends on the social rate of time preference (ρ), the elasticity of marginal utility of consumption or the coefficient of relative risk aversion (η), and the growth rate of consumption per capita (*g*). Weitzman (2007) notes that in balanced growth steady-state equilibrium g is essentially the underlying growth rate of labor-augmenting technological progress that, behind the scene, is pushing the entire economy forward (at least in a world without a greenhouse-warming externality).

Stern (2006) discusses the ethical and other issues in adopting this approach but uses this approach to analyze policy decisions about how to balance emission reductions with damages by estimating the marginal cost and marginal benefit of greenhouse gas (GHG) mitigation. Using values of ρ = 0.1% per annum, η =1 and *g*=1.3% per annum he arrives at a discount rate of *r*=1.4% per annum. Stern estimates the aggregate damage from global climate change as per cent of GDP, D/Y, at 5% and the current cost of ambitious abatement strategy as being equivalent to about 1% of GDP. Therefore, Stern argues for a strong mitigation strategy. He says: ‘The evidence shows that ignoring climate change will eventually damage economic growth. Our actions over the coming few decades could create risks of major disruption to economic and social activity, later in this century and in the next, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be difficult or impossible to reverse these changes. Tackling climate change is the pro-growth strategy for the longer term, and it can be done in a way that does not cap the aspirations for growth of rich or poor countries. The earlier effective action is taken, the less costly it will be’ (Executive Summary p.ii, Stern, 2006).

The Stern Review has generated heated discussion on the methodology used by Stern and also on the applicability of cost-benefit analysis for climate policies. Nordhaus says ‘these results are dramatically different from earlier economic models that use the same basic data and analytical structure. One of the major findings in the economics of climate change has been that efficient or "optimal" economic policies to slow climate change involve modest rates of emissions reductions in the near term, followed by sharp reductions in the medium and long term. We might call this the climate-policy ramp, in which policies to slow global warming increasingly tighten or ramp up over time' (Nordhaus, 2007, *p*.3). He argues that Stern's result depends decisively on the assumption of near –zero time discount rate combined with a specific (logarithmic) utility function. He says the need for extreme immediate action will not survive the substitution of assumptions that are consistent with today's marketplace real interest rates and savings rates. Assuming ρ=1.5% per annum, g= 2% per annum and $\eta = 2$, he arrives at a value of r=5.5%.

Weitzman (2007), using ρ=2 % per annum, g=2 % per annum and $\eta = 2$, gets a value of 6 % per annum for r. He notes that the present discounted value of a given global-warming loss from a century hence at the interest rate of $r = 6$ % is one hundredth of the present discounted value of the same loss at Stern's annual interest rate of r=1.4 %. Thus the benefit cost ratio is very sensitive to the choice of the discount rate.

3. Uncertainty and Climate Change

Uncertainty is pervasive in analysis of climate change. The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2007) mentions different stages of uncertainty. The stages are (a) uncertainty about greenhouse gas emissions scenarios, (b) uncertainty about the responses of carbon cycle to the emissions, (c) uncertainty about the sensitivity of the climate to changes in the carbon cycle, (d) uncertainty about the policy responses, (e) uncertainty about the technological change and (f) and uncertainty about impact on human well-being and ecosystem.

Cost benefit analysis can deal with uncertainty relying on expected utility theory. The IPCC reports give some information about tail probabilities but the inferences are based largely on means and variances, and some times on the first and ninth decile values. Heal and Kriström note that if uncertainty is central then attitude towards risk and the degree of risk aversion will be presumably central parameters. They note that the risks are not exogenous but are generated by our own activities. This endogeniety of the risks raise questions about the use of markets and insurance for hedging some of the risk associated with possible climate change. They note that this is the macro-level equivalent of moral hazard. Further, some of the risks are correlated. Some of the changes in climate and in the natural environment may be irreversible. Uncertainty reduction is possible through learning and generating new information about climate change. The possibilities of irreversibility and learning provide breeding ground for use of option values, Bayesian learning and precautionary approach. They attempt to develop a general model with outputs from physical and natural capital, incorporating changes in GHG emissions, carbon sequestration and investment in minimizing GHG emissions, but recognize that no analytical solution is feasible.

Weitzman (2007) notes that an important feature of interest rates under uncertainty is that they do not aggregate arithmetically into a simple certainty-equivalent interest rate. A 0.5 chance of r = 6% and a 0.5 chance of r = 1.4% are not at all the same thing as splitting the difference by selecting the average r = 3:7%. It is not discount rates that need to be averaged but discount factors. A 0.5 chance of a discount factor of e^{-6} a century hence and a 0.5 chance of a discount factor of $e^{-1.4}$ a century hence make an expected discount factor of $0.5e^{-6} + 0.5e^{-1.4}$ century hence, which is equivalent to an effective interest rate of r = 2%.

Weitzman (2009) analyzes the implications of structural uncertainty for the economics of low probability, high-impact catastrophic climate change. He shows that thicker right tail for the distribution of global temperature change results in thicker left tail for the distribution of g [2]. He says that as we move towards probabilities in the tails of the g distribution, we are increasingly moving into the unknown territory of subjective uncertainty where our probability estimates of the probability density function themselves becomes increasingly diffuse because the frequencies of rare events in the tails cannot be pinned down by previous experiences, past observations, or computer simulations. He argues that the thickened tails of the reduced form distribution of *g* have surprisingly strong effects on cost benefit calculation by lowering significantly expected utility and rising significantly expected marginal utility[3].

His dismal theorem makes economic analysis trickier and more open ended and raises difficult conceptual issues that cause the analysis to appear less scientifically conclusive and more contentiously subjective than what comes out of an empirical CBA of more usual thin tailed situations. He says that ‘the climate-change economist can help most by not presenting a cost-benefit estimate for what is inherently a fat-tailed situation with potentially unlimited downside exposure as if it is accurate and objective—and perhaps not even presenting the analysis as if it is an approximation to something that is accurate and objective—but instead by stressing somewhat more openly the fact that such an estimate might conceivably be arbitrarily inaccurate depending upon what is subjectively assumed about the high-temperature damages function along with assumptions about the fatness of the tails and/or where they have been cut off’’ (2009, p.18). He concludes that the catastrophe insurance aspect, can dominate the social-discounting aspect, the pure-risk aspect, and the consumption-smoothing aspect.

4. Development and other issues

The simplified and ultra-stylized single world analysis based on the Ramsey model is grossly incomplete as a framework to analyze the challenge of climate change. Conceição *et al.* (2007) stress the need to consider asymmetries that exist in the world. They note that the distribution of cross-generational income intersects with climate change at two levels: first, in terms of the causes of climate change (emissions of greenhouse gases) and second, in terms of the effects of climate change. In terms of causes of climate change, developed countries have the overwhelming responsibility for the accumulated stocks of greenhouse gases in the atmosphere. According to the World Resources Institute, during 1850-2002, developed countries accounted for 75.6% of cumulative GHG emissions with the shares of USA and EU-25 being 29.3% and 26.5% respectively.

In terms of the effects of climate change, some regions in the North may benefit from warmer temperatures and increase in rainfall. But the effects in tropical regions are and will be overwhelmingly negative. The poorest countries and people are suffering the most in terms of the effects of climate anamolies, and this pattern is likely to persist in the future. If this pattern does persist, climate change is likely to drive income divergence and to deepen global inequalities.

Conceição *et al.* (2007) review a few studies that deal with heterogeneous time preferences and analyze the effects of such heterogeneity on aggregate discount rate. These studies conclude that the representative individual will have a declining discount rate when individuals have decreasing risk aversion preferences. Dasgupta (2007) interprets η as a measure of aversion towards consumption inequality among people. As climate change will have a disproportionate negative impact on world poor, he recommends increasing value of η from 1 to 3. If economic growth results in decrease in environmental quality over time the discount rate can even be negative.

GHG reduction is a global public good. Hence collective action at global level is necessary to solve free rider problem and ensure coordinated action among sovereign states. The United Nations Framework Convention on Climate Change (UNFCCC), which was established in 1992, acknowledges that change in the Earth's climate and its adverse effects are a common concern of mankind. Article 3.1 of the Convention states that the parties should protect the climate system for the benefit of present and future generations of humankind on the basis of equity and in accordance with their common but differentiated responsibilities (CDR) and respective capabilities. Accordingly, the developed country parties should take the lead in combating climate change and the adverse effects thereof. Article 3.3 mentions precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. It notes that, where there are severe threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures.

If climate change is a common concern of mankind and if each human being has an equal entitlement in the common property then sustainable use of the property is a matter of global concern. In this context, it is desirable to view the cumulative stock of GHGs as a debt burden to be borne by rich industrialized countries. The legal liability then requires them to undertake not only urgent action for mitigation of climate change but also provide technical and financial support to developing countries to assist hem in their climate change adaptation efforts. Instead of the question posed by Stern and Nordhaus 'how much and how fast should we react to the threat of global warming', the relevant question, from the viewpoint of sustainable development, is how soon we can correct the inequitable shares of the global commons by rich industrialized countries via binding reduction commitments of GHG emissions and moving all economies to low carbon trajectories based on the principle of CDR.

5. Concluding Remarks

The Stern Review highlighted the economics of climate change and persuaded policy makers to undertake early and strong action to combat global warming. It also generated heated debate on issues such as choices of social rate of time preference and elasticity of marginal utility of consumption, treatment of uncertainty and relevance of cost benefit analysis to climate change economics. Even though Stern adopts an international perspective, his Review does not fully incorporate the spirit of UNFCCC.

Nordhaus' criticism that Stern's case for early and urgent action depends largely on Stern's choices of low rate of social time preference and low elasticity of marginal utility of consumption is valid but his argument that the social rate of interest must have some relationship to observable market interest rate is not valid in the case of climate mitigation. The rationale for equating the social discount rate to private rate of return is based on the need for establishing a level playing field for both private and public sectors in a competitive economy with no externalities or public goods. The climate change problem is largely due to market failure, institutional failure and policy failure.

Weitzman has articulated the implications of thick tailed reduced form distribution of consumption growth for economic modeling and drawing policy inferences. Economists are aware of the difficulties in imputing values for non-marketable goods, particularly incommensurable values, but they have not developed suitable theoretical framework for analyzing catastrophes.

Weitzman urges the need for transparency in spelling out nature and quality of information about uncertainties and parameter values and cautions in presenting one's results.

Environmental economists are aware of the difficulties in valuing environmental damages and this is the reason most of them opt for a second-best solution i.e. given the socially preferred value of tolerable damage/ standard how to achieve the goal at least possible social cost via regulation, market or taxation. See for example Baumol and Oates (1987). Thus the cost effectiveness criterion is valid for choice among policies, once the goals are given. Social cost benefit analysis can also enable a decision maker to make an informed choice of a policy among a set of policy options.

The UNFCCC is a multilateral framework to deal with global warming. It has 193 members. Its view of climate change as a common concern of mankind and its principle of common but differentiated responsibilities of states according to their respective capabilities provide a framework for equitable access to the global commons and sharing of the costs of mitigation on the basis of states' cumulative contributions to GHG emissions.

The findings of recent studies such as (i) uncertainty about future interest rate lowers SDR, (ii) heterogeneity of preferences requires declining SDR, (iii) incorporation of natural capital or negative environmental quality lowers SDR, and (iv) in the presence of pervasive uncertainty like climate catastrophe there is justification for adopting "generalized precautionary approach" (Weitzman, 2009), support Stern's case for earlier effective action to combat global warming.

FOOTNOTES

1. This is an optimal control problem and this solution can be obtained by applying Pontryagin's maximum principle.
2. In Weitzman's formulation *g* stands for the unknown growth rate of comprehensive future consumption that includes the consumption of natural assets, ecosystems, species, and the like.
3. For assumptions and derivations of the result that the amount of present consumption the agent would be willing to give up in the present period to obtain one extra sure unit of consumption in the future period, which is a kind of shadow price for discounting future costs and benefits in project analysis, becoming infinity see pages 6-8 of Weitzman (2009). He labels the result as a dismal theorem.

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