Is There a Reason for Strong Mitigation? The Role of Time Preference, Inequality Aversion and Catastrophes

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Introduction

The quantification of the economic damages of current and future climate change is a very difficult task. Projections of future climate change are often uncertain. The historical linkages between climate events and economic damage can be only partially understood, because there are significant limitations in economic and climatic data, and climate change is only one of several sources of economic damage. The few estimates of economic response to climate change in the literature are contingent on highly uncertain assumptions about the future societies with which climate will interact.

Nevertheless, the challenge of global climate change has motivated a great deal of research and controversy surrounding the issue of optimal mitigation effort. In the research shown here, we examine the roles of time preference, inequality aversion and catastrophic warming scenarios on the implied welfare optimal carbon tax in a variant of the Regionally Integrated Climate and Economy (RICE) model (Nordhaus 2007, 2010). By using this well known, but simple Integrated Assessment Model (IAM) we are able to explore the policy implications of a range of scenarios and normative assumptions.

NICE model

We call our variant of the RICE model the NICE (Nested Inequalities, Climate and Economy). In the box to the right we show the most relevant equations of the model. Equations (4), (7), (8), and (9) are novel to NICE while the others are the same in both models.

- Equation 1 describes welfare (W) as a function of consumption (c), population (L), the utility discount rate (time preference) ρ, and the inequality aversion η. The summation goes over time (index t), 12 regions (index i) and sub-regional income quintiles (index j).
- We seek the carbon tax τ_t - in equation (2) - that optimizes W.
- The tax affects the mitigation rate (μ), which increases the mitigation cost - equation (3) - and decreases emissions - equations (10) and (11).
- Higher emissions lead to higher temperatures through the simple carbon and temperature cycles and forcing equations (13), (14), and (15). These are unmodified from RICE.
- Higher temperatures lead to higher damages, as given in equation (4). Parameters α_{1i} and α_{2i} replicate the damages in RICE. α_3 is a parameter that can be turned on and off to replicate Weitzman-like catastrophic damages – see section on catastrophic damages on the right.
- Average regional per-capita consumption – equation (6) - is the unsaved regional net output – equation (5) - divided by the population.
- In NICE we distribute the per-capita consumption of every region amongst 5 population quintiles.
- Pre-damage consumption is distributed according to current income distribution data, embodied in q_{ij} - equation (7).
- The damage is distributed according to a constant elasticity parameterization – equation (9) – and subtracted from each quintile's pre-damage consumption – equation (8).
- When ξ=1 damages are proportional to income, when ξ=0 damages are independent of income (all income quintiles experience the same amount of damage in absolute terms) and for ξ=-1 they are inversely proportional.
- Equation 10 shows the total emissions from fossil fuel sources by region and time (E_{it}) as a function of the total economic output (Y_{it}), the mitigation rate (μ_{it}) and the carbon intensity (σ_{it}).
- Equation 11 shows the total emissions (E_t) as a function of the emissions from fossil fuel combustion (E_{it}) and emissions from land use changes (EL_t).
- The masses of carbon (M) in the atmosphere, surface ocean and deep ocean (indices a, b and c respectively) depend on carbon cycle exchange coefficients (m) and the total anthropogenic carbon emissions (E_t) according to equation 13.
- The temperature (T) of the atmosphere and surface ocean (indices a and b respectively) depend on heat exchange coefficients (t) and radiative forcing from the atmospheric carbon according to equation 14.
- The radiative forcing F_t depends on the natural exogenous forcing F_{texo}, the concentration of carbon in the atmosphere x and the climate sensitivity ε according to equation 15. M_{aPI} stands for the preindustrial carbon concentration.

$$W(c_{ijt}) = \sum_{ijt} \frac{L_{ijt}}{(1+\rho)^t} \frac{c_{ijt}^{1-\eta} - 1}{1-\eta} \quad (1)$$

$$\mu_{it} = \left(\frac{\tau_t \sigma_{it}}{\theta_{1it}\theta_2} \right)^{\frac{1}{\theta_2 - 1}} \quad (2)$$

$$\Lambda_{it}(\mu_{it}) = \theta_{1it}\mu_{it}^{\theta_2} \quad (3)$$

$$D_{it}(T_{at}) = \alpha_{1i}T_{at} + \alpha_{2i}T_{at}^{\ 2} + \alpha_3 T_{at}^{\ 7} \quad (4)$$

$$Y_{it} = \frac{1 - \Lambda_{it}(\mu_{it})}{1 + D_{it}(T_{at})} Q_{it} \quad (5)$$

$$\bar{c}_{it} = \frac{1 - s_{it}}{L_{it}} Y_{it} \quad (6)$$

$$c_{ijt}^{pre} = 5\bar{c}_{it}(1 + D_{it})q_{ij} \quad (7)$$

$$c_{ijt} = c_{ijt}^{pre} - 5\bar{c}_{it} D_{it} d_{ij} q_{ij} \quad (8)$$

$$d_{ij} = \frac{q_{ij}^{\xi}}{\sum_{ij} q_{ij}^{\xi}} \quad (9)$$

$$E_{it} = \sigma_{it}(1 - \mu_{it})Y_{it} \quad (10)$$

$$E_t = \sum_{i=1}^{12} E_{it} + EL_t \quad (11)$$

$$\begin{bmatrix} M_{at} \\ M_{bt} \\ M_{ct} \end{bmatrix} = \begin{bmatrix} m_{aa} & m_{ba} & 0 \\ m_{ab} & m_{bb} & m_{cb} \\ 0 & m_{bc} & m_{cc} \end{bmatrix} \begin{bmatrix} M_{at-1} \\ M_{bt-1} \\ M_{ct-1} \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} E_t \quad (13)$$

$$\begin{bmatrix} T_{at} \\ T_{bt} \end{bmatrix} = \begin{bmatrix} t_{aa} & t_{ba} \\ t_{ab} & t_{bb} \end{bmatrix} \begin{bmatrix} T_{at-1} \\ T_{bt-1} \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} F_t\left(\frac{M_{at} + M_{at+1}}{2} \right) \quad (14)$$

$$F_t(x) = \varepsilon \log_2\left(\frac{x}{M_{aPI}} \right) + F_{texo} \quad (15)$$

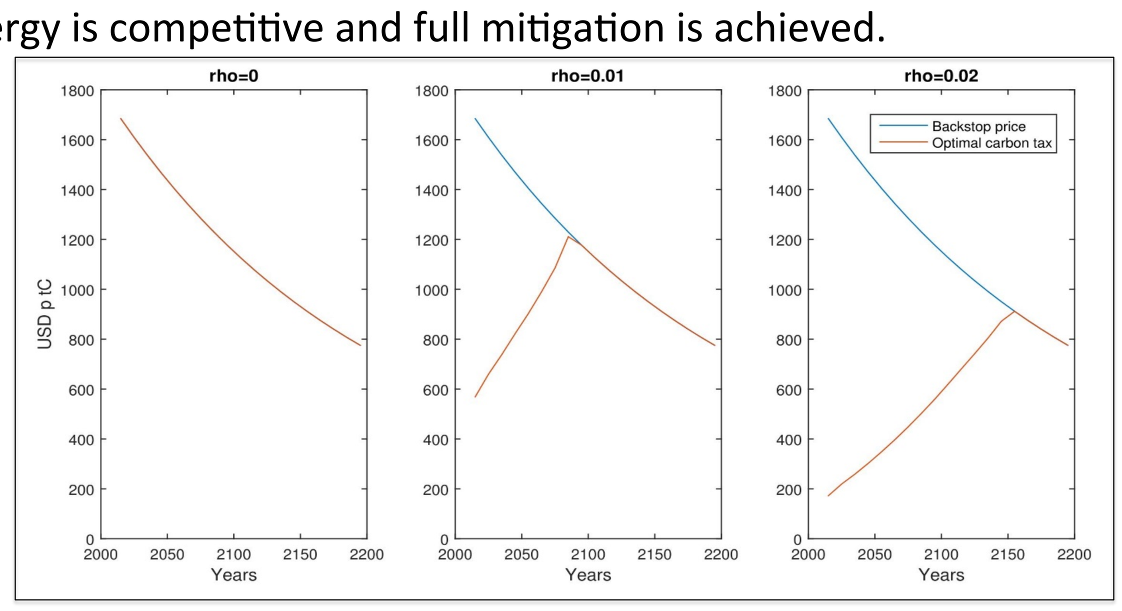
Only inequality aversion or discounting can justify postponing mitigation

In RICE/NICE growth assumptions are such that future generations are substantially better off than current generations. The inequality aversion parameter η applies to inequality across space and time equally in the welfare function – equation (1). In as far as future generations are richer, high values of η discount the costs to the future relative to the present; just like the much debated discount rate.

When η=0, the objective simply maximizes total (possibly discounted) consumption. In this case the relative affluence of the future over the present has no impact and only the relative magnitude of the damages and mitigation costs matter. Because the former are significantly greater than the latter (even in the unmodified RICE model) very high mitigation levels become optimal. This is especially true if the utility discount rate ρ is also zero (left panel in figure). At higher values of ρ (middle and right panels), the future climate damages are discounted and the consequent carbon tax rate is not quite as high; but still significantly higher than in RICE.

The descending line in these graphs (in blue) is the assumed "backstop" price curve; the carbon tax at which renewable energy is competitive and full mitigation is achieved.

In the left panel (ρ=0), the carbon tax (in red) reaches the backstop price immediately. In the middle panel (ρ=1%/year) and right panel (ρ=2%/year) the carbon tax reaches the backstop by about 2090 and 2160, respectively.



Intragenerational and intergenerational inequality effects on the welfare optimal tax

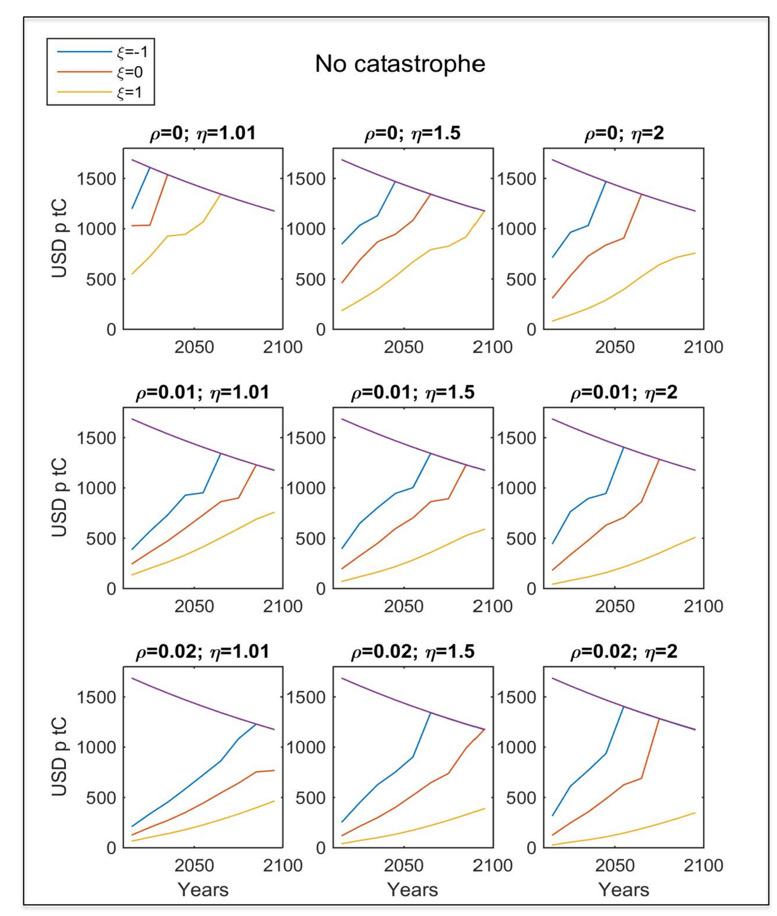
When η>0, the distribution of outcomes – across time and space – matters. Which matters more depends on a combination of things. In the figure below, we plot 27 optimal taxes, for three different values of η, ρ and ξ respectively. The discount rate ρ takes the values 0, 1%, and 2% per year. Nordhaus (2007) has argued for the upper end of this range and Stern (2006) and Dasgupta (2008) have argued for the lower end of this range. The inequality aversion parameter η takes values 1, 1.5 and 2. Nordhaus has argued for the upper end of this range and Stern chose the lower end. Dasgupta argues for much higher values of η.

One of the innovations in our modeling work is the use of a parameter for the income elasticity of climate damage, ξ. While other IAM studies have examined the elasticity of climate related damages to variations of income over time or for different sectors of an economy (Houser et al., 2014; Mendelsohn et al., 2011), we explicitly consider the differentiated climate related damages on different income quintiles within the same society.

As is clearly visible from the figure to the right, the optimal carbon tax is always greatest for a negative income elasticity of climate damage ξ=-1 and least for ξ=1. (In the case of zero inequality aversion, different values of ξ make no difference to the optimal carbon tax).

As the rate of time preference increases from 0 to 2% per year (from top to bottom), the optimal tax rate decreases. (This was also true in the case of zero inequality aversion.)

Increasing the inequality aversion η (from left to right) raises the carbon tax when damages are less than proportional to income and the discount rate is positive, due to a lower level of mitigation and greater damages falling on the poor. In absence of discounting, damages are sufficiently controlled under the optimal policy, so that intergenerational inequalities become more salient and increasing η lowers the optimal carbon tax.



Note that the spread between the optimal carbon tax for the three values of ξ increases with η.

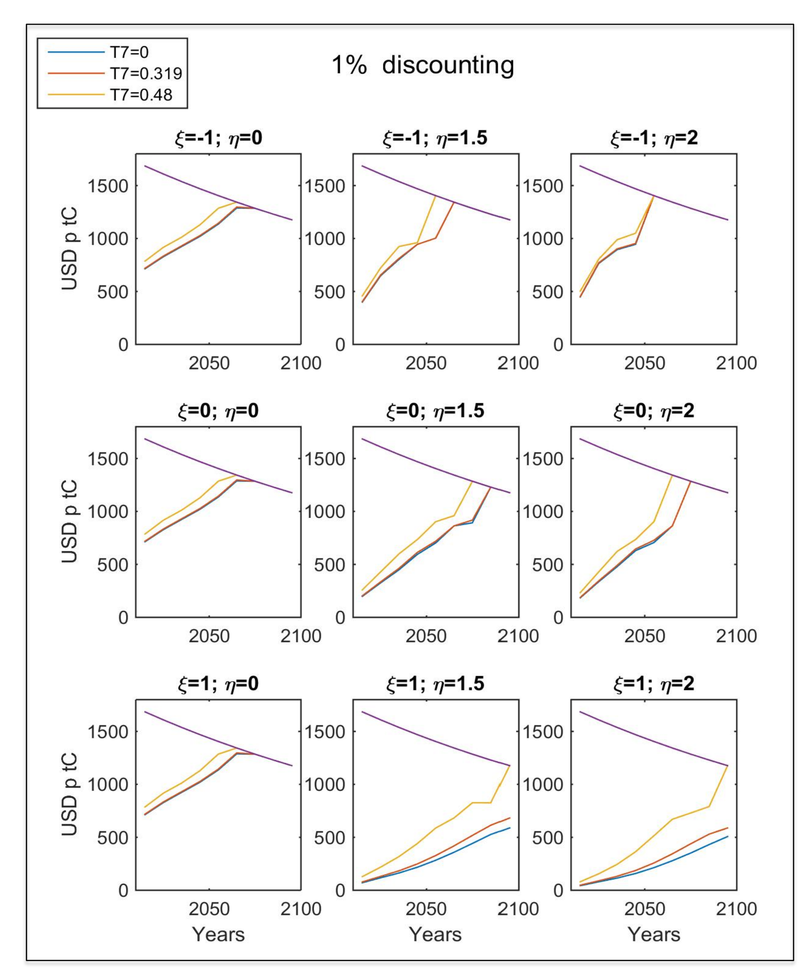
When do catastrophic damages matter?

In this section, we also explore the role of catastrophic warming scenarios on the global economy and the resulting optimal carbon tax rates. In the standard RICE model, the parameter α_3 from equation 5, corresponding to the T^7 term of the damage function is set to 0.

Here we consider three scenarios; the standard RICE model scenario, a scenario in which a 6°C rise in global mean temperature would lead to a halving of the global GDP and a scenario in which a 4°C rise in global mean temperature would lead to a halving of the global GDP (in blue, red and yellow respectively). These latter two scenarios are discussed by (Weitzman, 2012) and (Dietz and Stern, 2014) respectively. The corresponding α_3 values are 3.4e-6 and 5.9e-5, respectively.

For illustrative purposes, we fix the discount rate ρ to be 1%. We allow ξ to vary from -1 to 1 and η to vary from 0 to 2. As we see through all 9 figures, increasing α_3 increases the carbon tax.

When the income elasticity of damages is negative (top row), the total tax rates are higher, but the difference in tax between the different α_3 and η values are less pronounced (because presumably the high tax rate forces enough mitigation to limit the likelihood of having a 4 or 6°C temperature rise).



Conversely, when the income elasticity of damage is positive, the total tax rates are lower and the optimal tax rate becomes more sensitive to differences in α_3 and η, because the probability of catastrophic damages increases.

Conclusions/Future Work

- Lower discount rates imply higher welfare optimal carbon tax rates in all scenarios
- Under growth assumptions in the NICE model, zero inequality aversion and zero discounting leads to high carbon tax rates and implicitly rapid mitigation.
- Future intragenerational inequalities become salient under weak mitigation policy (high discounting) and when damages fall more heavily on the poor; intergenerational inequalities dominate otherwise
- The distribution of climate damages may strongly influence the welfare optimal carbon tax rate
- The possibility of catastrophic climate damages has a larger effect on the tax rate when damages are proportional to income than when they fall on the poor (which requires strong mitigation anyway).
- Future work will include studying population, growth and the distribution of abatement costs

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Selected References

- Dietz, S., and N. Stern, (2014), Endogenous Growth, Convexity of Damages and Climate Risk: How Nordhaus' Framework Supports Deep Cuts in Carbon Emissions, *Center for Climate Change Economics and Policy.*
- Dasgupta, P., (2008), Discounting climate change, *Journal of Risk Uncertainty*, 37, 141-169.
- Houser, T., R. Kopp, S. Hsiang, M. Delgado, A. Jina, K. Larsen, M. Mastrandrea, S. Mohan, R. Muir-Wood, D.J. Rasmussen, J. Rising, and P. Wilson, (2014), American Climate Prospectus: Economic Risks in the United States, prepared as input to the Risky Business Project, Rhodium Group.
- Mendelsohn, R., K. Emanuel, S. Chonabayashi, (2011), The Impact of Climate Change on Global Tropical Storm Damages, *The World Bank, Policy Research Working Paper 5562.*
- Nordhaus, W., (2010), Economic aspects of global warming in a post-Copenhagen environment, *PNAS, 107*, 11721-11726.
- Nordhaus, W., (2007), A Review of the Stern Review on the Economics of Climate Change, *Journal of Economic Literature, 45,* 686-702.
- Stern, N., HM Treasury Department, UK (2006). Stern Review on the Economics of Climate Change.
- Weitzman, M., (2012). GHG Targets as Insurance Against Catastrophic Climate Damages. *Journal of Public Economic Theory, 14,* 221-244
- Weitzman, M., (2011), Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change, *Review of Environmental Economics and Policy, 5,* 275-292.