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Environmental Catastrophes and Mitigation Policies in a Multi-Region World

Timothy Besley, London School of Economics
and
Avinash Dixit, Princeton University

Introduction

Some prominent issues emerging from research on climate change:

- Greenhouse gases (GHG) accumulation is driving global warming
- Uncertainty about damage fat-tailed, not normally distributed
- Risk of catastrophic events rises as GHGs accumulate
- GHGs worldwide public bad, but effects not uniform around world
- Two-sided uncertainty: action and inaction each with own risks
- Technological solution may make conservation efforts unnecessary

Aim of this paper

- Construct a theoretical model with all these features
- Obtain numerical solutions for plausible parameter values
- Use this to evaluate and compare alternative policies
- Keep model simple and solution method publicly available
  so others can explore effects of varying parameters etc

Exploratory work, but suggests

- Substantial investment to reduce risks is justified
- Policies in different countries are strategic complements

Highlighted features

- Catastrophic event Poisson process (all tail), arrival rate increasing function of GHG level
- Another Poisson process for arrival of total solution
- Not find optimal policies, which are
  (a) sensitive to unknown cost function
  (b) mostly undiscussed in international negotiations
- Instead find willingness to pay (compensating variation) for various policies

Model used in numerical work here;
more general theoretical specification in paper.

Definitions and notation

Carbon dynamics

Emission flow $= z_t$

About 60% dissipates quickly. Of the rest,

Permanent fraction $= \epsilon \approx$ 50%

Depreciation rate of the non-permanent $= \delta \approx$ 2.8%

Permanent stock $= P_t = \epsilon\ \Sigma_{\tau=0}^{t}\ z_\tau$

Depreciating stock $= D_t = (1-\epsilon)\ z_t + (1-\delta)\ D_{t-1}$

State variable $x_t = \ln(P_t + D_t)$

Poison processes

Arrival rate of catastrophe $\lambda(x) = e^{\gamma x}/[J + e^{\gamma x}]$

Arrival rate of miracle technology $= \mu$

One-region model (unified world)

GDP $y_t = y_0\,(1+g)^t$. Emission flow $z_t = z_0\,(1+\alpha)^t$

PDV cost of catastrophe (if it occurs) $K_t = K_0\,(1+g)^t$

Discount rate $r > g$

Expected net present value of economy:

$$\begin{aligned} V(x_0) &= y_0\,\frac{1+r}{r-g} - K_0\,\Lambda \\ \Lambda &= \sum_{t=0}^{\infty}\left[\frac{(1+g)(1-\mu)}{1+r}\right]^t\;\lambda(x_t) \end{aligned}$$

Many regions

ϵ, δ worldwide. $x = \ln($worldwide GHG stock$)$

y, z, K, g, α, r, J, γ, μ can differ across regions

Modeling effects of policies

Effects of changes in parameters α, μ, $\ldots$ channeled through Λ.

Compensating variation (CV): When Λ lowered to Λ',
suppose reducing GDP to $y\,(1-\theta)$ offsets this to restore old $V(x_0)$.

So θ is max fraction of GDP we should be willing to give up.

$$\theta = \frac{r-g}{1+r}\;\frac{K_0}{y_0}\;(\Lambda - \Lambda')$$

Similar formulas in multi-region case.

Spillovers: each region's Λ depends on policies of all.

Numerical work: Regions China, US, Europe, ROW
with data on fractions of world GDP and emissions.

Baseline parameters

Generally "optimistic" choices, so our results lower bounds on CV.

$r = 0.05,$ far from Stern Review, close to Weitzman et al

$g = 0.03, \quad \alpha = 0.03$

$\delta = 0.03, \quad \epsilon = 0.5,$ values from cited literature

$\lambda(.)$ Prob(no catastrophe) falls to 10% in 81 years

$\mu = 0.01,$ Prob(full tech sol'n) rises to 50% in 70 years

$y_0 = 1,$ normalization

$K_0 = 2,$ calculation based on costs of Katrina

Calculations on Excel file available upon request,
so readers can do their own experiments with model.

Main results

"Kyoto" reduction α from 0.03 to 0.021

When all regions do this, $\theta = 3.3\%$

When US drops out, θ for rest falls to 2.7% :

When others reduce, US CV only 0.6% of GDP (free riding)

When no others reduce, US CV only 0.4% of GDP (spillover)

Thus policies in different regions are "strategic complements"

Less discounting: r = 0.04

CV for Kyoto reduction worldwide rises to 4.8% of GDP

Tech solution: raise μ from 1% to 1.5%

CV $=$ 3.3% of GDP, almost same as for Kyoto $\downarrow$ of α

Conclusions

This model is deliberately simple; readers can vary assumptions and check robustness beyond our own experimentation. But some concrete and suggestive results emerge.

On reasonable or even climate-optimistic assumptions, sacrificing 1-5% of GDP for policies to counter climate change seems easily justifiable.

Pessimism is about national and international cooperation to achieve the required collective action in face of free riding. That should be focus of future research on this topic.