Economics of Controlling Climate Change under Uncertainty

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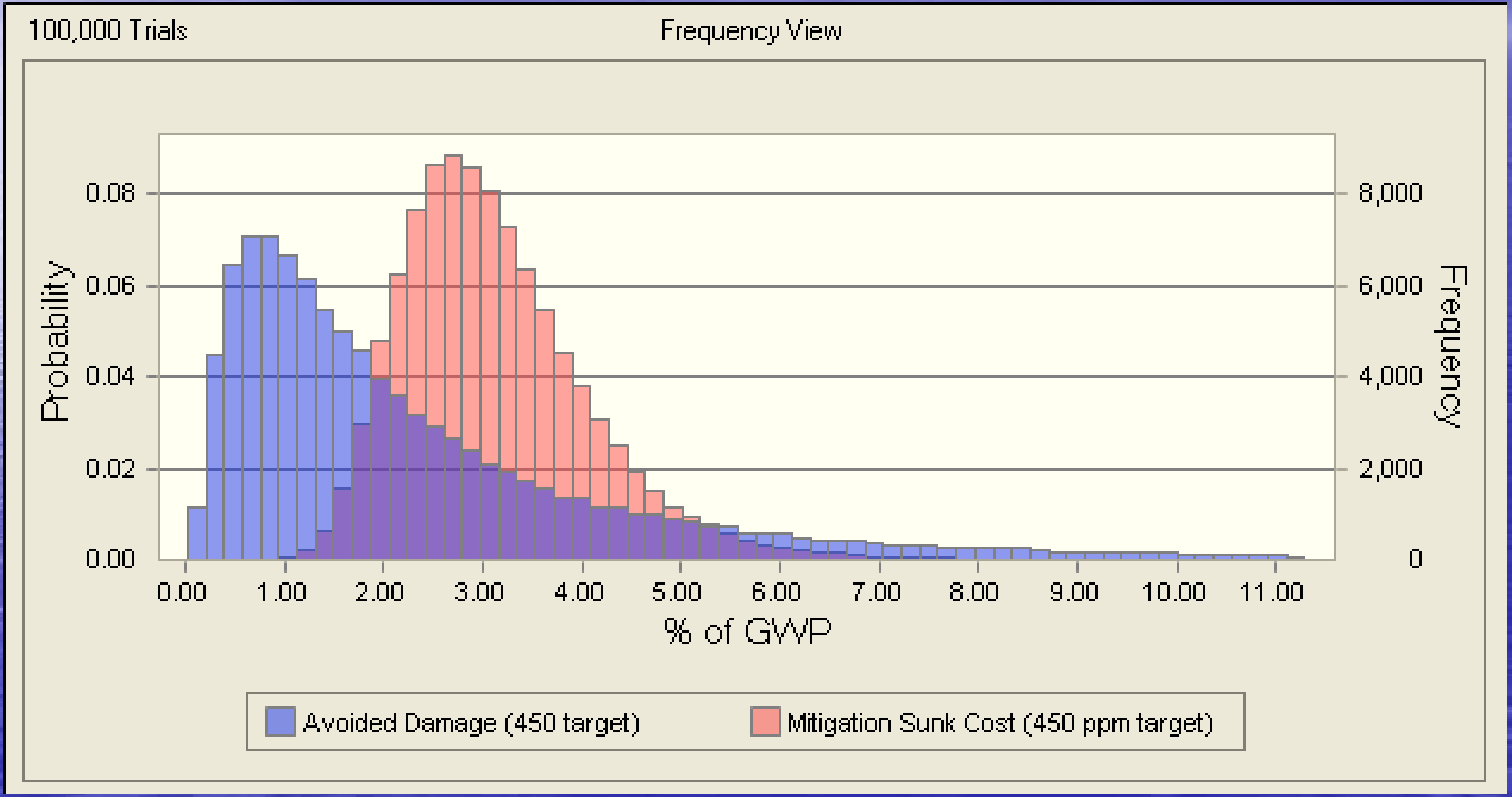
Uncertainty is at the heart of the climate change debate

- We do not know:
  - Magnitude of climate response to increased of GHG concentrations;
  - Cost of climate policy;
  - Business response to various instruments
- Technological developments have a significant random component;

Shortcomings of Expected Value Approach: Peak Tail and Variance



Integrated assessment of climate policy under uncertainty

- W. Nordhaus: "The first reservation is that the structure, equations, data, and parameters of the model all have major uncertain elements. Virtually none of the major components is completely understood. Moreover, because the model embodies long-term projections of poorly understood phenomena, the results should be viewed as having growing error bounds the further the projections move into the future".

Goal

- Investigate how the future uncertainties associated with climate change influence current decision on climate policy;
- Propose a decision rule in context of incompliant information on climate response to anthropogenic emission and uncertain cost of climate policy.

The modeling formwork

- General stochastic dynamic framework with irreversibility in climate change.
- Only one state variable and one control variable.
- Climate change depends on current GHG emissions and an sequence of random shocks.
- The welfare in each period depends on both current GHG emissions and the current climate state.

Scope of analysis

- Establish the dynamic programming foundations of the model including basic results on existence and qualitative nature of optimal policy.
- Investigate the economic and environmental conditions under which optimal GHG emission is decreasing in climate state
- Conditions under which it is optimal to improve the state of the climate from a certain current state.

Emission and climate response

- The emission flow in each period t satisfies:

$$0 \leq g_t \leq \overline{g}.$$

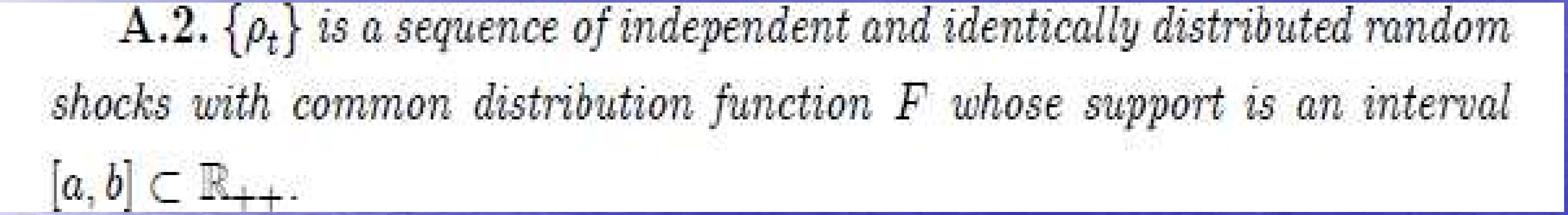
- The climate state variable evolves over time according to:

$$s_{t+1} = \rho_{t+1} f(g_t, s_t)$$

Properties of emission-response function

- The f(g,s) function allows the marginal change in climate from current GHG emission to depend on the current state of the climate (need not be additively separable).

Uncertainties



A.2. $\{\rho_t\}$ *is a sequence of independent and identically distributed random shocks with common distribution function* F *whose support is an interval* $[a, b] \subset \mathbb{R}_{++}$.

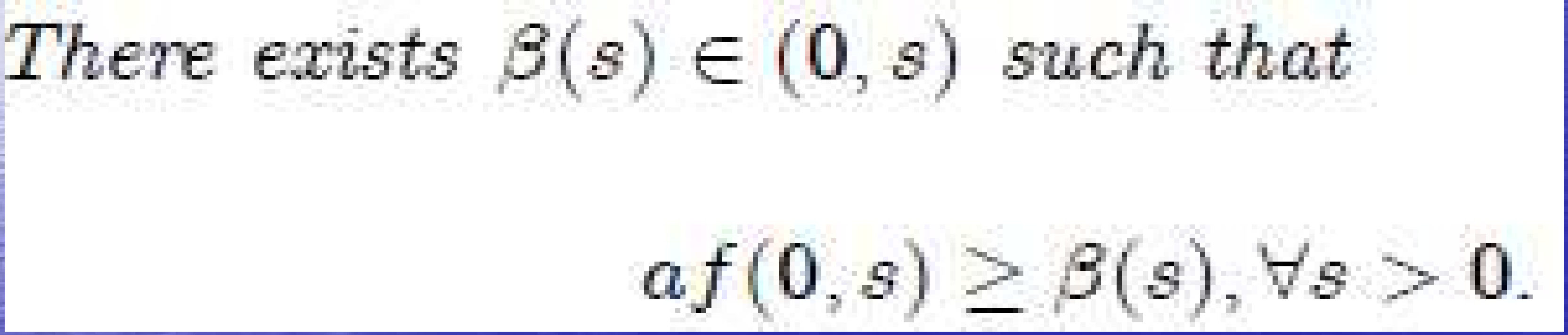
Utility Function

- Immediate utility increasing in emission;
- But decreasing in climate state;
- Marginal utility from emission decreasing in emission.

Properties of utility function

$$\lim_{g \to 0} w_1(g, s) = +\infty, \forall s \geq 0.$$

Irreversibility and positive feedback



There exists $\beta(s) \in (0, s)$ *such that*

$$af(0, s) \geq \beta(s), \forall s > 0.$$

This study and conventional IAM

- Utility function implicitly includes negative impacts of climate change
  - Usually in IAM damage presented as a fraction of GDP (e.g. DICE, PAGE etc.)
- Closed form solution allows to avoid complicated computations:
  - RBC-DICE offers limited ability for experiment;
  - Monte-Carlo analysis of DICE 2007 takes significant time
- Uncertainties in negative climate impact bounded (in contrast to Weitzman's analysis)

The model

$$\max E[\sum_{t=0}^{\infty} \delta^t w(g_t, s_t)]$$

subject to

$$\begin{aligned} s_{t+1} &= \rho_{t+1} f(g_t, s_t) \\ 0 &\leq g_t \leq \overline{g}. \end{aligned}$$

The model and IAM family

- The model is significantly more general than a stochastic stock pollution control model:
  - In contrast with Ramsey growth model, the state variable does not influence the feasible set of action;
  - In the growth model, capital determines the feasible set of consumption or investment.
  - Here, the feasible set from which action gt (the level of current GHG emission) can be chosen is independent of climate state.
  - The negative influence of climate state on the economy enters directly in the reduced form welfare function.

Current emission and climate state: net welfare gain and substitution

- The net dynamic social welfare gain from a marginal improvement in the climate state:

$$V'(s) \quad = \quad w_2(g(s),s) - w_1(g(s),s)\frac{f_2(g(s),s)}{f_1(g(s),s)}$$

- Current emission is a substitute for climate state in the "production function f" of tomorrow's climate state.

Intertemporal tradeoff between current emission and future welfare

The Euler equation (30):

$$\begin{aligned} w_1(g_t, s_t) \quad = \quad & \delta E_t[\{w_1(g_{t+1}, s_{t+1})\frac{f_2(g_{t+1}, s_{t+1})}{f_1(g_{t+1}, s_{t+1})} \\ & -w_2(g_{t+1}, s_{t+1})\}\rho_{t+1} f_1(g_t, s_t)] \end{aligned}$$

The term within {} on the right hand side is the marginal (dynamic) value of change in climate state tomorrow:

$$\delta E_t[\frac{u_2(y_{t+1}, s_{t+1})}{\gamma_1(y_t, s_t)}\rho_{t+1}]$$

Factors that lower current emission

Factors that increase the left hand side of (30) and therefore, make lower current emission desirable:

- Higher magnitude of marginal utility with climate worsening ($-w_2$);
- Higher rate of change of climate state with respect to climate state i.e., f_2
- Higher discount factor (surprisingly!);

Monotonicity of the optimal policy

If:

$w_{12}(g,s) < 0, f_{12}(g,s) \geq 0$ on the set $\{(g,s) : s > 0, 0 < g \leq \overline{g}\}$.

- Adverse climate change reduces welfare:

  $w_{12}(g,s) < 0$

- Higher *s* intensifies negative impact of current emission:

  $f_{12}(g,s) \geq 0$

Then:

$g(s)$ is decreasing in s.

Results

Suppose:

$$bf(0,s) < s \leq bf(\overline{g},s)$$

Let $\widehat{g}$ (sustainable level of emission) defined by:

$$bf(\widehat{g}(s),s) = s$$

If

$$\delta[w_1(\overline{g},\frac{a}{b}s)\frac{f_2(\overline{g},\frac{a}{b}s)}{f_1(\overline{g},\frac{a}{b}s)} - w_2(\overline{g},\frac{a}{b}s)][\frac{1}{w_1(\widehat{g}(s),s)}]E(\rho)f_1(\widehat{g}(s),s) \geq 1$$

Then it is optimal to improve the climate almost surly from state *s*.

Results

- The following makes conditions for climate improvements likely to hold:
  - Milder discount rate;
  - An increase in expected negative impact on climate attributed to current emission;
  - Increase in direct marginal welfare decline attributed to climate change;
  - An increase in marginal rate of substitution between current emission and current climate state (f_2/f_1) in the determination of future climate state.

Conclusions

- **If inequality (34) holds, then given a certain current state s, it is optimal to improve the state of the climate through current action (control of emission);**
- **$\hat{g}(s)$ is the level of current GHG emission that would allow society to sustain the current climate state under the worst environmental condition (affecting the relationship between GHG emission and climate state);**
- **$\hat{g}(s)$ is the highest level of current emission consistent with almost sure (with probability one) sustainability of current climate state.**

Conclusions

- Optimal climate policy and sustainable emission level could be determine even before a learning process completed;
- Future climate state is bounded from bellow:

$$s_{t+1} > (a/b) s_t$$

- Higher uncertainties implies greater risk of climatic change reflected by lower bound of future climate state.