International Climate Agreements and the Scream of Greta

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Motivation and Main Questions

- According to the Intergovernmental Panel on Climate Change (IPCC), climate change poses an existential threat to the planet
- Yet various attempts at international climate cooperation (Kyoto Protocol, Paris Agreement, etc) have so far failed to put the world on a path that could avoid catastrophe
  - unclear if the Glasgow agreement will make a difference (Greta screams "bla bla bla")
- Why is this problem so intractable?
- Can we expect an 11^{th}-hour solution?
- Will some countries, or even all, succumb to a climate catastrophe on the equilibrium path?
- Can international climate agreements (ICAs) help avert catastrophes?

Approach

- We consider a model that features the possibility of **climate catastrophe** and emphasizes two critical issues:
- **International ("horizontal") externalities** from CO_2 emissions
  - these externalities are well-studied, and ICAs in principle can address them
- **Intergenerational ("vertical") externalities**: the actions of the current generation that impact future generations who are not yet present
  - these externalities are less well-studied, no Coasian solution possible (the unborn can't bargain with us)
  - these externalities are what the Gretas of the world are complaining about
- We focus on how these two kinds of externalities interact in shaping the problem when climate catastrophes are possible, and the extent to which ICAs can address the problem
- We abstract from well-understood challenges of ICA participation and enforcement
  - but even in this optimistic case, things look pretty sobering

Main Findings

- "Horizontal" and "vertical" externalities interact in generating "diagonal" externalities from one country's generation to other countries' future generations
  - ICAs in principle can address horizontal externalities, but not vertical and diagonal externalities
- If the world faces a *common catastrophe point*, in the noncooperative equilibrium on which we focus the world will stop at the brink of abyss
  - a "warming phase," and then an "11^{th}-hour" solution; good news/bad news
- How can an ICA improve upon the noncooperative outcome?
  - the ICA can slow down warming and help generations during the warming phase
  - the ICA delays reaching the brink and may even avoid it forever; the generations that gain the most are those that would have lived at the brink absent the ICA
  - but once the brink is reached, the ICA no longer plays any role (beyond possibly a coordination role)
- With the unborn absent from the bargaining table, the ICA picks an extreme point on the inter-generational Pareto frontier
- If the social welfare function places positive weight directly on future generations, then:
  - the ICA does not go far enough in cooling the climate early on
  - the ICA may reach the brink when it should not
  - if it is socially optimal to reach the brink, this should be reached later than under the ICA

Main Findings

- In a world with *heterogenous catastrophe points*, a range of the most vulnerable countries is likely to collapse in the noncooperative scenario
  - this will happen even if the differences in catastrophe thresholds across countries are small
- An ICA is likely to save some countries from collapse relative to the noncooperative scenario
  - thus, the role of ICAs is potentially more expansive than in a common-brink world
- But even if the ICA saves a country, the country may have to pay a high price
  - and a country is less likely to be saved by the ICA if it faces constraints on international transfers
- Relative to a social optimum that places positive weight directly on future generations, ICAs may save too few countries
- But the reverse is also possible
  - the ICA may save *too many* countries relative to the social optimum

Related Literature

- Main novelty of our paper: dynamic analysis of ICAs with intergenerational externalities and the possibility of catastrophes
- Static analysis of ICAs: Barrett (1994), Nordhaus (2015)
    - main focus: participation issue
- Dynamic analysis of ICAs: Dutta and Radner (2004), Harstad (2012, 2021, forthcoming) and Battaglini and Harstad (2016)
    - participation issue, investments in green technology
    - no intergenerational externalities or possibility of catastrophe
- Optimal climate policy with catastrophe point
    - social planner approach: Besley and Dixit (2017), Lemoine and Rudik (2017)
    - ICA: Barrett (2013), but static model
- Intergenerational+international externalities: John and Pecchenino (1997), Kotlikoff et al. (2021a,b); but no possibility of catastrophe

The Basic Modeling Framework

- At time $t = 0$ there are M countries, each with a measure-one population of identical citizens
- "Successive generations" setting as in Fahri and Werning (2007)
  - each individual lives for one period and is replaced by a single descendant in the next period
- Let $u_{i,t}$ denote the material per-capita utility of generation t in country i
- Parents born in period $t \in \{0, 1, ..., \infty\}$ may be altruistic toward their only child
  - their utility is

$$\tilde{u}_{i,t} = u_{i,t} + \beta \tilde{u}_{i,t+1}$$

- The above is equivalent to assuming a dynastic utility function

$$\tilde{u}_{i,t} = \sum_{s=0}^{\infty} \beta^s u_{i,t+s}$$

- In our basic model we assume $\beta = 0$ (so $\tilde{u}_{i,t} = u_{i,t}$)
  - later we extend the model to the case of $\beta > 0$

The Basic Modeling Framework

- Generation t in country i chooses per capita carbon emissions $c_{i,t} \geq 0$
- A country's own emissions generate per capita economic benefit $B(c_{i,t})$, with $B(\cdot)$ increasing and concave
  - captures the fact that a higher level of emissions allows a higher level of consumption
- The global atmospheric carbon stock is $C_t = (1-\rho)C_{t-1} + c_t^w$, with c_t^w the aggregate world emissions at t and ρ the depreciation rate of the carbon stock (and with $C_{-1} = 0$)
- We capture the possibility of climate catastrophes by assuming that country i collapses if C_t exceeds the threshold level $\tilde{C}_i$, with countries symmetric in all other respects
- From the point of view of country i:
  - if $C_t \leq \tilde{C}_i$ the per capita cost of global warming is λC_t
  - if $C_t > \tilde{C}_i$ the country collapses and its citizens become climate refugees, suffering a one-time per capita utility cost L
- A collapsing country's refugees spread equally across the remaining countries, with each refugee imposing a one-time utility cost r on the country to which it immigrates

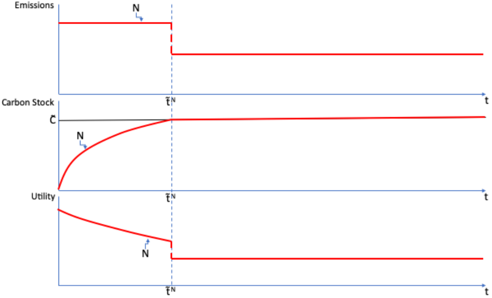
- We start by considering a world where countries face a common catastrophe point, so $\tilde{C}_i = \tilde{C}$ for all i (the "Common-Brink Scenario")
- Since in this world climate refugees have nowhere to go, we suppose L is extremely high ($L = \infty$)
- In this world countries are fully symmetric, so we omit the country subscript i
- Utility of a representative citizen in generation t:

$$u_t = \begin{cases} B(c_t) - \lambda C_t & \text{if} \quad C_t \leq \tilde{C} \\ -\infty & \text{if} \quad C_t > \tilde{C} \end{cases}$$

- What is the noncooperative (subgame perfect) equilibrium path of emissions?:
  - Will the world go over the brink?:
  - Can an ICA play a useful role?

Noncooperative Equilibrium with a Common Scenario

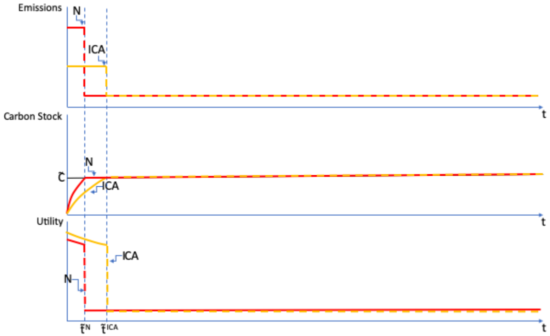
- The noncooperative equilibrium: during the warming phase, each country emits the BAU level $\bar{c}^N$ defined by $B'(\bar{c}^N) = \lambda$, imposing international externalities on other countries



- But when the world arrives at the brink, the game changes (to a "game of chicken")
- At the 11^{th} hour, countries find a way to save themselves even though there are extreme international externalities
  - because these are coupled with extreme *internalized costs* of increasing emissions
  - at a symmetric equilibrium (in undominated strategies), each country emits $\tilde{c} \equiv \frac{\rho \tilde{C}}{M} < \bar{c}^N$ for all $t \geq \tilde{t}^N$, so the carbon stock remains at $\tilde{C}$
- Good news: the brink generation survives. Bad news: it suffers a precipitous drop in utility

What can ICAs accomplish in a Common-Brink World?

- The ICA: during the warming phase, each country emits $\bar{c}^{ICA}$ defined by $B'(\bar{c}^{ICA}) = M\lambda$, internalizing the international externalities on other countries
- Define $C^{ICA} \equiv \frac{M}{\rho}\bar{c}^{ICA}$ as carbon stock reached in steady state if $\bar{c}^{ICA}$ were emitted forever
  - if $\tilde{C} < C^{ICA}$, then the brink is reached under the ICA at some point in time $\tilde{t}^{ICA} > \tilde{t}^{N}$



- At the 11^{th} hour, ICAs become redundant, beyond possibly coordinating on an efficient way to save the world, or to an undominated equilibrium that saves the world: Kyoto to Paris?
  - when $\tilde{C} < C^{ICA}$ the ICA's useful life is of limited duration
  - the ICA delays the world's arrival at the brink of climate catastrophe (forever if $\tilde{C} \geq C^{ICA}$) but, absent a coordination role, helping the world *avoid* climate catastrophe is *not* what the ICA is doing

Social Optimum with a Common Brink

- The ICA picks an extreme point on the intergenerational Pareto frontier
- How would things change if the Greta generation and the unborn generations had a say in the decisions of earlier generations
  - a "social optimum" that places positive weight on future generations directly
- We follow Fahri and Werning (2007) in postulating the intergenerational social welfare function

$$W = \sum_{t=0}^{\infty} \hat{\beta}^t u_t \text{ with } \hat{\beta} \in [\beta, 1)$$

- Maintaining our focus on the case of $\beta = 0$, how does the ICA compare with the social optimum if $\hat{\beta} > 0$?
- To write down the social optimum problem, we can treat the catastrophe point as a constraint: the carbon stock must never exceed the brink level $\tilde{C}$

$$\max \sum_{t=0}^{\infty} \hat{\beta}^t [B(c_t) - \lambda C_t]$$

$$\text{s.t. } C_t = (1-\rho)C_{t-1} + Mc_t \text{ for all } t$$

$$C_t \leq \tilde{C} \text{ for all } t$$

- The social optimum: if $\tilde{C}$ is above a critical level C^S (i.e., if $\tilde{C} \geq C^S$), then the no-catastrophe constraint doesn't bind and we show that optimal emissions are constant at $\bar{c}^S$, defined by

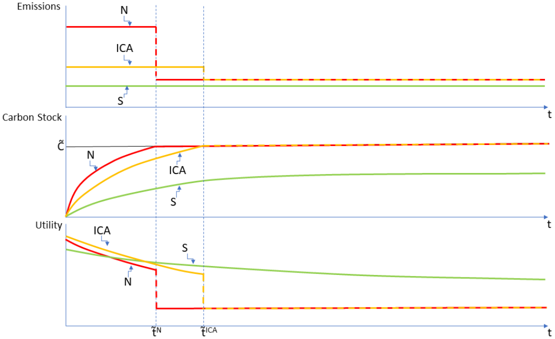
$$B'(\bar{c}^S) = \frac{M\lambda}{1 - \hat{\beta}(1-\rho)}$$

  - the marginal benefit of a country's emissions should equal the marginal cost to all countries and all future generations
  - note that $\bar{c}^S < \bar{c}^{ICA} < \bar{c}^N$, because the social optimum takes into account horizontal, vertical and diagonal externalities

- If $\tilde{C} < C^S$, the no-catastrophe constraint binds from some $\tilde{t}^S$ onwards, and we show that
  - the optimal emissions decrease until $t = \tilde{t}^S$ and then remain constant at the level that keeps the carbon stock constant at $\tilde{C}$, namely $\tilde{c} = \frac{\rho \tilde{C}}{M}$

- Note that $C^S < C^{ICA}$: the social optimum reaches the brink of catastrophe for a smaller parameter range than the ICA

- If $\tilde{C} \in (C^S, C^{ICA})$:



- The social optimum avoids reaching the brink and spares generations $t \geq \tilde{t}^{ICA}$ from a precipitous drop in utility and a miserable life at the brink
  - Generation $\tilde{t}^{ICA} \approx$ Greta's generation?

The Heterogeneous-Brink Scenario

- We next allow countries to have heterogeneous catastrophe points $\tilde{C}_i$
  - the common-brink scenario above highlights intergenerational distributional aspects
  - now international distributional aspects also become important
- We order countries according to $\tilde{C}_1 < \tilde{C}_2 < ... < \tilde{C}_M$ (country 1 could be the Maldives)
- In a world with heterogeneous brinks:
  - the refugee externality r becomes relevant
  - and now L need not be infinite, since citizens of a collapsing country can relocate to other countries
- With H_t indexing the most vulnerable country alive at t, the one-time per capita cost imposed on remaining countries by country H_t's collapse is

$$R(H_t) \equiv \frac{r}{M - H_t}$$

- Utility of a citizen living in country i at time t:

$$u_{i,t} = B(c_{i,t}) - \lambda C_t - L \cdot E_{i,t} - R(H_t) \cdot I_{i,t}$$

where $E_{i,t} = 1$ if country i collapses at t and $I_{i,t} = 1$ if a country other than i collapses at t

Noncooperative Equilibrium in the Heterogeneous-Brink Scenario

- Three possible phases of the noncooperative equilibrium path:
  - a warming phase, where warming takes place but no catastrophes occur
  - a catastrophe phase, where warming continues and a sequence of countries collapse
  - and a third phase where warming and catastrophes are brought to a halt
- The first and third phases are familiar from the common-brink scenario
- The possibility of a middle phase, in which some countries collapse along the noncooperative path, is new
- We assume for simplicity that an individual country is not able to fully offset the other countries' BAU emissions, so it cannot unilaterally stop the growth of the carbon stock
  - but if the rest of the world has collapsed, then the last remaining country (country M) can save itself as in the common-brink scenario

Noncooperative Equilibrium in the Heterogeneous-Brink Scenario

- Note the stark contrast relative to the common-brink case, where countries did whatever was necessary to avoid global collapse
  - each country now has its *own* brink generation,
  - who faces the prospect of catastrophe *alone* and up against the other countries,
  - and its only hope for assistance is the refugee externalities that it would impose on others
- We show that, if the refugee cost imposed on other countries by the collapse of country 1 is low relative to the consumption cost of cutting emissions enough to save country 1, then:
  - a non-empty subset of countries will collapse
  - this will happen even if the differences in collapse points across countries are small
  - the process will stop only when a country's collapse would impose a large enough cost on the remaining countries, or when country M is the lone surviving country
- The condition that the refugee externality imposed by the collapse of country 1 is relatively low seems empirically plausible
  - if the Maldives collapse, a relatively small population of climate refugees will be shared across many countries

Can ICAs save vulnerable countries?

- Will an ICA save countries that would collapse in the noncooperative scenario?
- Suppose first that unlimited international transfers are available
- We show that
  (i) a (weakly) larger set of countries survive under the ICA than in the noncooperative scenario, but
  (ii) the ICA may still let some countries collapse
- Basic intuition for (i):
  - if a given country causes the collapse of country k by unilaterally increasing its own emissions, it suffers some refugee costs, but it also imposes a negative refugee externality on all other countries
  - the ICA can address this externality
- Basic intuition for (ii):
  - the ICA will let a country collapse if $L + r$ (the global cost of climate refugees if the country collapses) is smaller than the global consumption cost of stopping the growth of the carbon stock

Can ICAs save vulnerable countries?

- Thus the role of an ICA is potentially more expansive than in a common-brink world, as it may save some countries from collapse
- But note: even if a country is "saved" by the ICA, it may not fare very well
  - a country at the brink is saved by the ICA if $L + r$ is high enough, but it has to compensate other countries for helping out (since the noncooperative equilibrium is the threat point for ICA negotiations)
  - even if it has the resources to do so, the cost may be very large
- If international transfers are limited (e.g. by resource constraints), things look even bleaker for vulnerable countries
  - the set of countries that the ICA will save from collapse is smaller when transfers are more constrained

ICA vs Social Optimum in the Heterogeneous-Brink Model

- Does the ICA save too few or too many countries, relative to a social optimum that places positive weight directly on future generations?
- We show that as judged by a social planner with $\hat{\beta} > 0$, the ICA may not save enough countries from collapse
- But the reverse is also possible
  - the number of countries that collapse under the ICA – and the long-term extent of global warming – may be *lower* than the social optimum
- Why would a social planner let more countries collapse than the ICA?
  - the social planner wants to shift utility toward future generations relative to the ICA
  - raising emissions and crossing a country's brink imposes refugee costs on today's generation; thus, future generations won't have to deal with this brink and the costs associated with crossing it
  - this indirect effect can dominate the direct effect on utility of the higher carbon stock, which goes in the other direction
  - but note, this possibility can arise only if refugee costs are borne mostly by today's generation

Intergenerational Altruism

- How are our results affected if $\beta > 0$?
- Multiple noncooperative equilibria (for reasons similar to folk theorem)
  - focus on finite T game
- Analytical results for 2-period game; need to rely on numerical approach for $T > 2$
- For the common-brink case, our main findings (e.g., avoiding a climate catastrophe is not the purpose of an ICA, the useful life of an ICA is likely to be finite) are robust to $\beta > 0$, but we also highlight a new effect in the noncooperative scenario
  - a *dynamic free-rider* effect when approaching the brink
  - as the world gets close to the brink, if an individual country increases emissions today, it understands that other countries will help avoid catastrophe tomorrow
  - this effect pushes toward increasing emissions, especially in the run-up to the brink
  - but there are also "avoidance behaviors" that can arise, and even "second-order" dynamic free-rider effects
- For the heterogeneous-brink case, our main findings (e.g. the ICA saves more countries than the noncooperative equilibrium) are robust to $\beta > 0$
  - and now there is an asymmetric dynamic free-rider effect

Conclusion

- A simple framework to think about the implications of international and intergenerational climate externalities when catastrophic outcomes are possible
- We examined how ICAs can improve on the noncooperative outcome by addressing horizontal externalities, their effects on future generations, and how they compare with a social optimum that places positive weight on future generations
- Extensions:
  - uncertainty/heterogeneous beliefs about catastrophe points
  - investments in adaptation versus mitigation
  - lags in the impact of carbon emissions
  - the role of international trade
  - political economy: the role of lobbying by fossil fuel industries

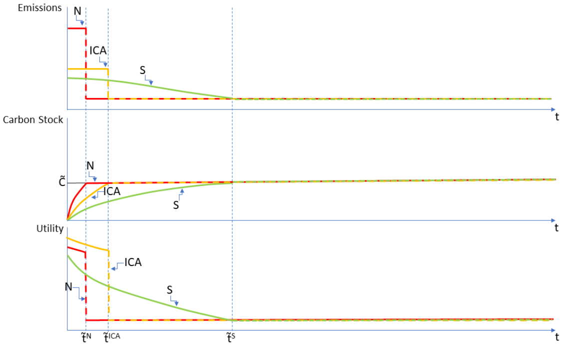
Extra Material

Greta Thunberg at the UN's 2019 Climate Action Summit in New York City

"...You have stolen my dreams and my childhood with your empty words...How dare you! For more than 30 years, the science has been crystal clear...The popular idea of cutting our emissions in half in 10 years only gives us a 50% chance of staying below 1.5 degrees [Celsius], and the risk of setting off irreversible chain reactions beyond human control. Fifty percent may be acceptable to you ... [but it] is simply not acceptable to us — we who have to live with the consequences. To have a 67% chance of staying below a 1.5 degrees global temperature rise – the best odds given by the [Intergovernmental Panel on Climate Change] – the world had 420 gigatons of CO_2 left to emit back on Jan. 1st, 2018. Today that figure is already down to less than 350 gigatons. How dare you pretend that this can be solved with just 'business as usual' and some technical solutions? With today's emissions levels, that remaining CO_2 budget will be entirely gone within less than 8 1/2 years...You are failing us. But the young people are starting to understand your betrayal. The eyes of all future generations are upon you. And if you choose to fail us, I say: We will never forgive you. We will not let you get away with this. Right here, right now is where we draw the line. The world is waking up. And change is coming, whether you like it or not."

ICA vs Social Optimum with a Common Brink

- If $\tilde{C} < C^S$:



- If the social optimum reaches the brink, it gets there later and more gradually than the ICA. This benefits only the generations soon after the ICA hits the brink

A Domino Effect in the Heterogeneous-Brink Scenario?

- Is there a "domino effect" when countries collapse on the noncooperative equilibrium path?
- A given country i can reach the brink only if countries $1, 2, ..., i-1$ all have collapsed

  $\Longrightarrow$ a basic "domino effect"

- But *conditional on a country reaching the brink*, the likelihood of collapse is lower if more countries collapsed in the past

  $\Longrightarrow$ an "anti-domino effect"

- Intuition for the anti-domino effect:
  - the per capita cost imposed by country k's collapse on remaining countries increases with k, as countries that collapse later release more refugees on a smaller ROW population, so countries $j > k$ have stronger incentives to "help out" country k
  - as more countries collapse, the BAU emissions level goes down, as each country internalizes a bigger share of the cost of climate change, so C_t grows more slowly

Further details on ICAs in the Heterogeneous-Brink Scenario

- Suppose country k is at the brink, and compare the conditions for country k to survive under the noncooperative equilibrium and under the ICA

- No-defect conditions for a noncooperative equilibrium with survival of country k:

$$
\begin{aligned}
G_k &\equiv v_k(c_k^N) - v_k(c_k^{save}) \leq \frac{r}{M-k} \\
G_k^0 &\equiv v_k(c_k^N) - v_k(0) \leq L
\end{aligned}
$$

- The ICA will save country k (provided transfers are available) if:

$$
\Gamma_k \equiv v_k^{ICA}(c^{ICA}) - v_k^{ICA}\left(\frac{\rho \tilde{C}_k}{M}\right) \leq \frac{L+r}{M-k+1}
$$

- Note $\frac{L+r}{M-k+1}$ is the population-weighted average of the own cost L and the external cost $\frac{r}{M-k}$; and (it can be shown that) Γ_k is lower than the population-weighted average of G_k and G_k^0

- This implies that under the ICA country k survives for a larger set of parameters than under the noncooperative equilibrium

Figure 5(a): Common Brink, Noncooperative Equilibrium

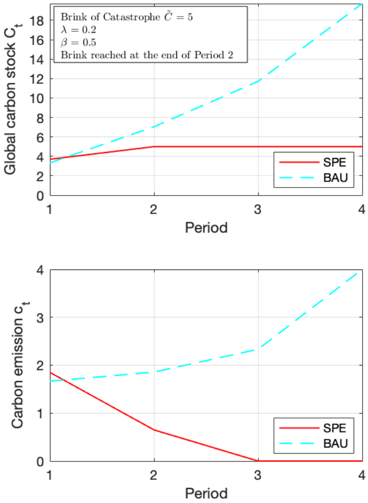


Figure 5(b): Common Brink, Noncooperative Equilibrium

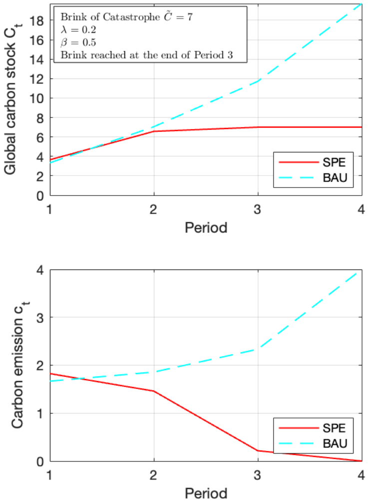


Figure 5(c): Common Brink, Noncooperative Equilibrium

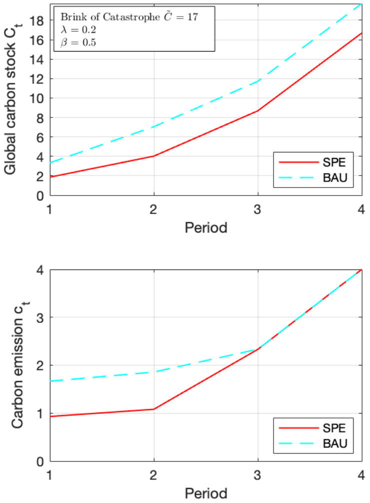


Figure 5(d): Common Brink, Noncooperative Equilibrium