Strategic Implications of Counter-Geoengineering: Escalation, Cooperation, or Nonuse?

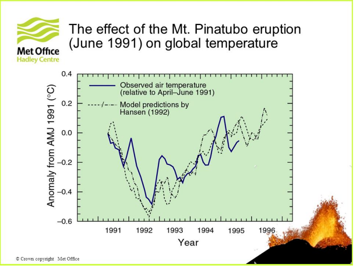
Daniel Heyen
Grantham Research Institute
London School of Economics

joint with
Joshua Horton (Harvard Kennedy School)
Juan Moreno-Cruz (Georgia Tech)

March 8th, 2018
FEEM Milan

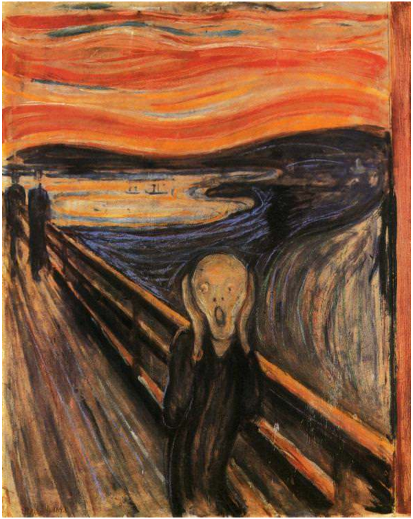
Geoengineering

(a) Mount Pinatubo 1991



(b) Temperature response (global)

Geoengineering



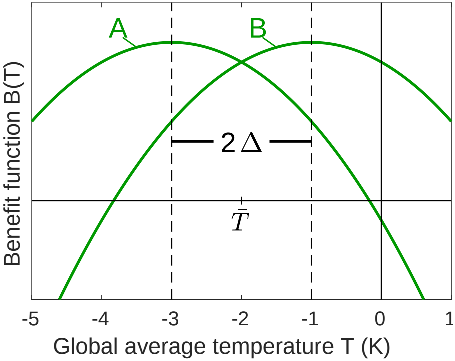
Geoengineering

- Geoengineering: Deliberate large scale intervention in climate system to counteract global warming
- Solar Geoengineering: **fast** global cooling, **low costs**
- Concern: unilateral deployment to detriment of others (NAS 2015)
- **'Free driver'** externality (Weitzman 2015)
- Counter-Geoengineering (CG) might **counteract excessive cooling** (Parker et al. 2017)
- Does CG **change the global-thermostat game?**
- Can CG **tilt the game in favor of cooperation?** (nuclear deterrence)

This paper

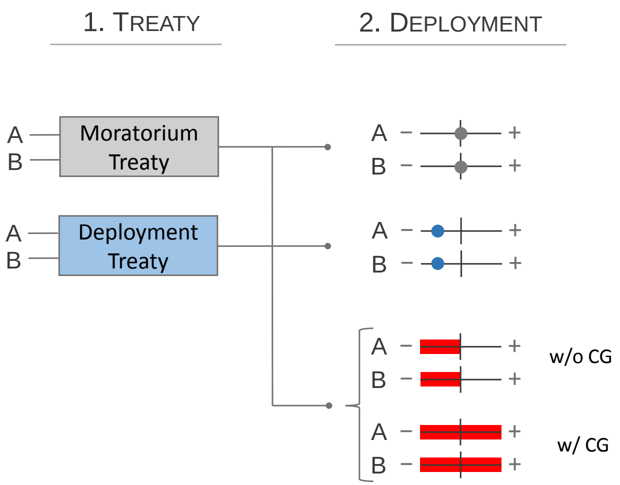
- Two **heterogeneous** (blocs of) countries
- **Public good game** with quadratic costs and benefits
- **Cooperation**: Moratorium Treaty and Deployment Treaty
- Comparison game outcomes **without CG** vs. **with CG**
- Findings
  - Non-cooperative equilibria worse ('free driver' $\rightarrow$ 'arms race')
  - Increased cooperation incentives
  - Ambiguous welfare effects: Key parameter **benefit-cost ratio** and **preference asymmetry**

Benefits and costs

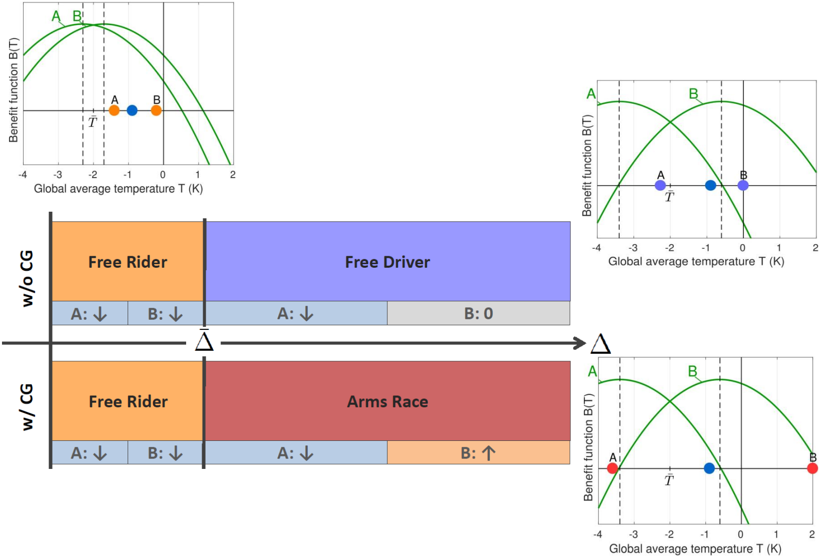


- Benefits $B_i(T) = -b/2\,(T - T_i)^2 + const$
- Global average temperature with intervention: $T = g_A + g_B$
- without CG: $g_i \leq 0$; with CG: $g_i \in \mathbb{R}$
- Costs $C(g_i) = c/2\, g_i^2$
- **Global-thermostat** game

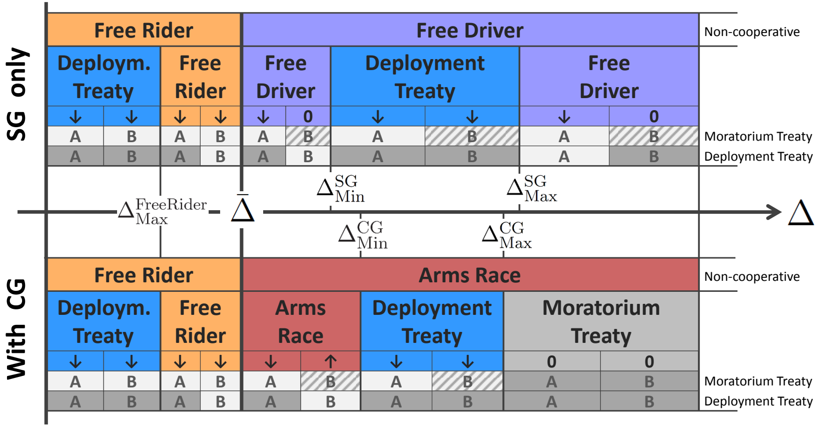
Timeline


1. TREATY
2. DEPLOYMENT
A
B
Moratorium Treaty
A
B
Deployment Treaty
A − +
B − +
A − +
B − +
A − +
B − +
w/o CG
A − +
B − +
w/ CG

Deployment stage: Nash equilibria

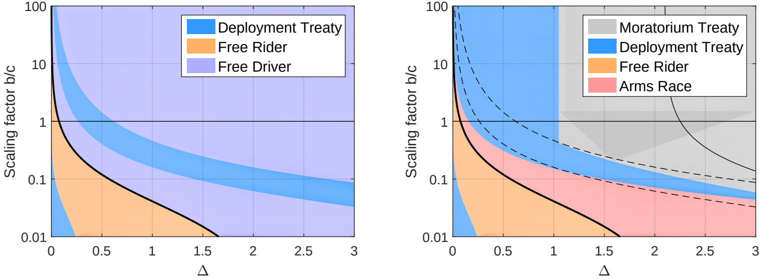


Treaty equilibria



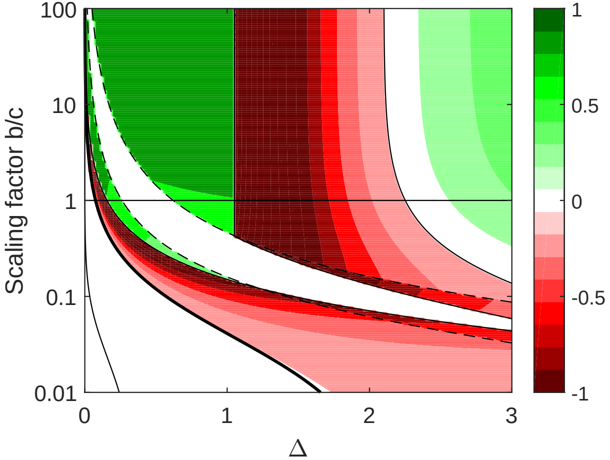
Calibration and sensitivity analysis

- $\bar{T} = -2.1K$ (Shaviv 2005)
- $b = 179.5 \text{ bn}\,\$/K^2$ (Burke et al. 2015)
- $c = 13.4 \text{ bn}\,\$/K^2$ (NAS 2015)



(a) Without CG. (b) With CG.

Welfare effect

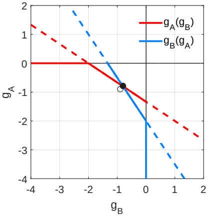


Conclusion

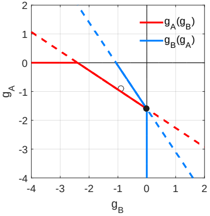
- Counter-Geoengineering may **change the global-thermostat game**
- **Non-cooperation unattractive**: 'arms race'
- This often **strengthens cooperation** incentives
- **Ambiguous welfare effects**: Key parameter **benefit-cost ratio** and **preference asymmetry**
- Findings emphasize importance of **cooperation design / governance**
- **Limitations**
  - Climate = Temperature
  - Two countries

Supplementary Slides

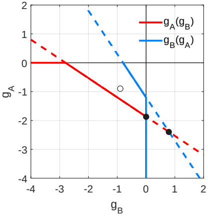
Best response functions



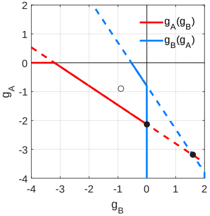
$\Delta = 0$



$\Delta = \bar{\Delta}$



$\Delta = 2\bar{\Delta}$



$\Delta = 3\bar{\Delta}$

Deployment levels

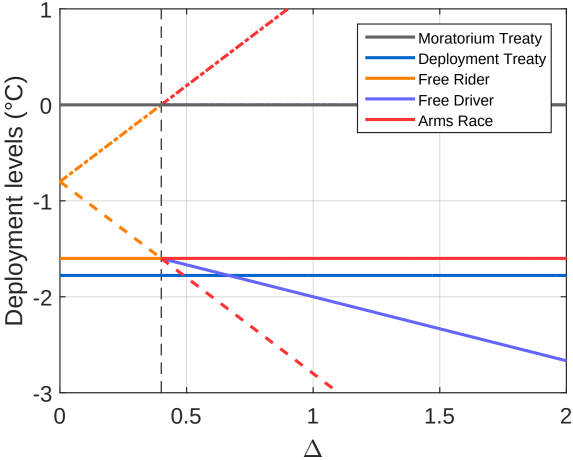


Figure: Quantities

The general case with n countries?

- Non-cooperative equilibria straightforward (and interesting)
- Cooperation: We determine the *stable* coalitions, equilibrium selection not the focus. Stability defined relative to non-cooperative outcomes
- Open membership game
- Deployment Treaty: For simplicity at most one SG coalition, no CG coalition. Stable if externally and internally stable
- Moratorium Treaty stable if *all* prefer it to non-cooperative case

Equilibria $n = 7$, free driver

Equilibria $n = 7$, free driver, Payoffs

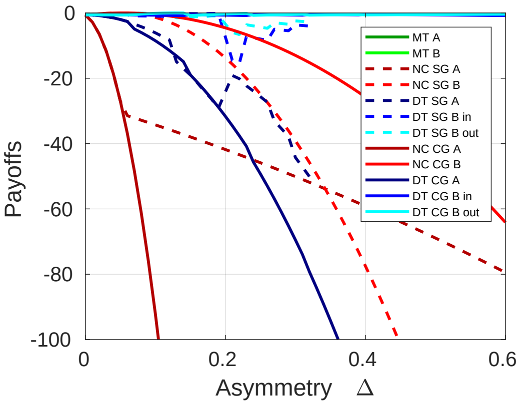


Figure: Quantities

Equilibria $n = 7$, free driver, Payoffs

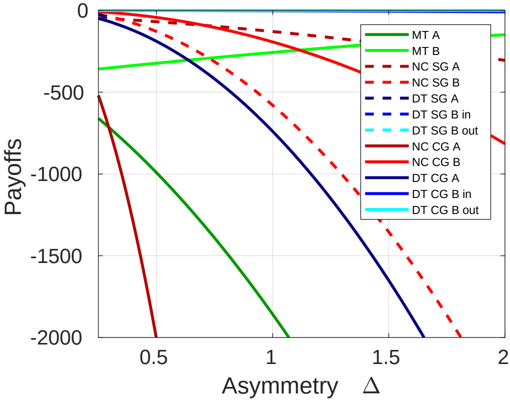


Figure: Quantities

The generalized free driver framework

- Heyen, D. / Millner, A. / Tavoni, A. (work in progress)

Quadratic specification

- Quadratic costs and benefits (generalizing Barrett 1994 and McGinty 2007)

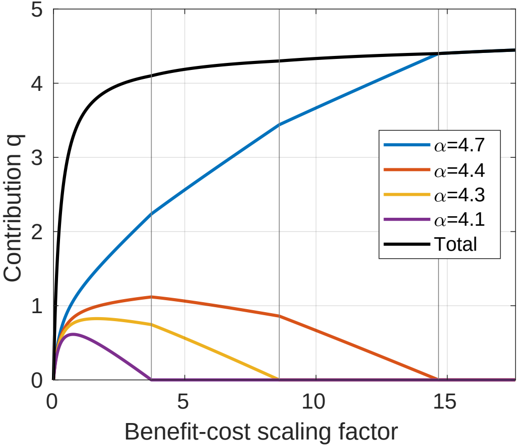
$$C_i(q_i) = \frac{c_i}{2} q_i^2 \quad , \quad B_i(Q) = -\frac{b_i}{2} (Q - \alpha_i)^2$$

- Equilibrium of free rider degree $r = m$, i.e. $d = n - m$

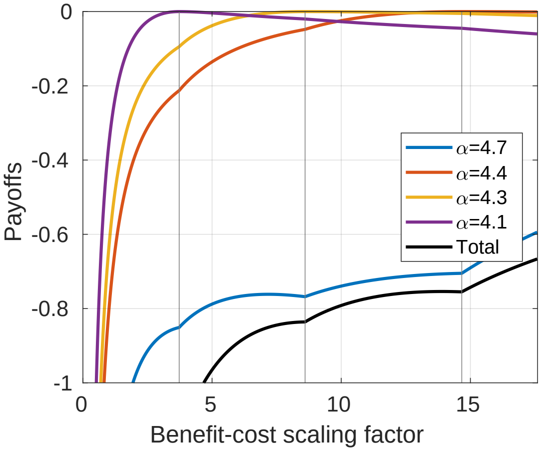
$$q_k^{*(m)} = \begin{cases} \theta_k \alpha_k - \frac{\Theta_m}{1+\Theta_m} \theta_k \bar{\alpha}^{(m)} \geq 0 & k = 1, \ldots, m \\ 0 & k = m+1, \ldots, n \end{cases}$$

- Here,
  - $\theta_i = b_i / c_i$ is benefit-cost parameter, $\Theta_m = \sum_{i=1}^{m} \theta_i$
  - $\bar{\alpha}^{(m)} = (\sum_{i=1}^{m} \theta_i \alpha_i) / \Theta_m$ weighted average
- **Proposition**. Fix $\alpha_1 \geq \ldots \geq \alpha_n$.
  (i) For a given $\theta = (\theta_i)_i$, there is a unique equilibrium
  (ii) For any $d = 0, \ldots, n-1$ and given θ, there is a ϑ such that $\vartheta\theta$ gives rise to equilibrium of free driver degree d

Equilibria: Contribution levels



Equilibria: Payoffs



Heterogeneous climate impacts

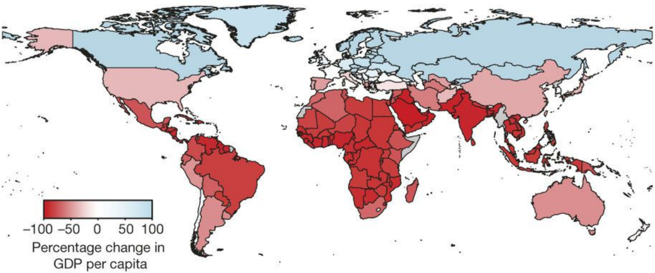


Figure: Burke et al. (2015, *Nature*)