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The Effects of Trade Sanctions in International Environmental Agreements

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Motivation and Outline of Talk

- Discussion on Post-Kyoto agreements ongoing
- Linking climate coalitions to trade sanctions proposed, e.g. Barrett 1997, Aldy et al. 2001, Stiglitz 2007
- Implementation in *optimal growth* modeling framework non-trivial

Motivation and Outline of Talk

- Discussion on Post-Kyoto agreements ongoing
- Linking climate coalitions to trade sanctions proposed, e.g. Barrett 1997, Aldy et al. 2001, Stiglitz 2007
- Implementation in *optimal growth* modeling framework non-trivial
- How can we implement trade sanctions, and what are potential effects on climate treaties?
 - Model of coalition formation
 - The Competitive Equilibrium (*externalities!*)
 - Results: effects of sanctions on coalition formation

International Environmental Agreements as a Cartel Stability game

- Coalition formation: two stage game
 - Stage 1: **Membership game**
 - Players either sign the IEA or do not
 - Stage 2: **Emission game**
 - Players decide on investments + trade → emission trajectories

International Environmental Agreements as a Cartel Stability game

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- Stage 2: **Nash Equilibrium**
 - "Partial Agreement Nash Equilibrium" (Chander/Tulkens)
 - Members to the IEA act jointly ("as one player")
- Stage 1: **Cartel Stability** (d'Aspremont/Gabszewicz)
 - "internally stable" := no member has incentive to leave

Economy equations

- Players maximize **welfare**

$$\max_{\{in_{it}, im_{it}\}} \text{welfare}_i$$

$$\text{welfare}_i = \int_0^\infty e^{-\rho t} l_{it} U(c_{it}/l_{it}) dt$$

- **Consumption** is an Armington aggregate

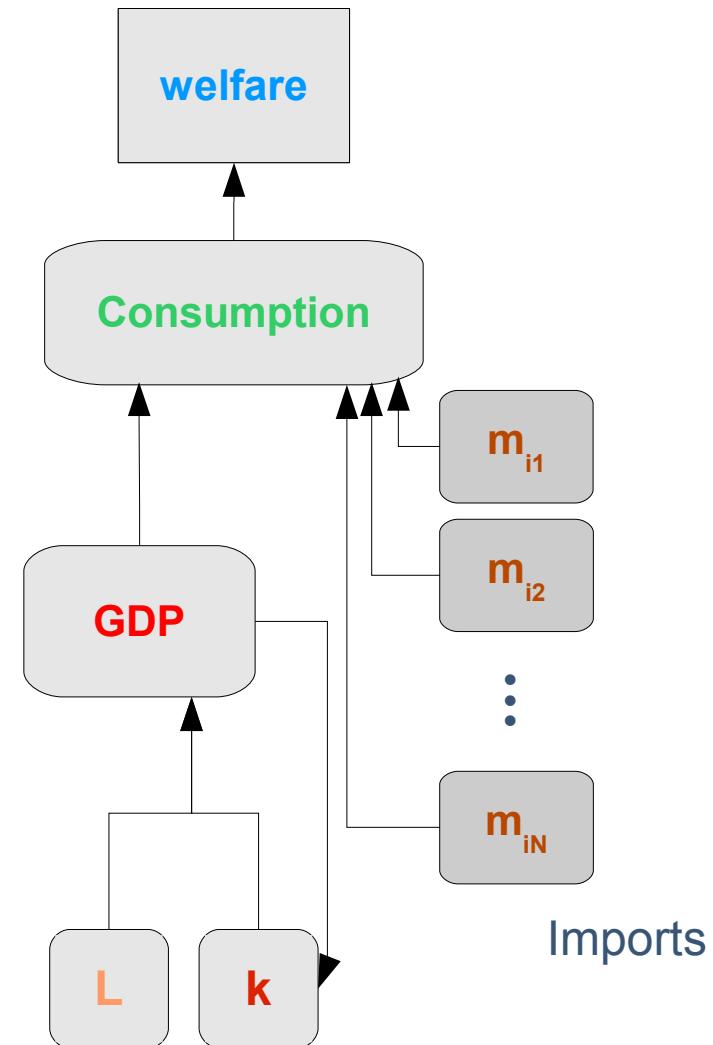
$$c_{it} = \left[s^{dom} (c_{it}^{dom})^{\rho^A} + \sum_{j \neq i} s_j^{for} (c_{ijt}^{for})^{\rho^A} \right]^{(1/\rho^A)}$$

- ...of domestically produced

$$GDP = (k_{it})^\beta (a_{it} l_{it})^{(1-\beta)}$$

- ...and imported goods

$$c_{ijt}^{for} = m_{ijt}$$



Emission externality: Damages

- Emissions and abatement

$$e_{it} = \sigma_{it} y_{it}$$

$$\sigma_{it} = (1 + km_{it})^{-\psi}$$

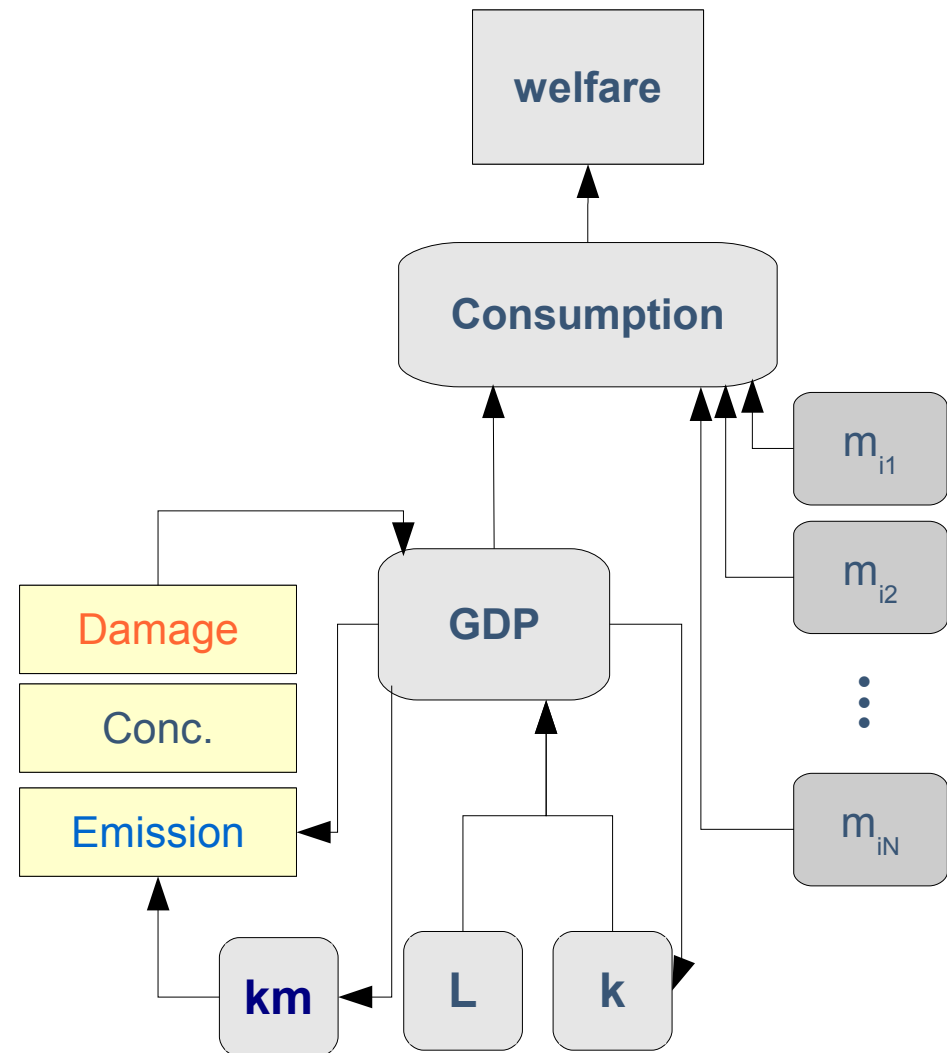
$$\frac{d}{dt} km_{it} = i_{ekm} im_{it}$$

- Translation of emissions to

- concentration to
- temperature to
- **damages**

$$\Omega_{it} = 1 / (1 + dam1_i (temp_t)^{dam2_i})$$

$$y_{it} = \Omega_{it} GDP(k_{it}, l_{it})$$



Trade externality: Import Tariffs

- Coalition S imposes **import tariff**

$$c_{ijt}^{for} = (1 - \tau_{ij}) m_{ijt} \quad \text{for } i \in S, j \notin S$$

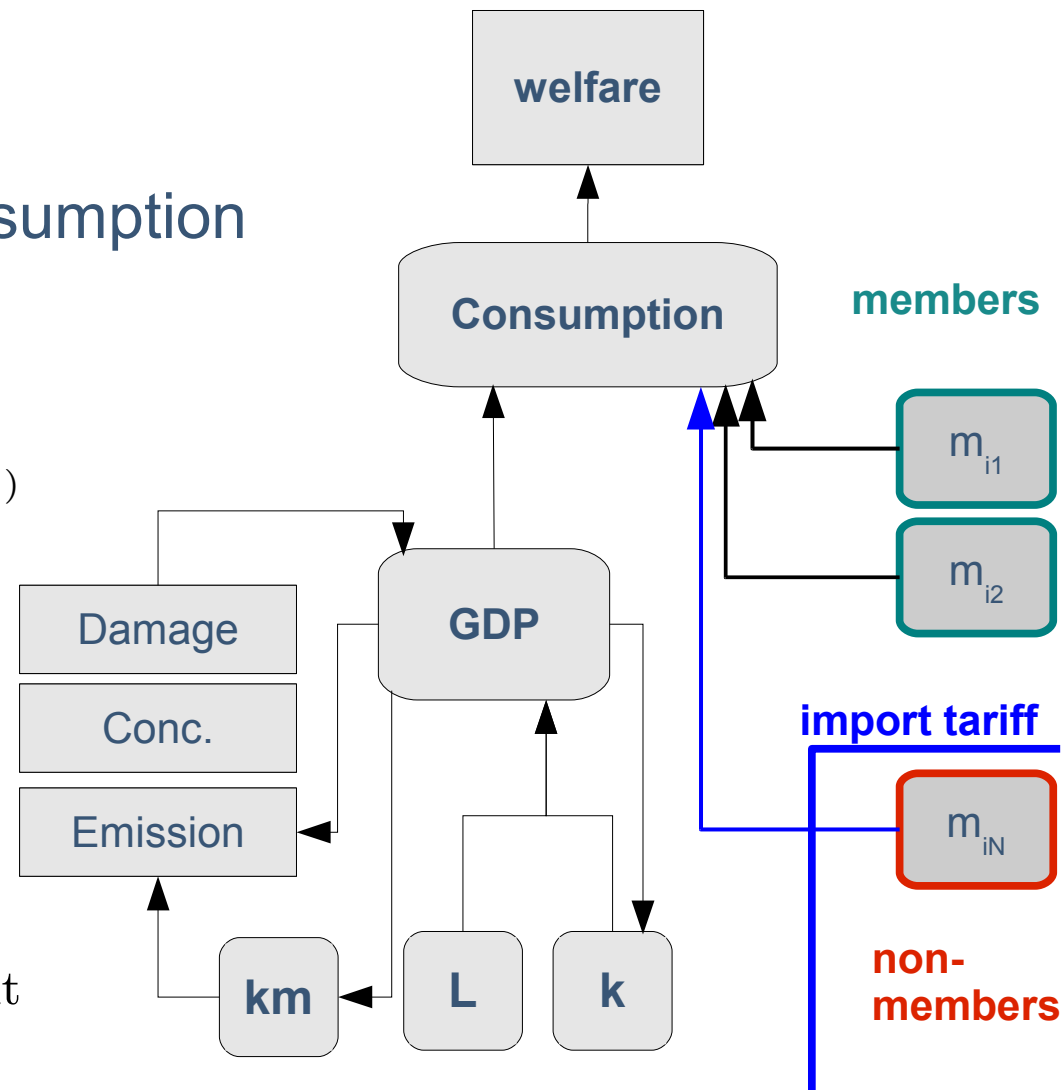
- Tariff revenue is recycled in consumption

$$tr_{ijt} = \tau_{ij} m_{ijt}$$

$$c_{it} = \left[s^{dom} (c_i^{dom_t})^{\rho^A} + \sum_{j \neq i} s_j^{for} (c_{ijt}^{for} + tr_{ijt})^{\rho^A} \right]^{(1/\rho^A)}$$

- Intertemporal budget balanced
 - import value = export value

$$\int_0^\infty \sum_{j \neq i} p_{ijt}^m m_{ijt} dt = \int_0^\infty \sum_{j \neq i} p_{ijt}^x x_{ijt} dt$$



Competitive Equilibrium

- Search for Nash equilibrium using *Fictitious Play*



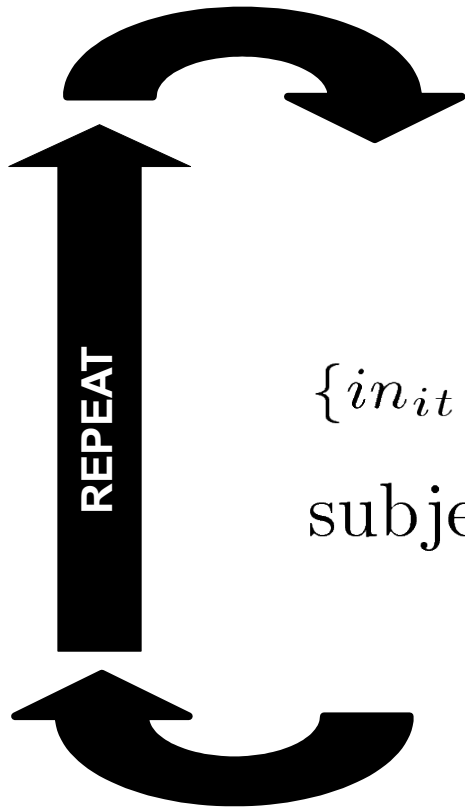
$$\forall_i \max_{\{in_{it}, im_{it}, m_{ijt}, x_{ijt}\}} \text{payoff}_i$$

subject to *economy* and *climate* equations
and $e_{kt} = \overline{e_{kt}}$ for $k \neq i$

- *Problem:* m_{ijt}, x_{ijt} : market **price levels** unknown

Competitive Equilibrium

- Determine competitive equilibrium using *Negishi's Approach*



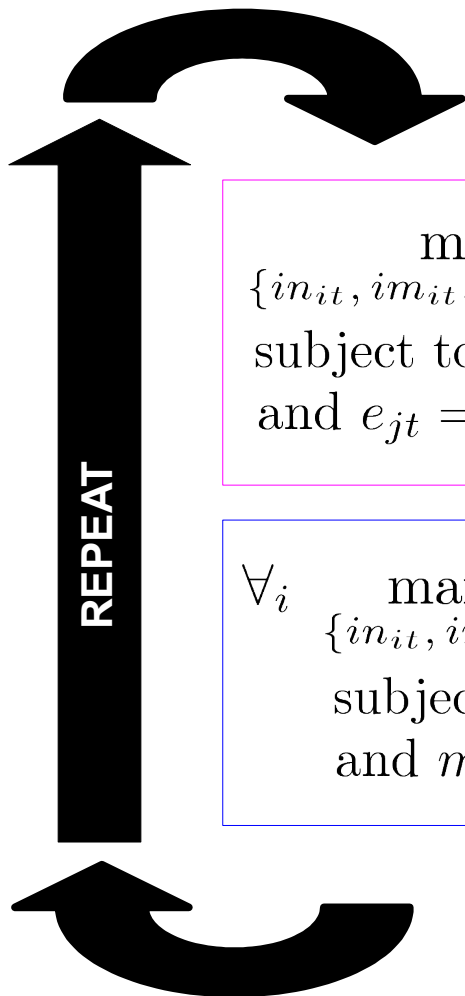
$$\max_{\{in_{it}, im_{it}, m_{ijt}, x_{ijt}\}} \sum_i \delta_i \text{payoff}_i$$

subject to *economy* and *climate* equations

- *Problem:* presence of **externalities** (tariffs and emissions)

Competitive Equilibrium

- Alternately **fix** emissions (in **Negishi's Approach**) and trade (in **Fictitious Play**)



$$\max_{\{in_{it}, im_{it}, m_{ijt}, x_{ijt}\}} \sum_i \delta_i \text{payoff}_i$$

subject to *economy* and *climate* equations
and $e_{jt} = \overline{e_{jt}}$

$$\Rightarrow m_{ijt}, x_{ijt}$$

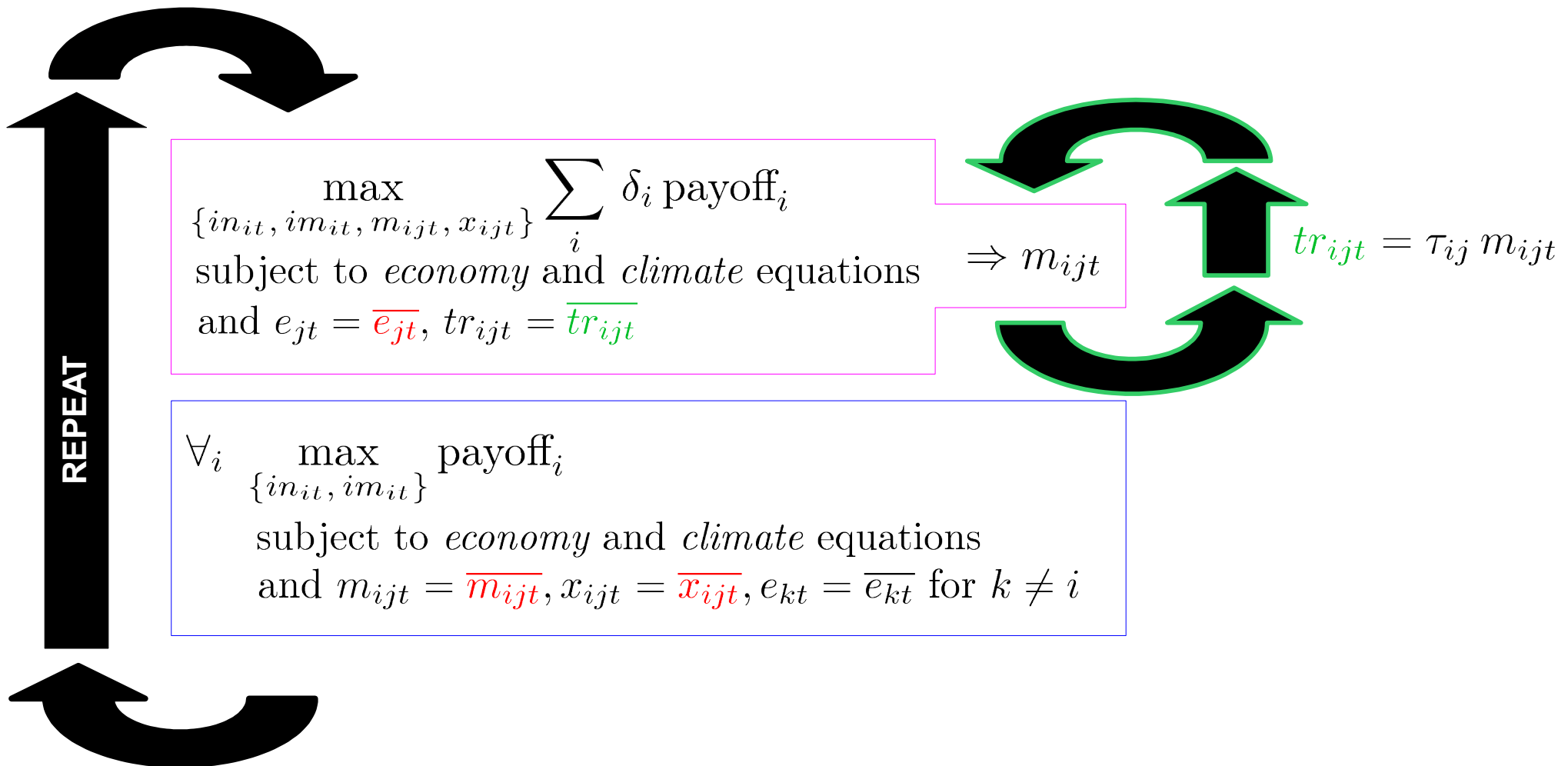
$$\forall_i \max_{\{in_{it}, im_{it}\}} \text{payoff}_i$$

subject to *economy* and *climate* equations
and $m_{ijt} = \overline{m_{ijt}}, x_{ijt} = \overline{x_{ijt}}, e_{kt} = \overline{e_{kt}}$ for $k \neq i$

$$\Rightarrow e_{it}$$

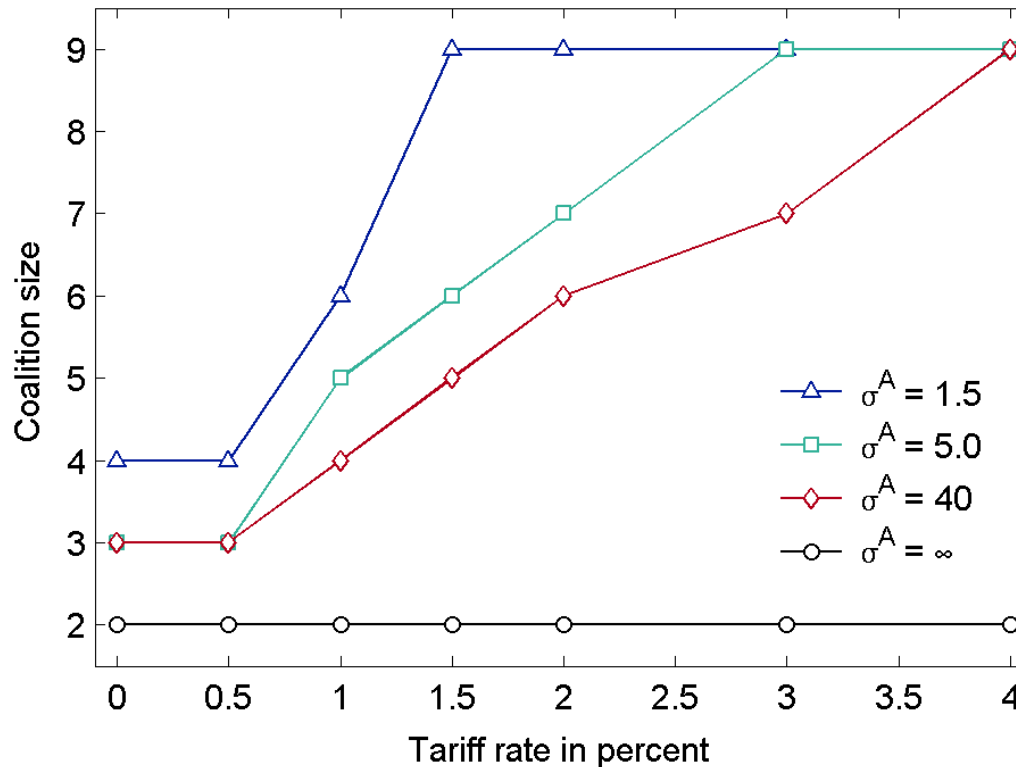
Competitive Equilibrium

- Treat tariff revenue recycling as a **parameter**, and update it outside the model



Results

Effect on Participation

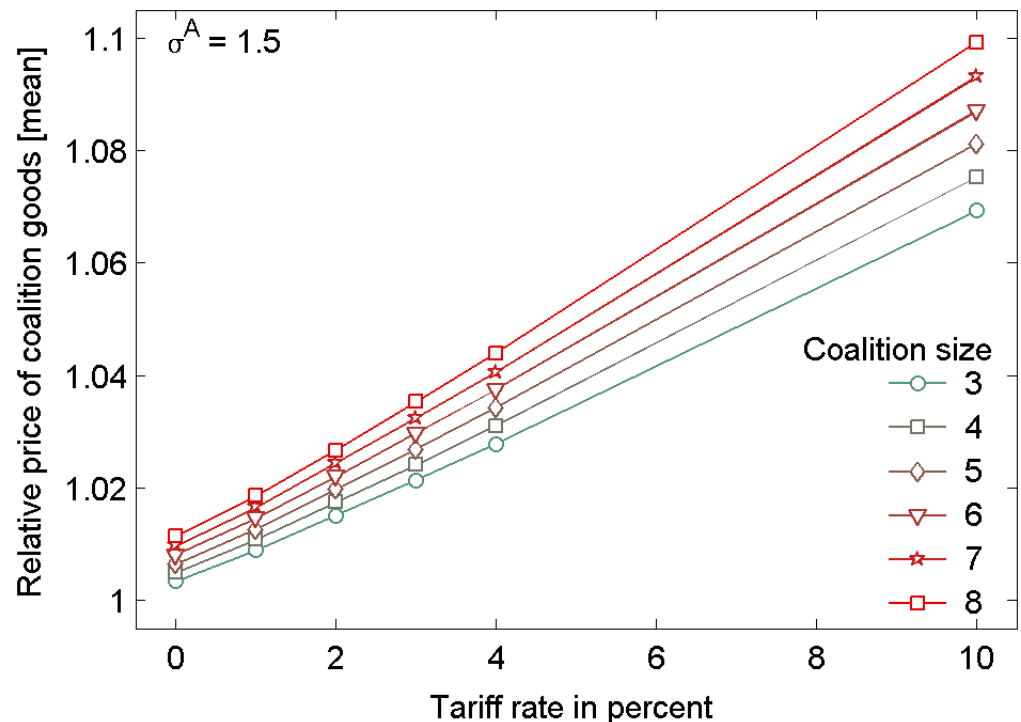


- Participation = Size of largest stable coalition
 - rises with the tariff rate τ
 - shrinks with elasticity of substitution σ

Why does it work?

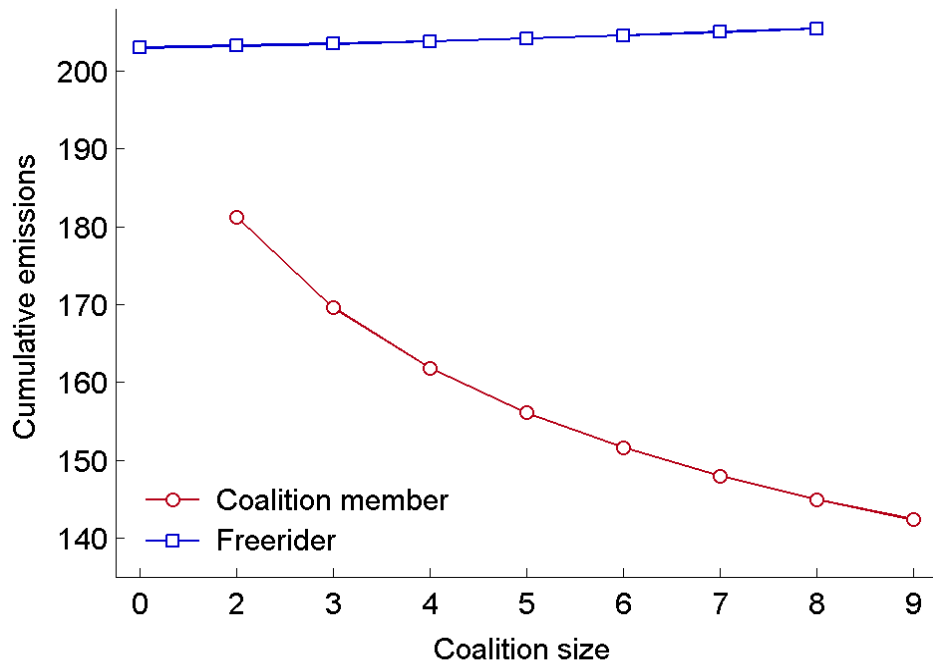
The price effect of tariffs

- Effects of tariffs are due to the assumption of monopolistic supply:
 - Players are price takers
 - Coalition good becomes rel. more expensive
 - Tariffs allow to realize market power
- Note: Coalition good scarcer due to reduced production

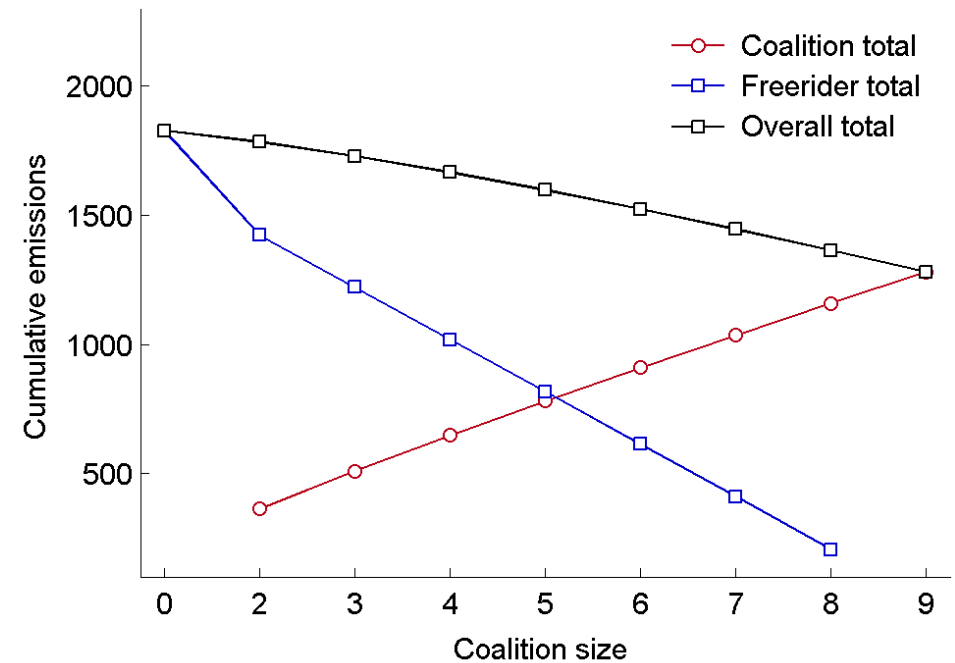


What about Leakage?

emissions of a single player



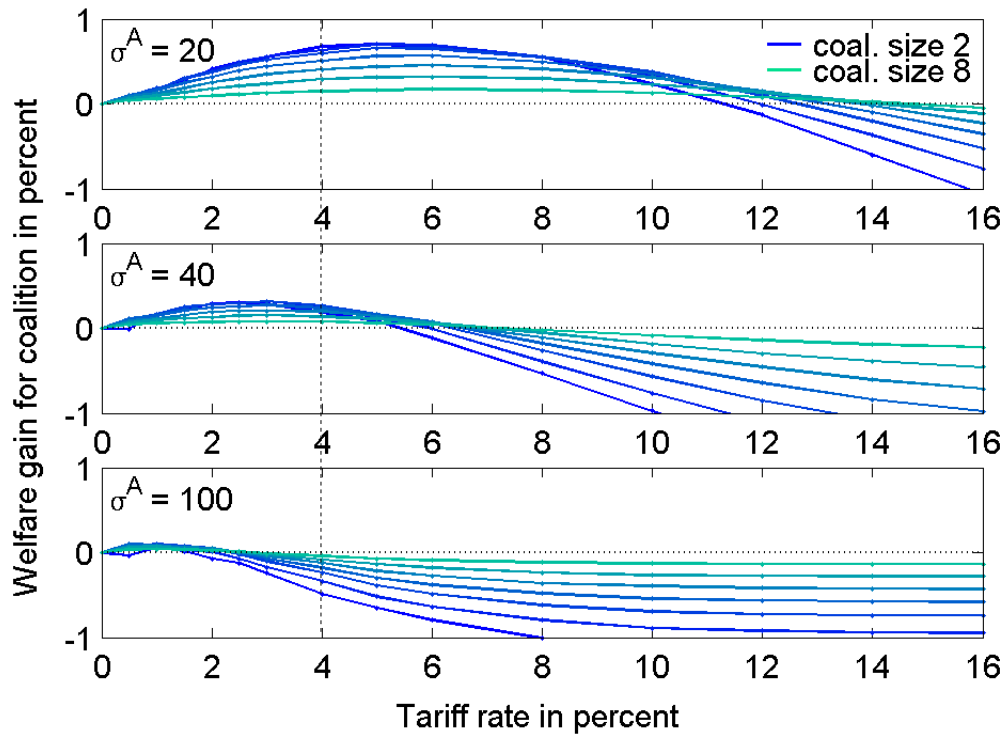
total emissions



- Non-members show free-riding behavior

- Overall emissions decrease unambiguously

Are tariffs credible?



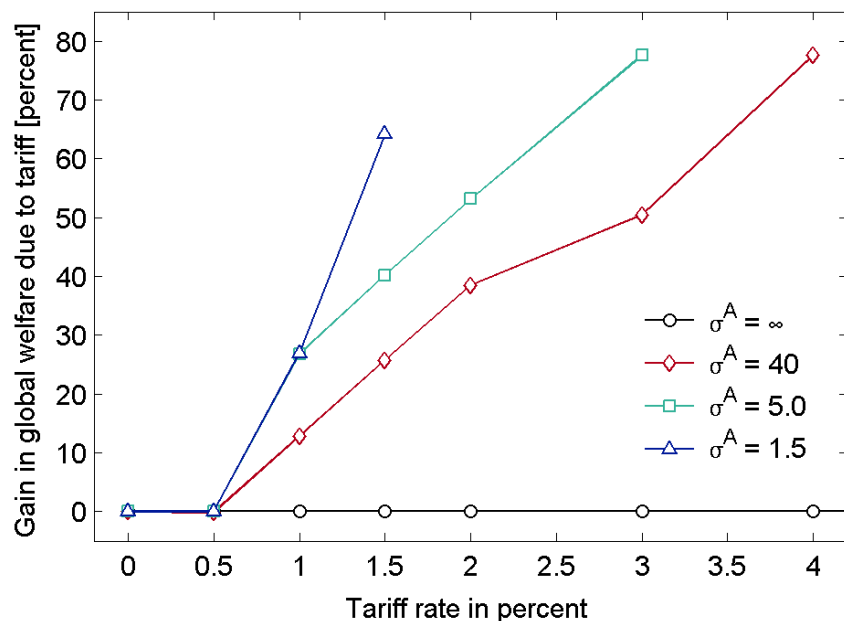
Welfare gain = difference of welfare with tariffs and welfare without tariffs for a given coalition

- Threatening tariffs is credible if beneficial for coalition
- a tariff allows exploiting market power, hence is credible if
 - substitutability σ is *low*
 - tariffs τ are not *too high*
- smaller coalition means more non-members means more players that *pay* tariffs

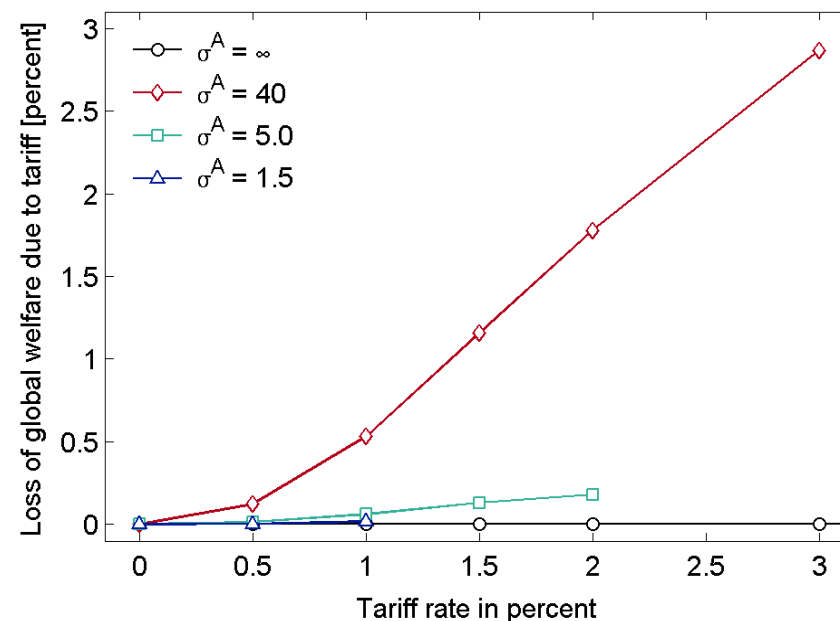
Will tariffs reduce global welfare?

- Tariffs raise participation
- Participation closes gap between Nash and Pareto
- Tariffs obstruct trade
 - Reduce volume/efficiency
- Welfare loss compared to same equilibrium without tariffs

Welfare gains of *stable* coalitions with and without tariffs



Welfare losses of a given coalition with and without tariffs



Further Research

- Depart from symmetric players
 - heterogeneous players
 - calibrated to real world regions
- «Softer» trade restrictions
 - Border tax adjustments
 - Implicit trade restrictions through technology standards

Thanks!

Assumption that guided our choice of parameter values

- Economic growth at ~2.5 percent per year
- Savings rate
 - at ~23 percent
 - approximately constant savings rate during first century
- Trade: export ratio ~30 percent
- Temperature increase 3°C by 2100, 7.5°C by 2200 in BAU
- Climate change damages 6 percent in 2100, 17 percent in 2200
- Abatement costs: optimal reduces temperature to 2.4°C in 2100

Numerically testing the Competitive Equilibrium

- Use *market prices* from equilibrium
- Solve

$$\forall_i \max_{\{in_{it}, im_{it}, m_{ijt}, x_{ijt}\}} \text{payoff}_i$$

subject to *economy* and *climate* equations
and the *intertemporal budget constraint*

$$\int_0^{\infty} \sum_{j \neq i} p_{ijt}^m m_{ijt} dt = \int_0^{\infty} \sum_{j \neq i} p_{ijt}^x x_{ijt} dt$$

and $e_{kt} = \bar{e}_{kt}$ for $k \neq i$

- Compare to «competitive equilibrium»

Summary

- Model of coalition stability with externalities
 - Emissions damages
 - Trade sanctions
- Solved by combining Fictitious Play and Negishi's Approach in an iteration
- Tariffs
 - Raise participation
 - Credibility depends on σ
 - Welfare effect of coalitions outweighs losses from restricting free trade
- Main drivers of results
 - Monopolistic supply assumption
 - Elasticity of substitution between Armington goods