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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

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- 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: Emission game
    - Players decide on investments + trade → emission trajectories
- 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

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

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

- Consumption is an Armington aggregate

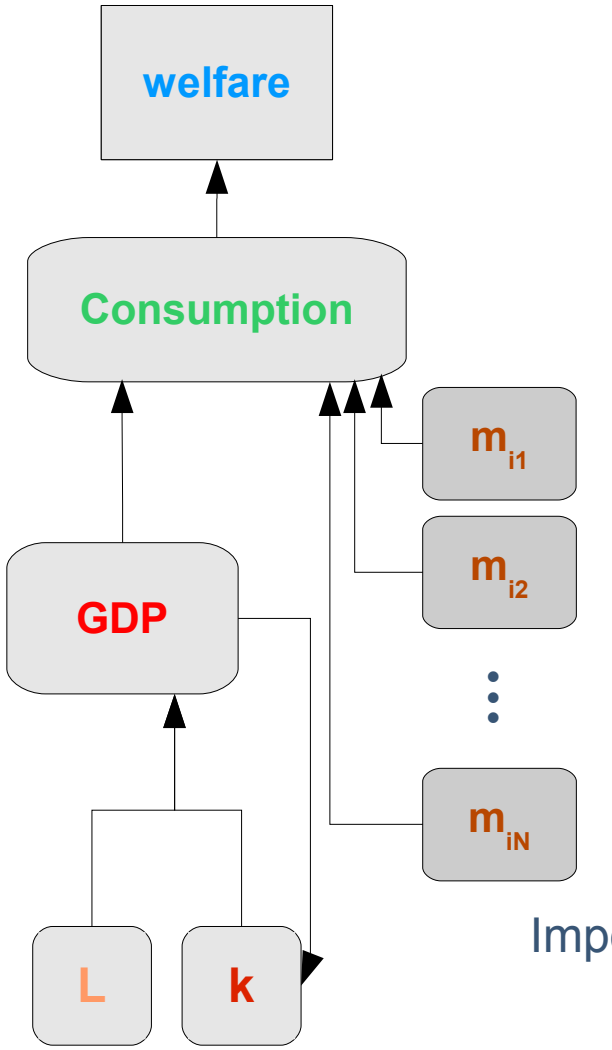
$$c_{it} = \left[s^{dom} (c_{it}^{dom})^{\rho^A} + \sum_{j \neq i} s_j^{for}\, (c_{ijt}^{for})^{\rho^A} \right]^{(1/\rho^A)}$$

- ...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

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

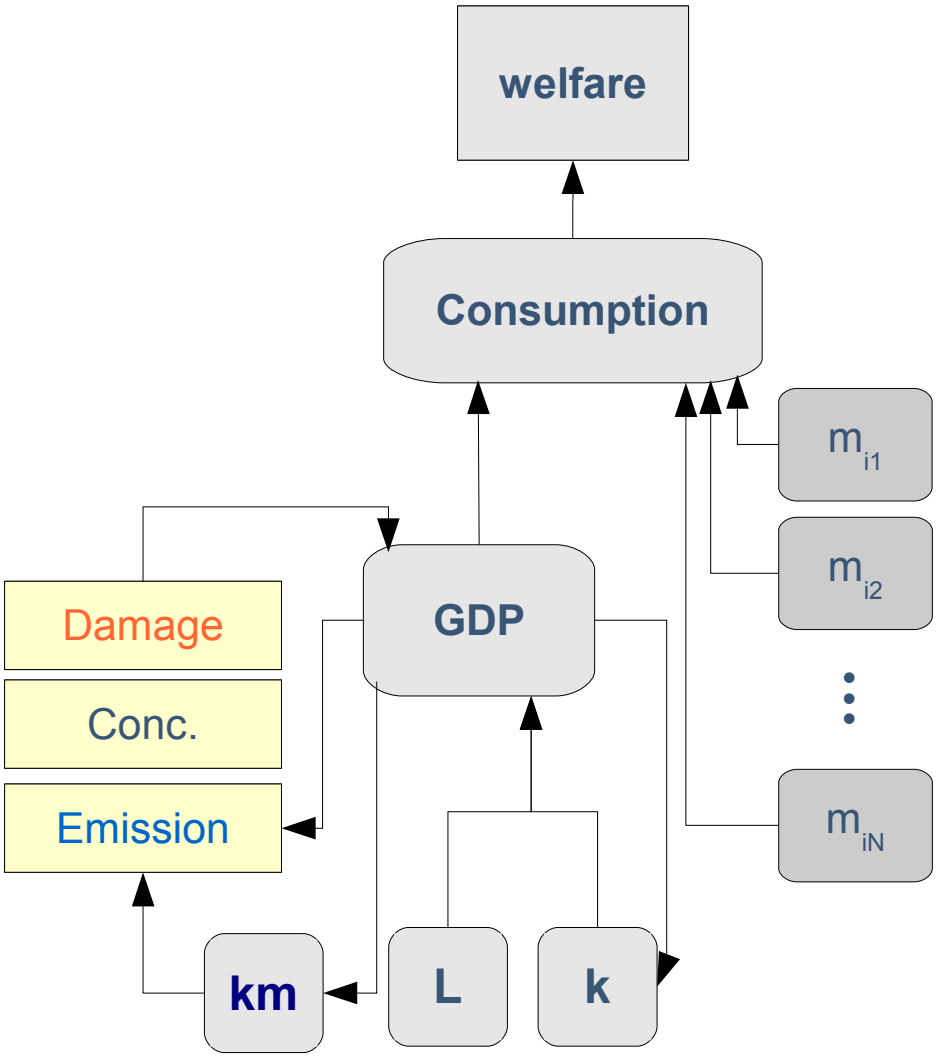
$$\sigma_{it} = (1 + km_{it})^{-\psi}$$

$$\frac{d}{dt} km_{it} = iekm\ im_{it}$$

- 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

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

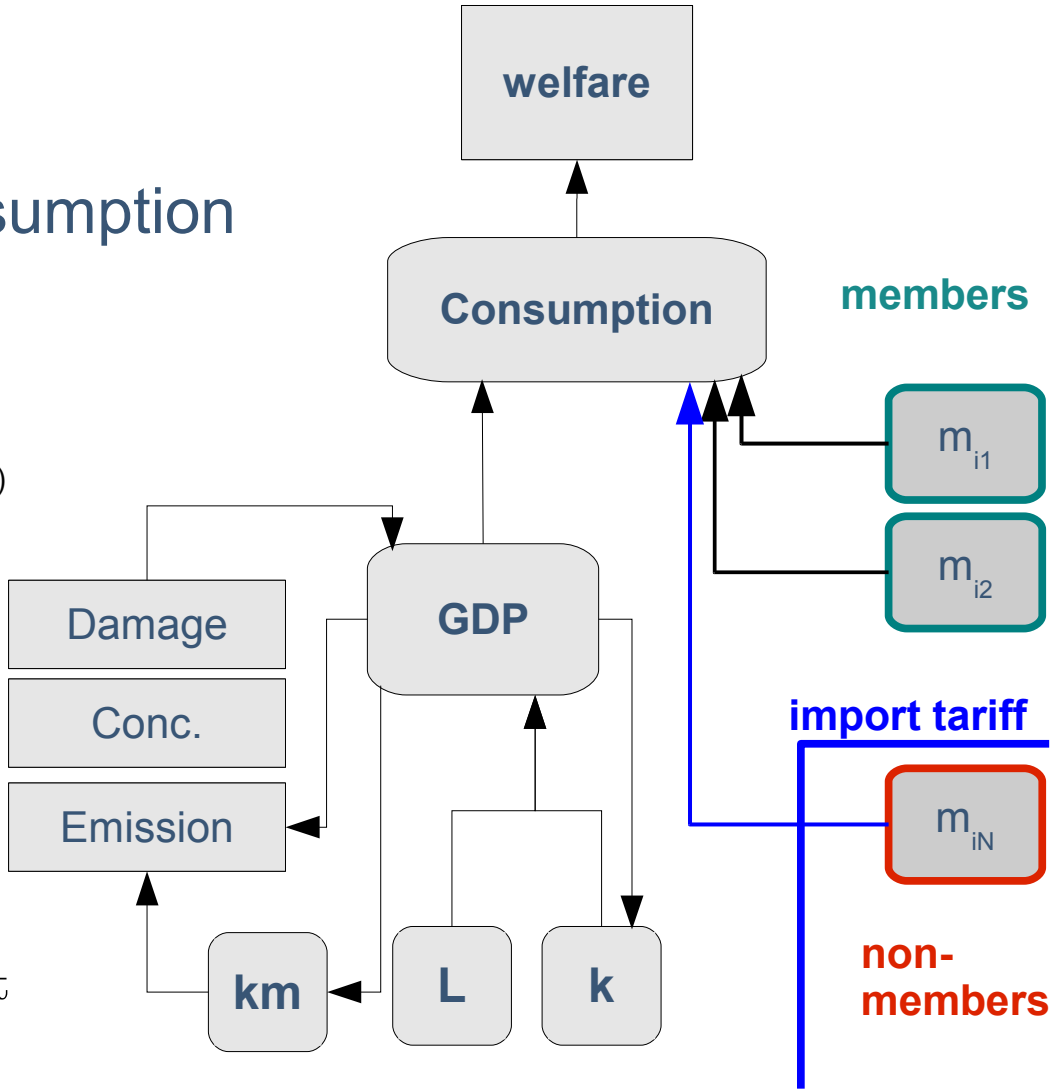
- Tariff revenue is recycled in consumption

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

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

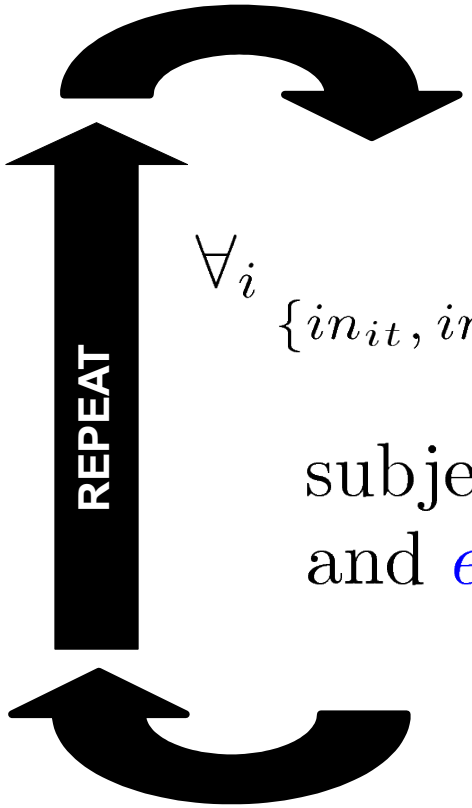
- Intertemporal budget balanced
  - import value = export value

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



Competitive Equilibrium

- Search for Nash equilibrium using *Fictitious Play*



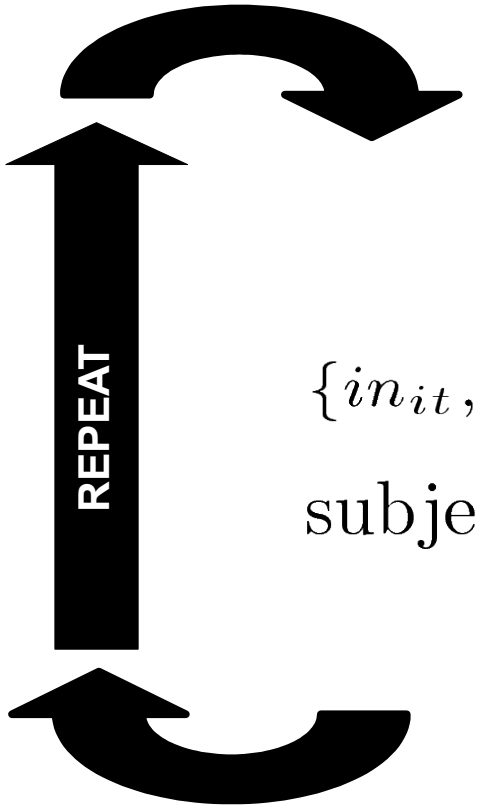
$$\forall_i \quad \max_{\{in_{it},\, im_{it},\, m_{ijt},\, x_{ijt}\}} \text{payoff}_i$$

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

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

Competitive Equilibrium

- Determine competitive equilibrium using *Negishi's Approach*



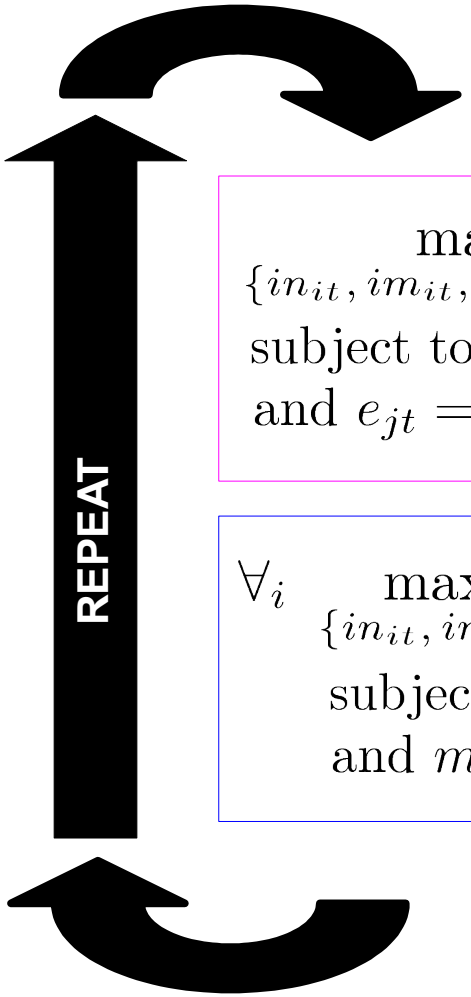
$$\max_{\{in_{it},\, im_{it},\, m_{ijt},\, x_{ijt}\}} \sum_i \delta_i \,\text{payoff}_i$$

$$\text{subject to } \textit{economy} \text{ and } \textit{climate} \text{ equations}$$

- *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 $e_{jt} = \overline{e_{jt}}$

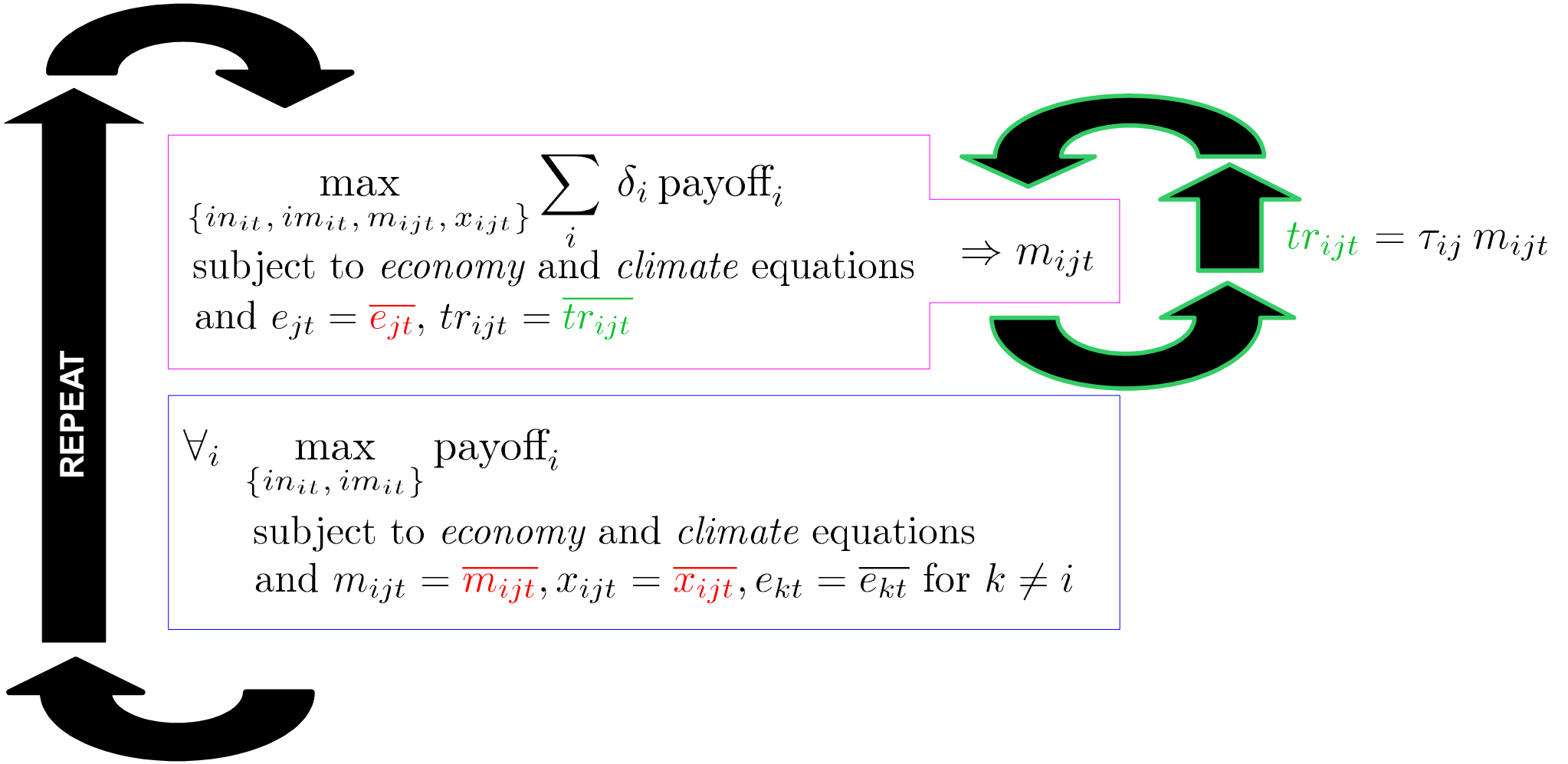
$$\Rightarrow m_{ijt},\ x_{ijt}$$

$$\forall_i \quad \max_{\{in_{it},\, im_{it}\}} \text{payoff}_i$$
subject to *economy* and *climate* equations
and $m_{ijt} = \overline{m_{ijt}}, x_{ijt} = \overline{x_{ijt}}, e_{kt} = \overline{e_{kt}}$ for $k \neq i$

$$\Rightarrow e_{it}$$

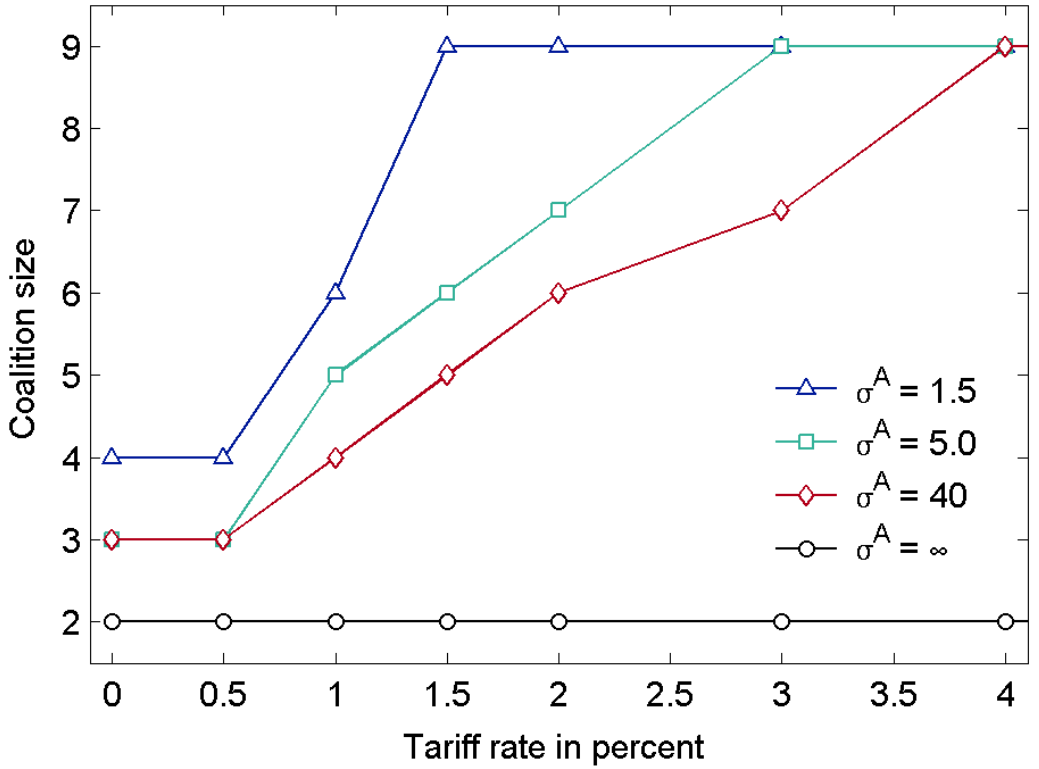
Competitive Equilibrium

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



Results

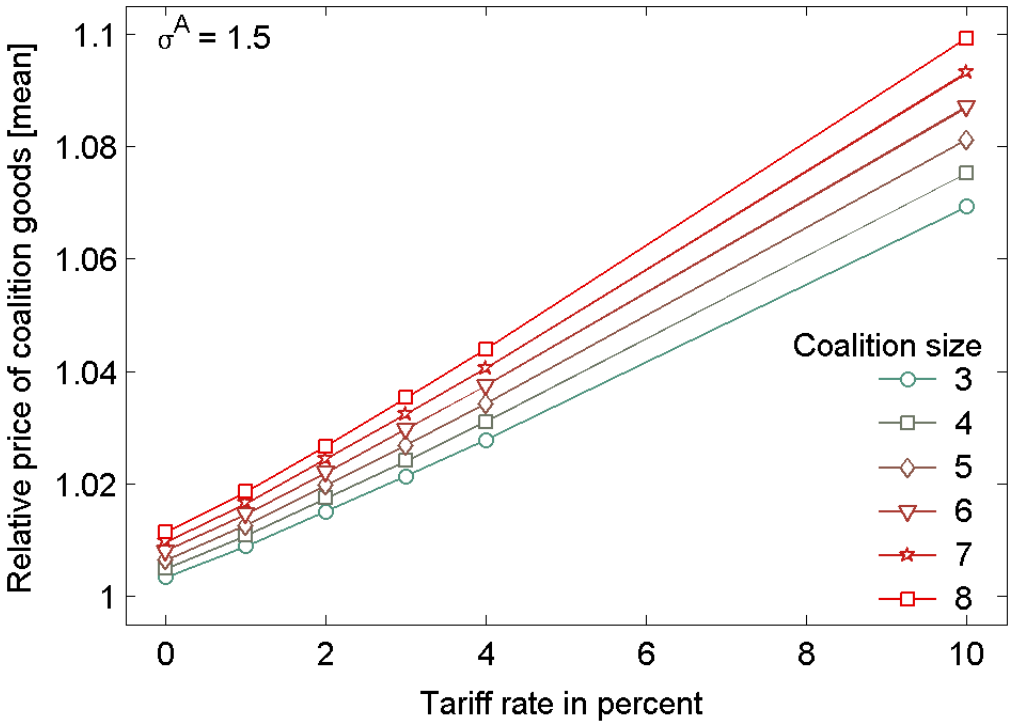
Effect on Participation



- 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

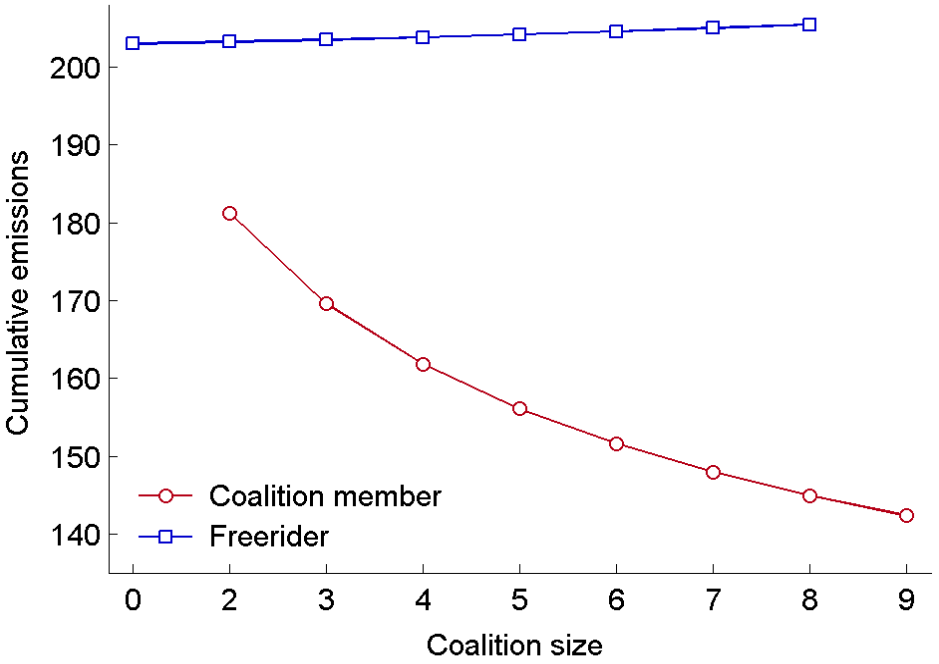
- Effects of tariffs are due to the assumption of monopolistic supply:
  - Players are price takers
  - Coalition good becomes rel. more expensive
  - Tariffs allow to realize market power



- Note: Coalition good scarcer due to reduced production

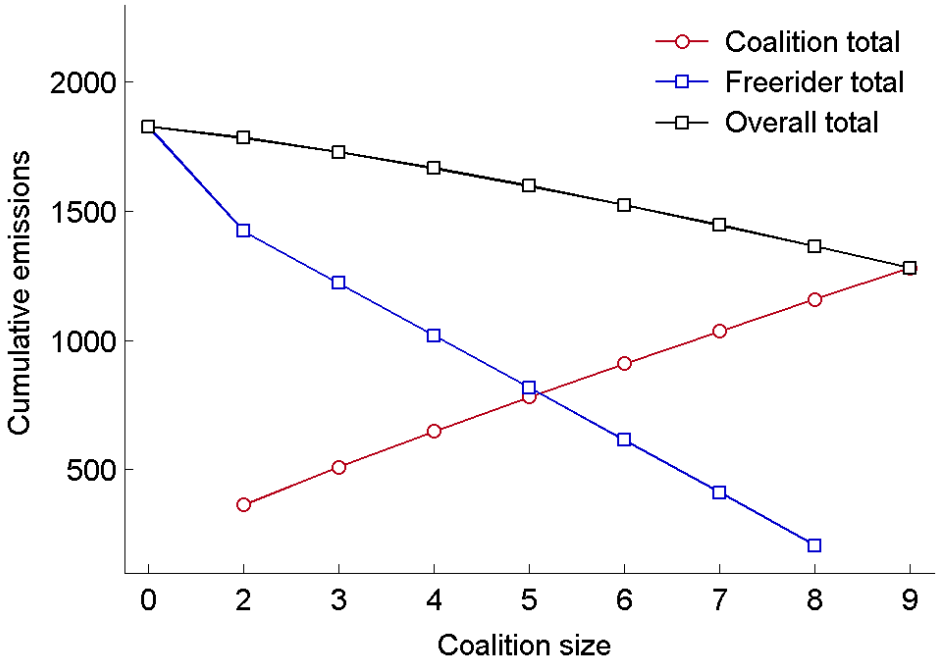
What about Leakage?

emissions of a single player



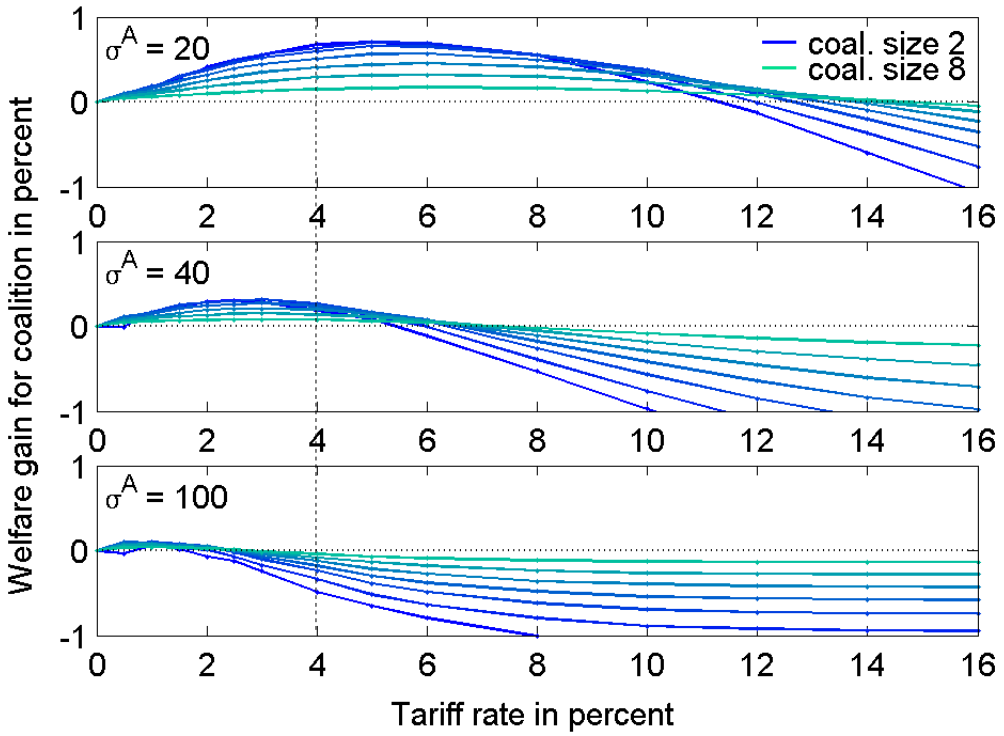
- Non-members show free-riding behavior

total emissions



- Overall emissions decrease unambiguously

Are tariffs credible?



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

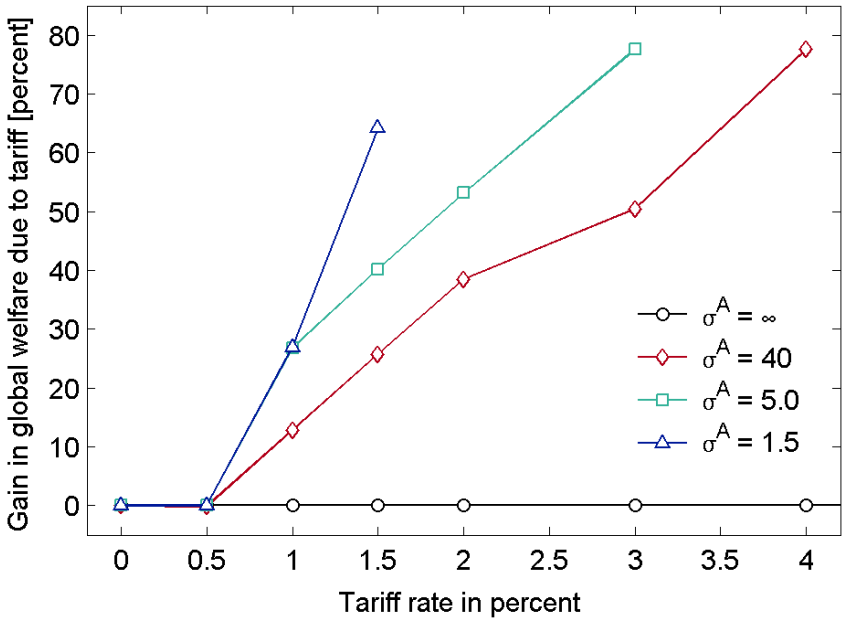
- Threatening tariffs is credible if beneficial for coalition
- a tariff allows exploiting market power, hence is credible if
  - substitutability σ is *low*
  - tariffs τ are not *too high*
- smaller coalition means more non-members means more players that *pay* tariffs

Will tariffs reduce global welfare?

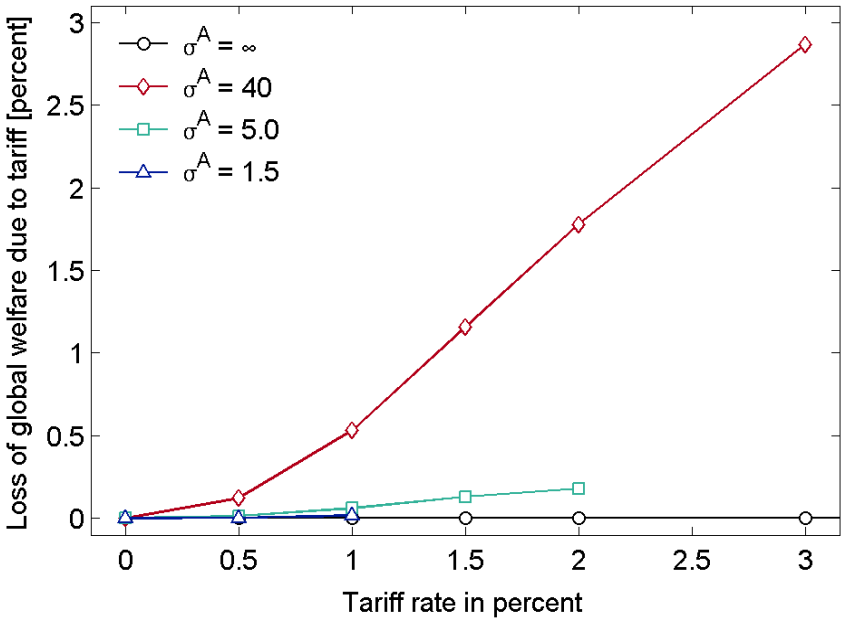
- Tariffs raise participation
- Participation closes gap between Nash and Pareto

- 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*

$$\int_0^\infty \sum_{j \neq i} p^m_{ijt}\, m_{ijt}\ \mathrm{dt} = \int_0^\infty \sum_{j \neq i} p^x_{ijt}\, x_{ijt}\ \mathrm{dt}$$

and $e_{kt} = \overline{e_{kt}}$ for $k \neq i$

- Compare to «competitive equilibrium»

Summary

- Model of coalition stability with externalities
  - Emissions damages
  - Trade sanctions
- Solved by combining Ficticious 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