Carbon Border Adjustments: from Optimal to Practical

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Basic Question

- What's the best **you** can do? (i.e. EU, EU+US, OECD, …)
  - to reduce **global** emissions
  - at **minimum cost** to your citizens
  - if **rest of the world** ignores the problem
  - but you aren't out to hurt ROW (and ROW retains sovereignty)
- Optimize over a set of **quantities**: fossil fuel extracted, energy used in production, imports, exports, and consumption (anticipating ROW reactions)
- **Ignore** how policy is implemented: **regulation, cap and trade, or carbon taxes**

Simple Qualitative Answer

- Take the following **actions**:
  - reduce your extraction of fossil fuels
  - uniformly reduce energy intensity of all goods you produce and/or consume
  - reduce consumption of goods that embody energy (intensive margin, including imports)
  - don’t change the set of goods you import (extensive margin of imports)
  - reduce exports of goods if your comparative advantage is strong (intensive margin of exports)
  - expand range exports even if your comparative advantage is weak (extensive margin of exports)
- By how much? The formula comes later!

Economic Rationale

- **Balance lower supply and demand** for energy to moderate fuel-price effects in ROW
- Reduce fossil fuel **supply** by extracting less (pushes up global energy price)
- Reduce **demand** by hitting all possible margins (pushes down global energy price)
  - produce with energy saving techniques
  - dictate energy saving techniques for imports
  - consume less of energy intensive goods
  - export less of goods ROW would never produce for themselves
  - export goods that ROW would otherwise produce using more fossil fuels

Implications for Carbon Taxes

- Start upstream (extraction) as with several bills in the US Congress
- Tax energy extraction: tax rate equals marginal damages from global emissions
- Partial carbon border adjustments on energy:
  - tax energy imports and rebate tax on exports (< extraction tax rate), pushes part of the tax downstream from extractors to producers
- Same partial CBA's on carbon content of goods imports
  - import margin unchanged relative to no policy
- No CBA's for exports of goods; instead a subsidy per unit for marginal exporters
  - export margin expands relative to no policy
- Bills in Congress have full CBA's, removes effective tax on extractors and goods exporters

Implications for CBAM

- Carbon border adjustments emerge from our optimization, a rationale for CBAM
  - CBA's not part of the maximization problem itself, just a feature of the solution
- Features of optimal CBA's found in CBAM
  - CBA's on imported goods (impose green incentives on importers)
  - no CBA's for exported goods (retain green incentives for exporters)
  - free allowance to exporters per unit exported (to promote green exports of marginal exporters)
- Features of optimal CBA's not found in CBAM
  - energy extraction should face an "effective tax" (could be added via taxes or regulation)

Outline

1. Model
2. Planner's problem
3. Implementing optimal policy
4. Quantitative illustration

Model Structure

- **Countries:** Home (formerly “you”) and Foreign* (formerly ROW)
- **Endowments:** labor L and and a distribution of energy deposits E
- **Sectors:** energy, goods, and services (it’s a mini CGE)
  - energy extracted from deposits using labor
  - differentiated goods produced using labor and energy
  - services provided by labor
- **Mobility:** labor freely mobile across sectors but immobile across countries
- **Trade:** energy and services costlessly traded; goods traded subject to iceberg costs

Carbon in the Model

1. Carbon is pulled from the earth by energy extractors

2. It's then embodied in energy trade

3. Released into the atmosphere through combustion by goods producer, or utilities generating electricity for them

4. Carbon is embodied in these goods, which are traded prior to being consumed

5. Carbon can be tracked all the way from its extraction to where the goods embodying the carbon are ultimately consumed

   Convenient to measure it, at each stage, in units of CO_2

Foundations

- Build on Markusen (1975) in modeling energy extraction, externalities, and policy
- Combine with Dornbusch, Fischer, and Samuelson (DFS, 1977) to get trade in differentiated goods produced with energy
- Follow Costinot, Donaldson, Vogel, and Werning (CDVW, 2015), who use the primal method to derive optimal unilateral trade policy in DFS
- Follow Böhringer, Lange, and Rutherford (2014) by replacing trade balance with requirement that Home's policy doesn't reduce Foreign's welfare

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Home's Planning Problem

- The planner seeks to maximize Home's welfare by choosing
  - **Energy:** Home's extraction and the global price of energy
  - **Services:** quantity of services provided and consumed
  - **Goods:**
    - quantity produced in Home for domestic consumption and for export
    - quantity of imported for consumption in Home
    - energy intensity of production for all three
- Foreign chooses extraction, production, and consumption, responding to energy price

Solution: Three Wedges

- Marginal product of energy to producers and consumers in Home vs. Foreign

$$\lambda_e > p_e$$

- Marginal return to energy extraction in Home vs. Foreign

$$\lambda_e - \varphi^W < p_e$$

- Marginal cost of Home exports vs. marginal utility of consuming in Foreign

$$\tau a_j \lambda_e^{1-\alpha} > p_j^* \qquad j \in (j_0, \bar{j}_x)$$

Magnitude of Wedges

- Lagrange multiplier and Foreign energy price must satisfy two equations
  - wedges balance three forms of leakage anticipating Foreign response

$$\left((\lambda_e - \varphi^W) - p_e\right) \frac{\partial Q_e^*}{\partial p_e} = (\lambda_e - p_e)\frac{\partial G_e^*}{\partial p_e} + \int_{j_0}^{\bar{j}_x} (\tau a_j \lambda_e^{1-\alpha} - p_j^*)\frac{\partial c_j^*}{\partial p_e} dj$$

  - energy market clears

$$C_e(p_e, \lambda_e) + C_e^*(p_e, \lambda_e) = Q_e(p_e, \lambda_e) + Q_e^*(p_e)$$

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Implementing as a Carbon Tax

- **Global energy price** p_e
- **Extraction tax** $t_e = \varphi^W$
- **Border adjustment**

$$t_b = \lambda_e - p_e = \frac{\varphi^W \epsilon_S^* Q_e^* - \sigma^*(1-\alpha)S}{\epsilon_S^* Q_e^* + \epsilon_D^* C_e^{FF}}$$

$$0 < t_b < \varphi^W$$

$$S = \int_{j_0}^{\bar{j}_x} (\tau a_j \lambda_e^{1-\alpha} - p_j^*) x_j dj$$

  - applies to imports and exports of energy; to imports of goods but not to exports of goods

- **Markusen reasoning**: balancing act between taxing supply and demand
- **Fischer and Fox reasoning:** tax the energy content of exports, even with rebates
- **New reasoning:** use export subsidy to replace Foreign production with green production

Other Policies

- If we carefully limit what the planner can choose, other policies emerge
  - extraction-consumption hybrid
  - get same optimal extraction tax $t_e = \varphi^W$
  - border adjustment both on energy and on carbon embodied in goods

$$t_b = \varphi^W \frac{\epsilon_S^* Q_e^*}{\epsilon_S^* Q_e^* + \epsilon_D^* C_e^*}$$

- If we let planner choose everything (as if Foreign joins the coalition)
  - global optimum $t_e = \varphi^W$

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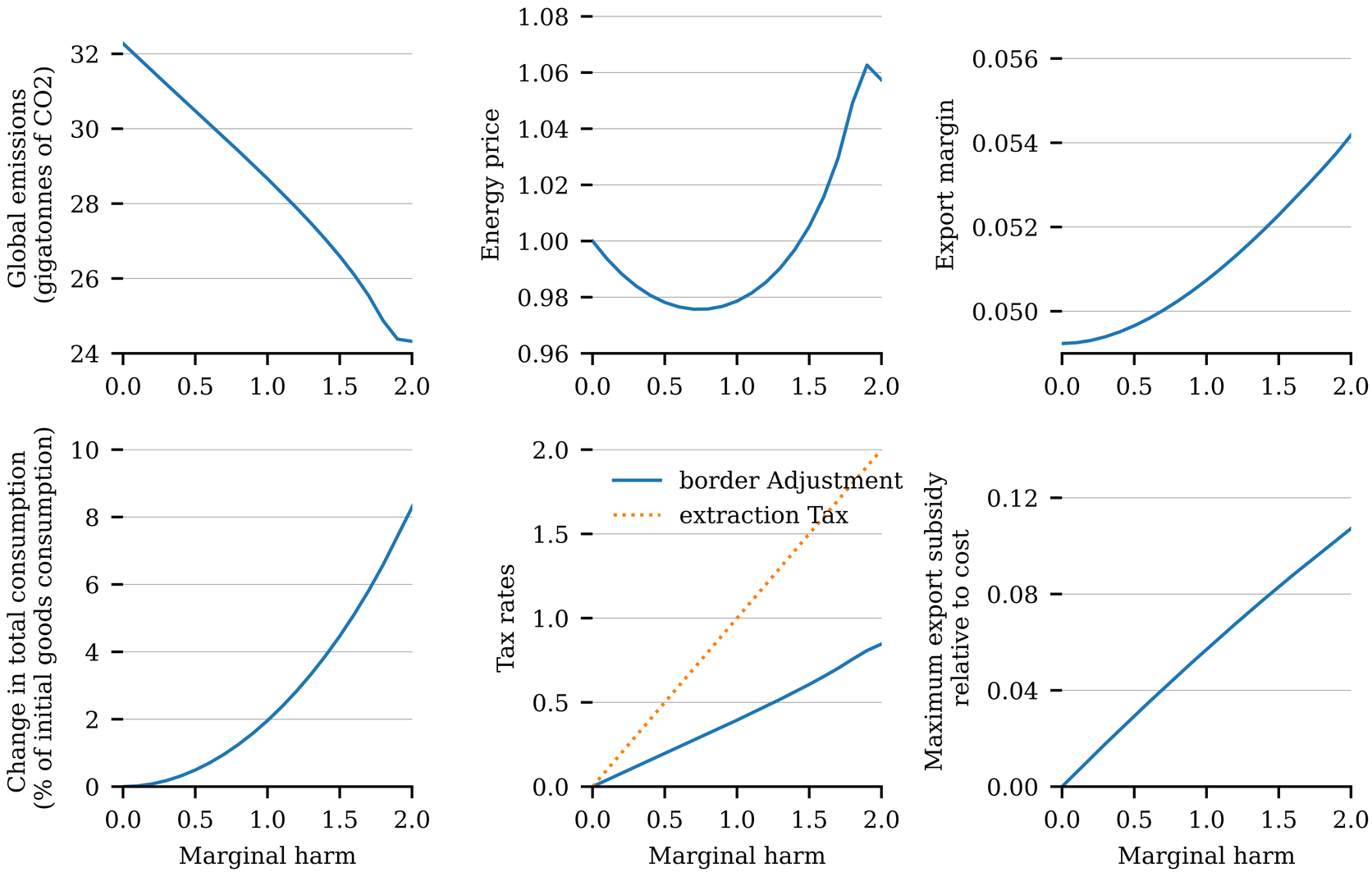
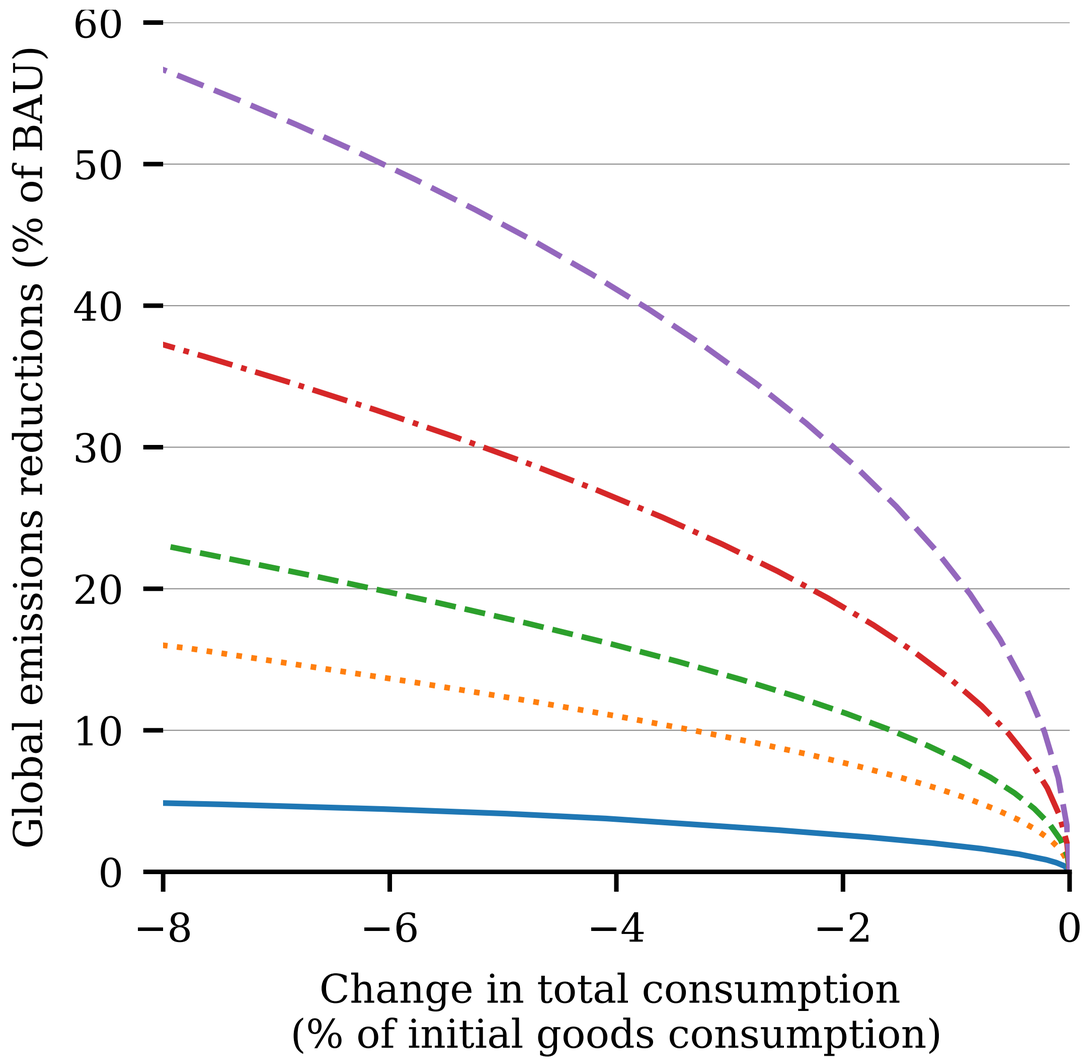
Calibration

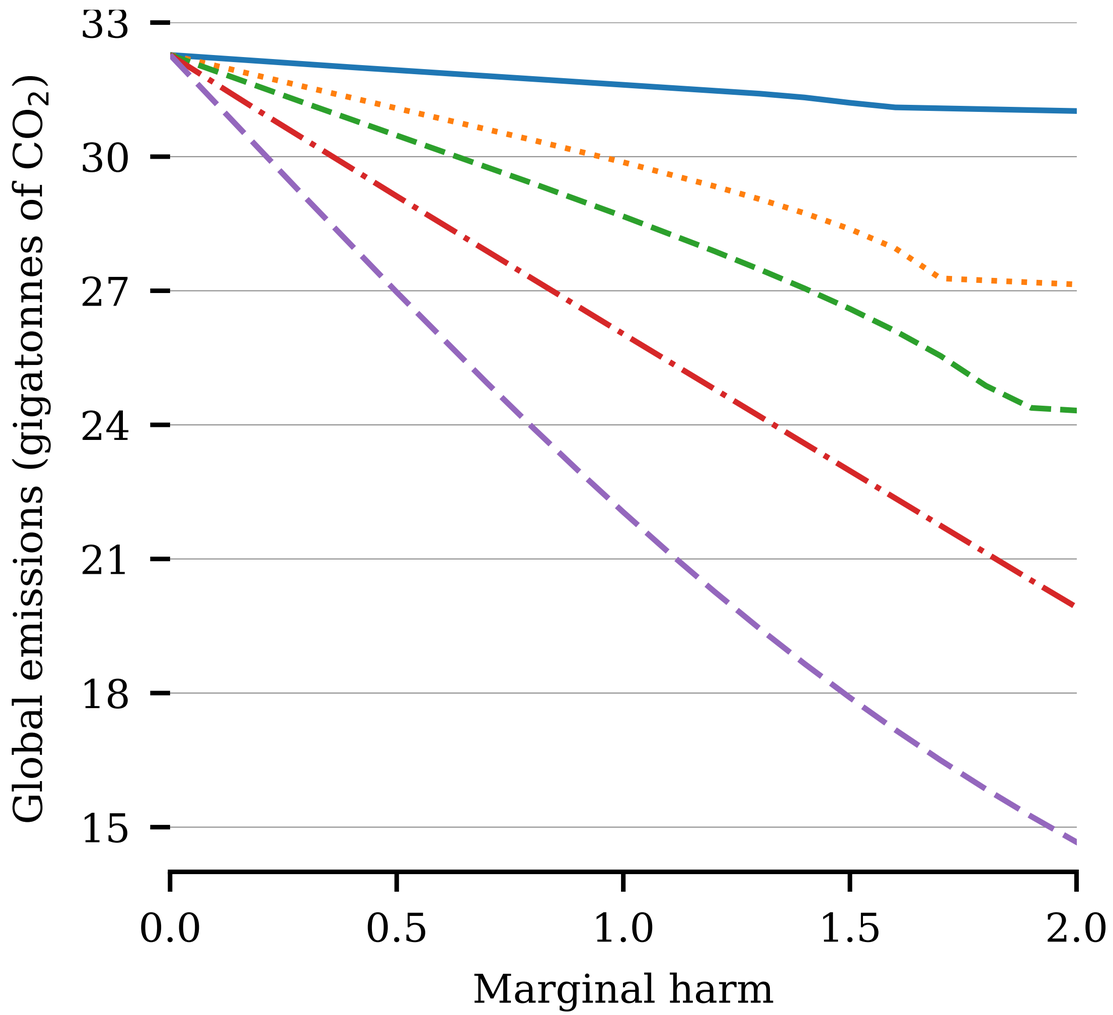
- All results are relative to a BAU scenario, with energy price normalized to 1
- Calibrate to a matrix of extraction and carbon flows between the two regions
- Other parameters:
  - energy share in production $1 - \alpha = 0.15$
  - elasticity of energy supply $\epsilon_S = \epsilon_S^* = 0.5$
  - elasticity of substitution in consumption $\sigma = \sigma^* = 1$
  - trade elasticity $\theta = 4$

Optimal Policy for the OECD



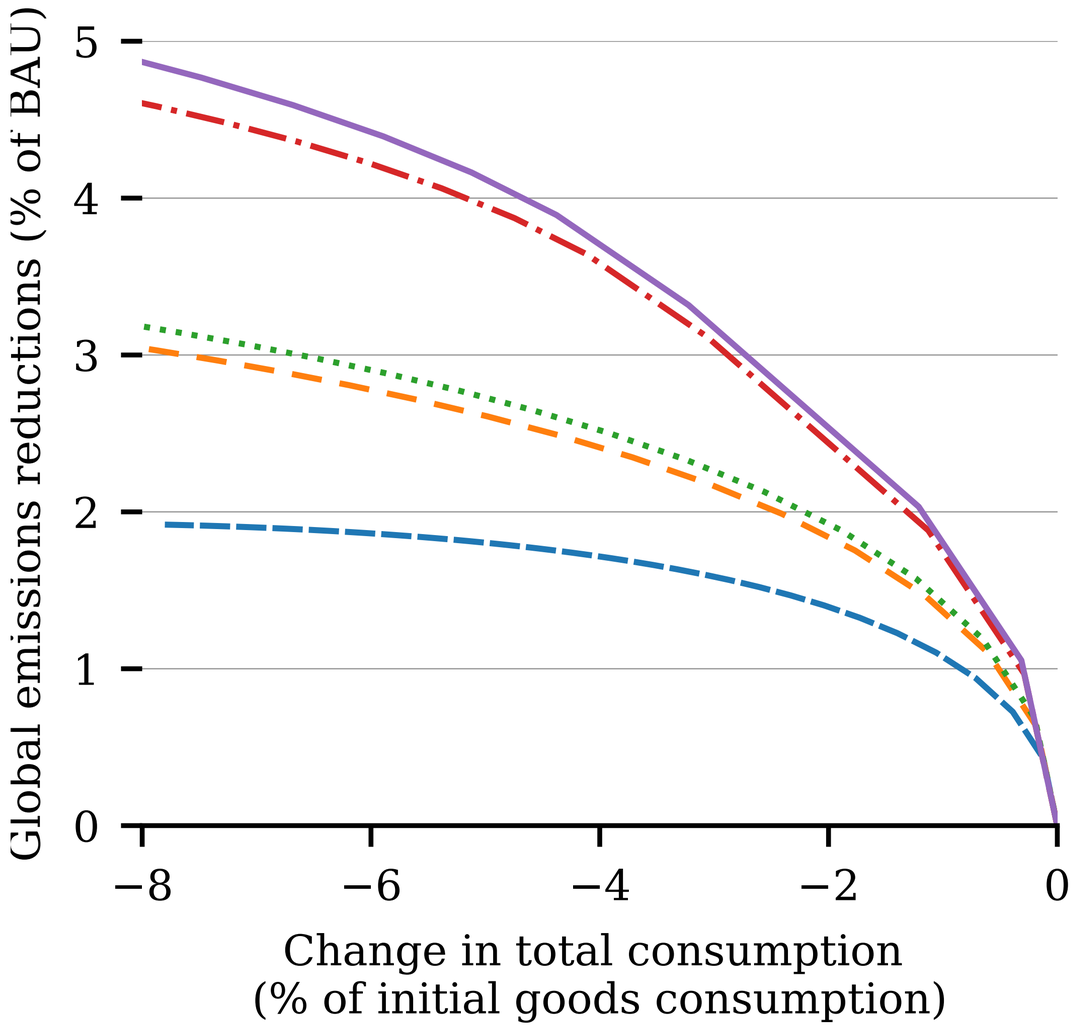
Coalition Size

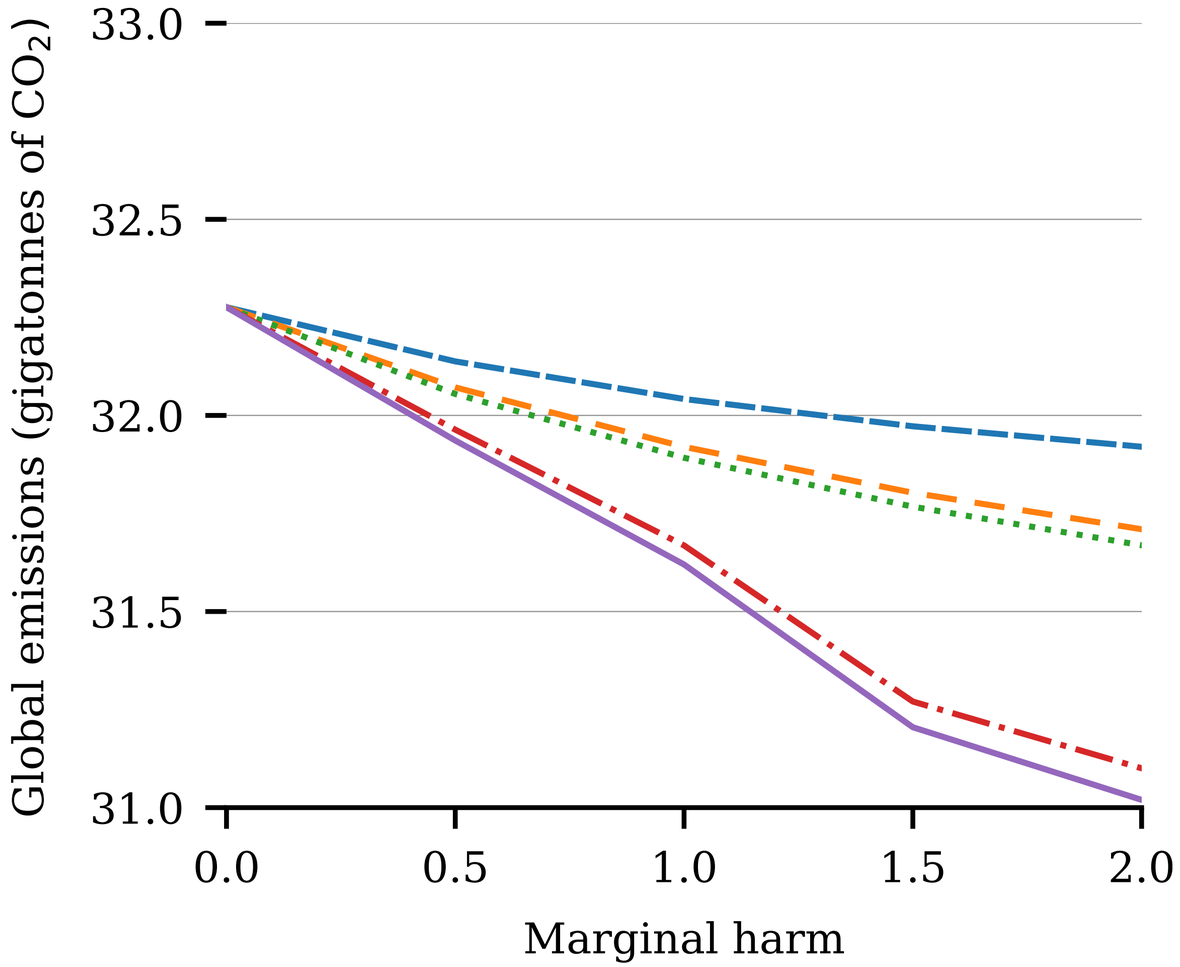




EU EU+US OECD OECD+China World

Policies for the EU





production tax
production-consumption
extraction-consumption
optimal
consumption tax

Conclusions

- I look forward to the discussion!
- For details of our analysis
  - “Optimal Unilateral Carbon Policy” (joint with David Weisbach) a draft of the paper is posted on Samuel Kortum’s web page