Unilaterally Optimal Carbon Policy

Samuel Kortum and David Weisbach

Indiana University
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- If many countries don't participate, international trade generates *carbon leakage*
  - non-coalition countries increase emissions as coalition countries reduce them
- We consider principles for design of a carbon tax in such a world

Related Literature

- Seminal paper on this issue: Markusen (1975)
- Specific issues: Hoel (1994), Keen and Kotsogiannis (2014), Balistreri, Kaffine, and Yonezawa (2014), Jakob, Steckel, and Edenhofer (2014)
- Larger issues: Farrokhi and Lashkaripour (2021), Fischer and Fox (2011), Fowlie (2009), Harstad (2012), Nordhaus (2015), …
- Talk today combines two papers: Kortum and Weisbach (2021) and Weisbach, Kortum, Wang, and Yao (2022)

Outline

1. Overview
2. Basic Model
3. Trade in Goods
4. Quantitative Illustration

Theory and Policy

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- Compare these policies to a bill in Congress
  - H.R. 2307: "Energy Innovation and Carbon Dividend Act of 2021"

‘‘Subtitle L—CARBON DIVIDENDS AND CARBON FEE

‘‘CHAPTER 101—CARBON FEES

‘‘(f) Covered Entity.—The term ‘covered entity’ means—

‘‘(1) in the case of crude oil—

‘‘(A) a refinery operating in the United States, and

‘‘(B) any importer of any petroleum or petroleum product into the United States,

‘‘(2) in the case of coal—

‘‘(A) any coal mining operation in the United States, and

‘‘(B) any importer of coal into the United States,

‘‘(3) in the case of natural gas—

‘‘(A) any entity entering pipeline quality natural gas into the natural gas transmission system, and

‘‘(B) any importer of natural gas into the United States,

"CHAPTER 102—CARBON BORDER FEE ADJUSTMENT

"(c) IMPORTS TO THE UNITED STATES.—

"(1) IMPORTED COVERED FUELS FEE.—In the case of any person that imports into the United States any covered fuel, there shall be imposed a fee equal to the total carbon fee that would be imposed on the fuel's greenhouse gas content under the domestic carbon fee.

"(2) IMPORTED CARBON-INTENSIVE PRODUCTS FEE.—In the case of any person that imports into the United States any carbon-intensive product, there shall be imposed a fee equal to the total carbon fee which would have accumulated upon the greenhouse gas content of the imported carbon-intensive product had the imported carbon-intensive product been produced domestically and subject to the domestic carbon fee.

"(d) REFUND ON EXPORTS FROM UNITED STATES.—

"(1) COVERED FUELS.—Under regulations prescribed by the Secretary, in the case of a covered fuel produced in the United States with respect to which the fee under section 9902 was paid, there shall be allowed as a credit or refund (without interest) to any exporter of such covered fuels an amount equal to the total carbon fee levied upon the exported covered fuel up to the time of its exportation.

"(2) CARBON-INTENSIVE PRODUCTS.—Under regulations prescribed by the Secretary, there shall be allowed a credit or refund (without interest) to exporters of carbon-intensive products manufactured or produced in the United States an amount equal to the total carbon fees accumulated upon the greenhouse gas content of the exported carbon-intensive product up to the time of exportation.

Summary of H.R. 2307

- Tax domestic fossil fuels (extraction) and add border adjustments
  - imports of fossil fuels are taxed at the same rate
  - tax is refunded on fossil-fuel exports
  - … implies tax is on energy use by producers; no *effective tax* on fossil-fuel extraction
  - border adjustments on imports and exports of carbon-intensive products
  - … pushes tax from producers to consumers of those products
  - all border adjustments are at the same rate as the underlying tax
- Compare to the unilateral optimal policy that we derive

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  - import margin unchanged relative to no policy
- No BAs for exports of goods; instead a subsidy per unit for marginal exporters
  - export margin expands relative to no policy

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- No BAs for goods exports; mimics a production tax
  - incentivizes correct energy intensity by domestic producers
- Subsidy per unit exported expands the reach of domestic policy
  - crowds out foreign production of goods for foreign consumers

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- Optimal subsidies to expand the reach of domestic policy require our Full Model

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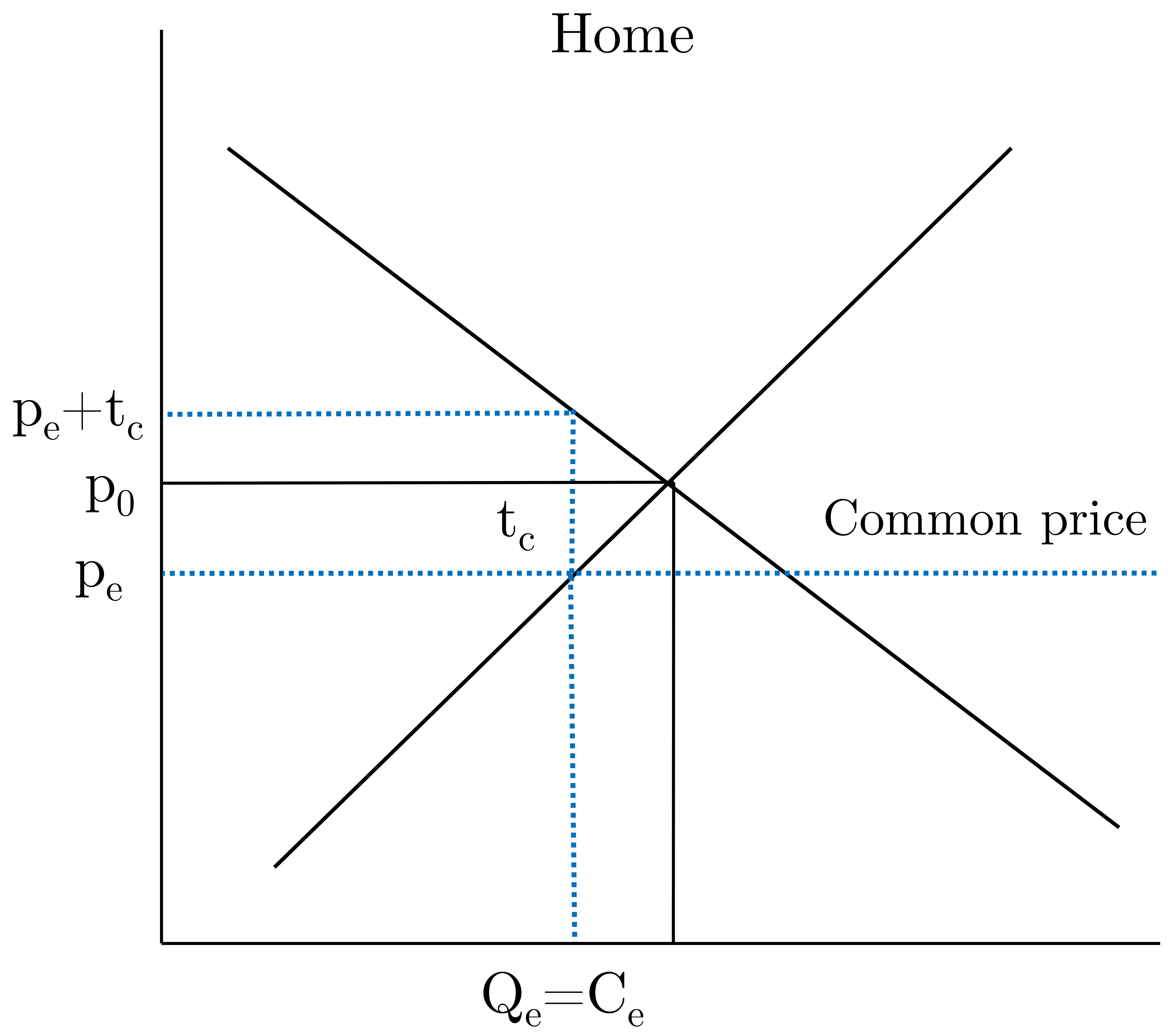
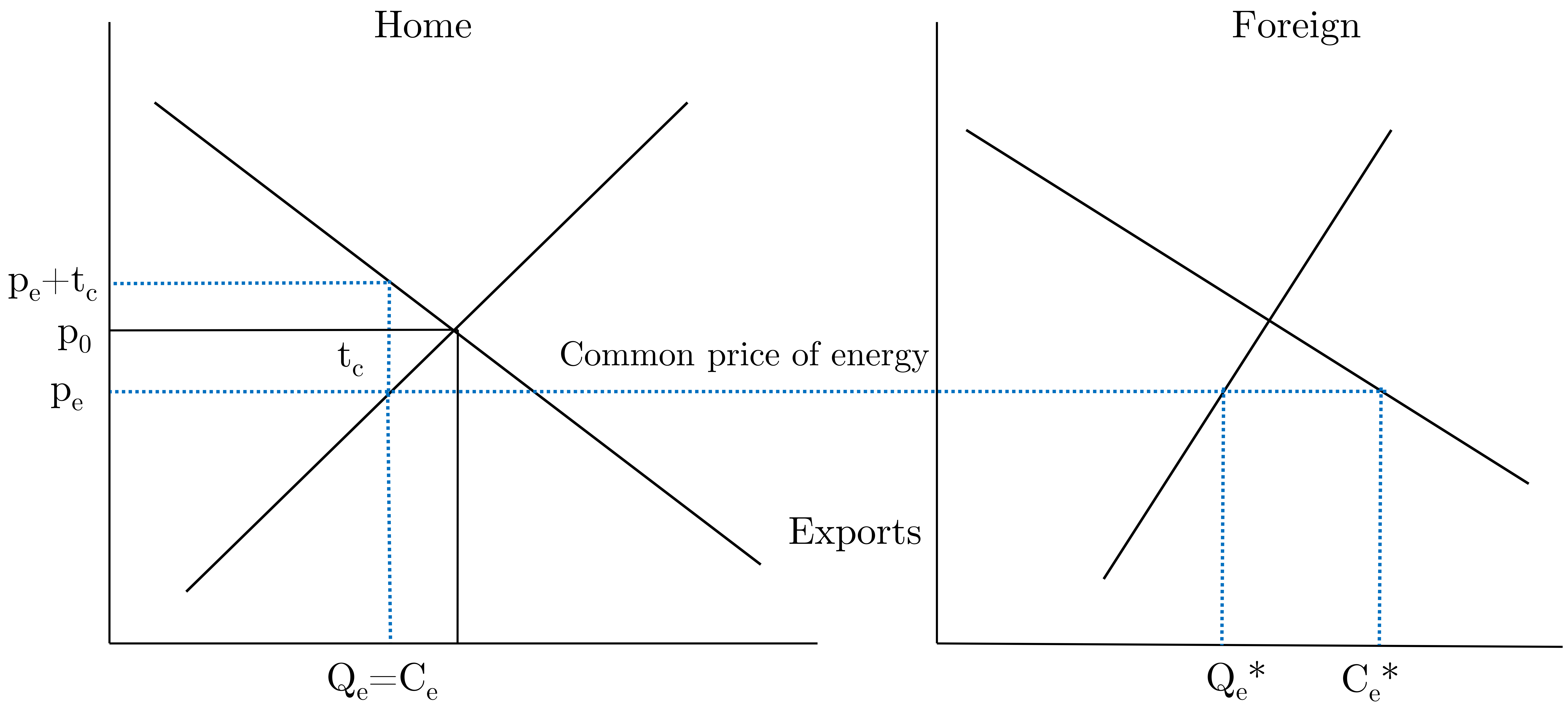
Basic Model

- Two countries extract fossil fuels, produce a numeraire service, and trade them
- Key to basic model is that energy is simply consumed (heating homes)
  - in full model, energy is used to produce goods that are also traded.)
- Home designs a climate policy while Foreign is passive
  - Home only considers Pareto improvements (maintains Foreign welfare)
- Our results here can be found in Markusen (1975) and most directly in Hoel (1994)
- Illustrate with a set of figures

Home in Autarky

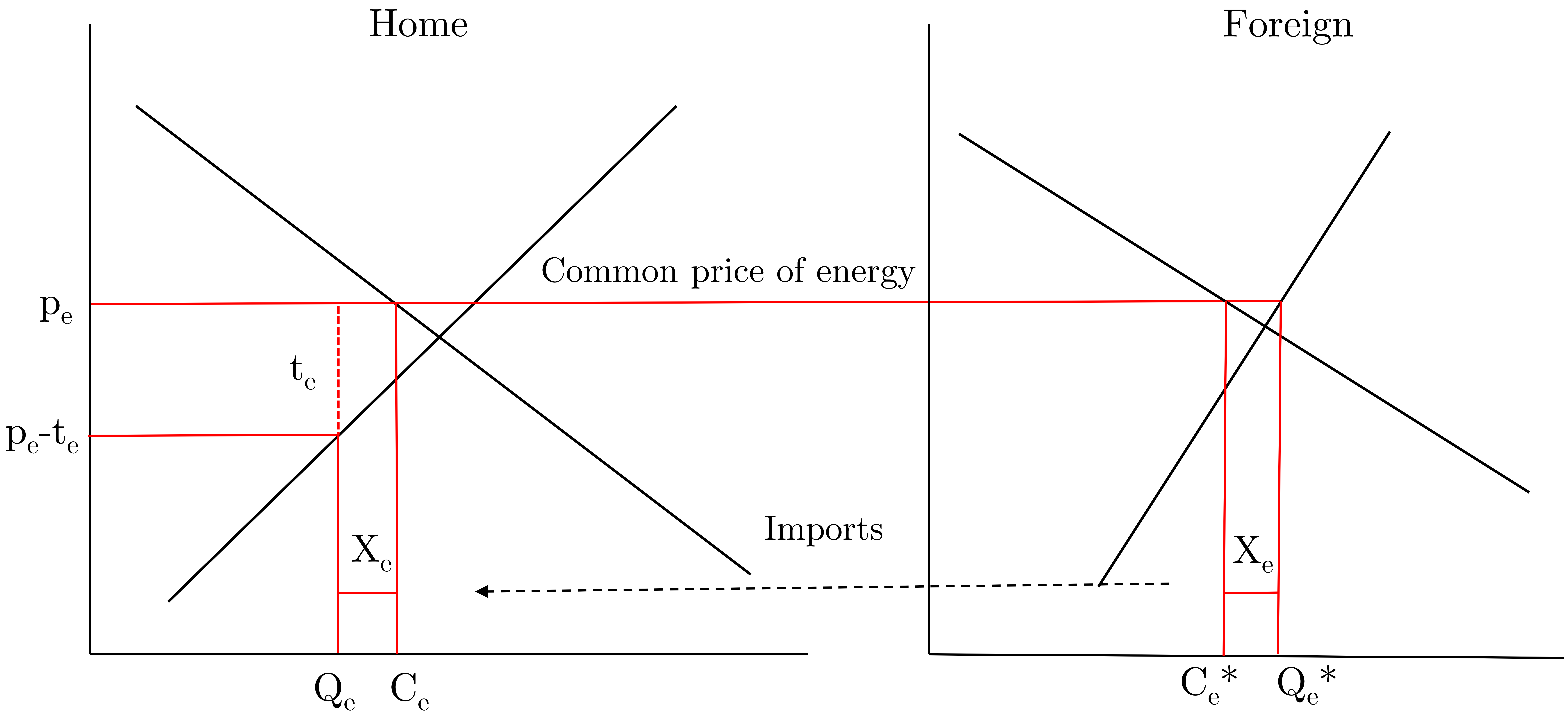


NOT a Trade Equilibrium



Consumption Tax with Trade

Extraction Tax with Trade



Model Elements

- Countries endowed with labor L and fossil fuels
- Services and energy are costlessly traded
- Services produced one-for-one with labor
- Labor to extract energy (convex) $c(Q_e) \quad c^*(Q_e^*)$
- Global emissions $E = Q_e^W = Q_e + Q_e^*$
- Welfare (concave) $U = C_s + u(C_e) - \varphi E \qquad U^* = C_s^* + u^*(C_e^*) - \varphi^* E$
- Foreign response to energy price: $Q_e^*(p_e) \quad C_e^*(p_e)$

Home's Planning Problem

- Home set's a global emission target $\bar{E}$ and keeps Foreign welfare at $\bar{U}^*$
  - transfers services to Foreign $C_s^*(p_e, \bar{E}) = \bar{U}^* + \varphi^* \bar{E} - u^*(C_e^*(p_e))$
- Home solves $$\max_{p_e} C_s + u(C_e) - \varphi \bar{E}$$
  - subject to

$$C_e = \bar{E} - C_e^*(p_e)$$

$$C_s = L + L^* - c(\bar{E} - Q_e^*(p_e)) - c^*(Q_e^*(p_e)) - C_s^*(p_e, \bar{E})$$

- First-order condition

$$\underbrace{(p_e - c')Q_e^{*\prime}}_{\text{extraction wedge}} = \underbrace{(u' - p_e)\,|\,C_e^{*\prime}\,|}_{\text{consumption wedge}}$$

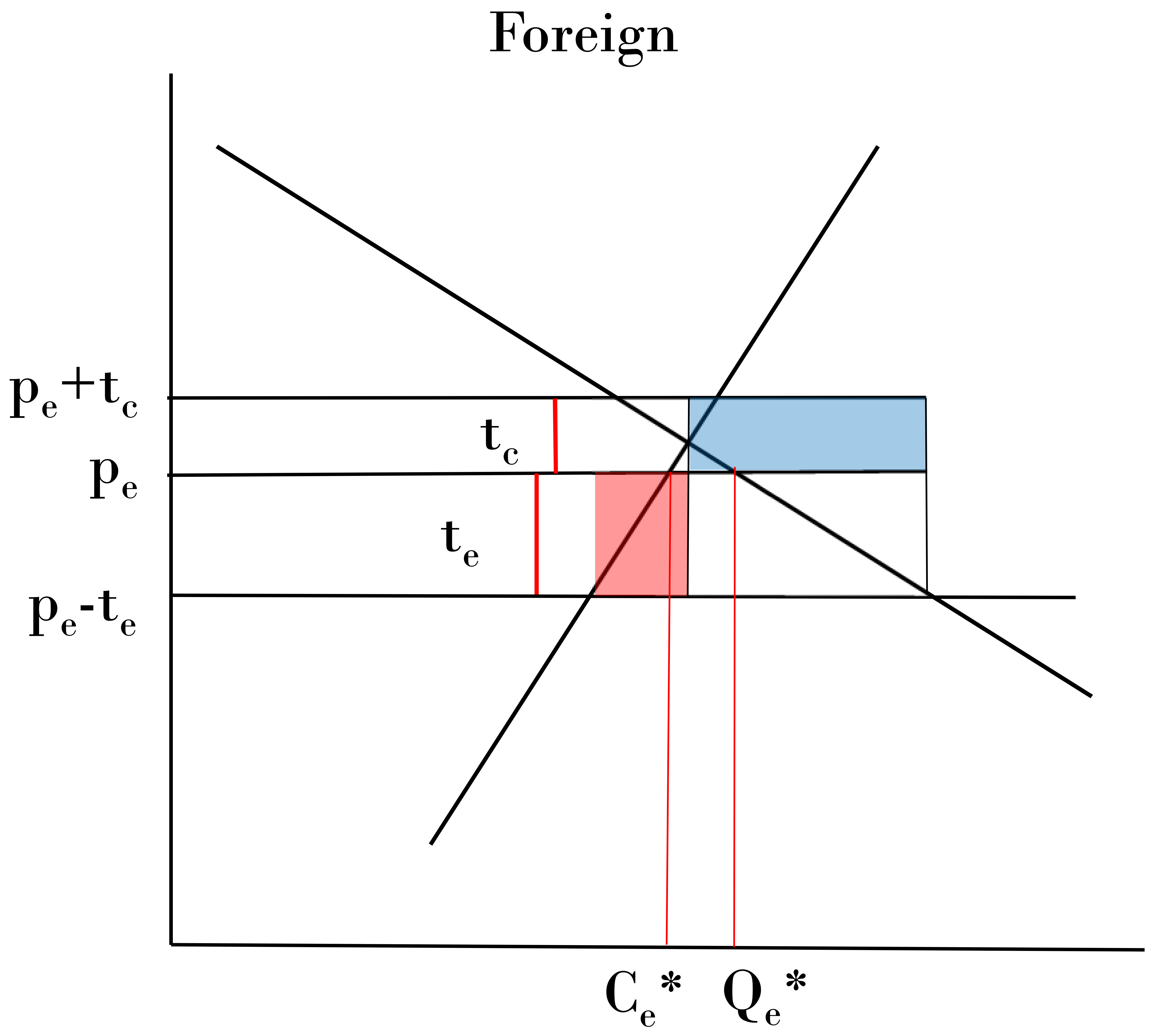
Implications for Carbon Tax

- Home equates taxes with the corresponding wedges
- Optimal ratio of extraction to consumption tax

$$\frac{t_e}{t_c} = \frac{|C_e^{*\prime}|}{Q_e^{*\prime}}$$

- If the emissions goal is set optimally $$t_e + t_c = \varphi^W$$
- Implementation:
  - nominal tax on Home extraction $$\tau = t_e + t_c = \varphi^W$$
  - border adjustment on energy imports and exports $$\beta_e = t_c$$
- Key takeaway for policy (partial BA) $$\beta_e < \tau$$

Optimal Mix of Taxes



Policy Coordination

- Suppose Foreign already had an extraction and consumption tax
  - with $$t_e^* + t_c^* = \mu^*$$
- Home's optimal policy is then:

$$t_e = t_e^* + (\varphi^W - \mu^*)\frac{|C_e^{*\prime}|}{Q_e^{*\prime} + |C_e^{*\prime}|}$$

$$t_c = t_c^* + (\varphi^W - \mu^*)\frac{Q_e^{*\prime}}{Q_e^{*\prime} + |C_e^{*\prime}|}$$

- If $\mu^* = \varphi^W$ then get the global optimum

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What's New?

- Add a manufacturing sector, with energy used in production of goods
- These goods are traded
- Consumers want the goods, not energy itself
- Now we can distinguish a production tax from a consumption tax
- Maintain numeraire services, fossil-fuel extraction, and trade in energy
- Given a set of taxes, Home sets the rates

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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

Carbon in the World

- Gt of CO2 in 2015 (IEA and OECD TECO2) with Home as the OECD

	Home	Foreign	Total
Home	$C_e^d = 11.3$	$C_e^m = 2.5$	$C_e = 13.8$
Foreign	$C_e^x = 0.9$	$C_e^f = 17.6$	$C_e^* = 18.5$
Total	$G_e = 12.2$	$G_e^* = 20.1$	$C_e^W = 32.3$
Extraction	$Q_e = 8.6$	$Q_e^* = 23.7$	$Q_e^W = 32.3$

Welfare

- Replace utility from energy consumption (in Basic Model)
  - with indirect utility from implicit consumption of energy used to produce goods
  - carbon taxes can make energy price different depending on where goods are produced

$$U = Y + \tilde{u} - \varphi E \qquad U^* = Y^* + \tilde{u}^* - \varphi^* E$$

  - income in Home and Foreign $\quad Y = L + R_e + R_t - T \qquad Y^* = L^* + R_e^* + T$
  - Home transfer of services keep Foreign welfare constant
- Home maximizes: $\quad \mathscr{L} = R_e + R_e^* + \tilde{u} + \tilde{u}^* - \varphi^W \bar{E} - \mu(E - \bar{E})$

Market Economy with Carbon Taxes

- Unlike in the Basic Model, we need to spell out sources of income
- Rents to the energy sector $R_e = (p_e - t_e)Q_e - c(Q_e)$ $\quad R_e^* = p_e Q_e^* - c^*(Q_e^*)$
- Tax revenue in Home (consumption-tax case) $R_t = t_e Q_e + t_c C_e$
- Market clearing (consumption-tax case) $Q_e(p_e - t_e) + Q_e^*(p_e) = C_e(p_e + t_c) + C_e^*(p_e)$
- In general, taxes on domestic consumption, imports, and exports

$$R_t = t_e Q_e + t_d C_e^d + t_m C_e^m + t_x C_e^x$$

- Apply Roy's identity, Hotelling's lemma, and Shepard's lemma to simplify FOC's

Tax Extraction and Consumption

- Tax rates $t_c = t_d = t_m \qquad t_x = 0$

- Optimal ratio is identical to that for the Basic Model $$\frac{t_e}{t_c} = \frac{|C_e^{*\prime}|}{Q_e^{*\prime}}$$
  - spread the tax burden, although other taxes may be even better

- If we optimize the emissions goal $$t_e + t_c = \varphi^W$$

- Consumption tax is analytically attractive, doesn't mess with trade, no leakage
  - relative prices of domestic and imported goods stay the same as without taxes

- Implement with nominal extraction tax $$\tau = t_e + t_c$$
  - and partial border adjustments on both energy and goods $$\beta_e = \beta_m = \beta_x = t_c$$

Tax Extraction and Production

- Tax rates $t_p = t_d = t_x \qquad t_m = 0$
- We now need to consider (marginal) leakage $$\Lambda = -\frac{\partial G_e^*/\partial t_p}{\partial G_e/\partial t_p} > 0$$
- The optimal ratio becomes $$\frac{t_e}{t_p} = \frac{|G_e^{*\prime}| + \Lambda |G_e^\prime|}{(1-\Lambda)Q_e^{*\prime}}$$
    - leakage gets you to shift toward an extraction tax
- Also gets you to tax less in total $$t_e + t_p = \varphi^W - \frac{\Lambda \varphi^W Q_e^{*\prime}}{Q_e^{*\prime} + |G_e^{*\prime}| + \Lambda |G_e^\prime|}$$
- Implementation is trivial; nominal extraction tax $$\tau = t_e + t_p$$
    - and partial border adjustment, only on energy $\beta_e = t_p \qquad \beta_m = \beta_x = 0$

Tax Extraction, Consumption, and Production

- Initially unconstrained $t_c = t_d = t_m \qquad t_p = t_x$
- Need to define Foreign (marginal) leakage $$\Lambda^* = -\frac{\partial C_e^f / \partial t_x}{\partial C_e^x / \partial t_x} > 0$$
- The optimal ratio becomes $$\frac{t_e}{t_c} = \frac{|C_e^{f'}| + \Lambda^* |C_e^{x'}|}{Q_e^{*\prime}}$$
  - the production tax (only on Home exports) $t_p = t_x = (1 - \Lambda^*)t_c$
- Get back full Pigouvian taxation $t_e + t_c = \varphi^W$
- Implementation is more intricate; nominal extraction tax $\tau = t_e + t_c$
  - partial BA on energy $\beta_e = t_c$, goods imports $\beta_m = t_c$, and goods exports $\beta_x = t_c - t_x$

Summary of Intermediate Model

Policy	τ	β_e	β_m	β_x
Extraction-Production	$t_e + t_p < \mu$	t_p	0	0
Extraction-Consumption	$t_e + t_c = \mu$	t_c	t_c	t_c
Extraction-Production-Consumption	$t_e + t_c = \mu$	t_c	t_c	$t_c - t_x$

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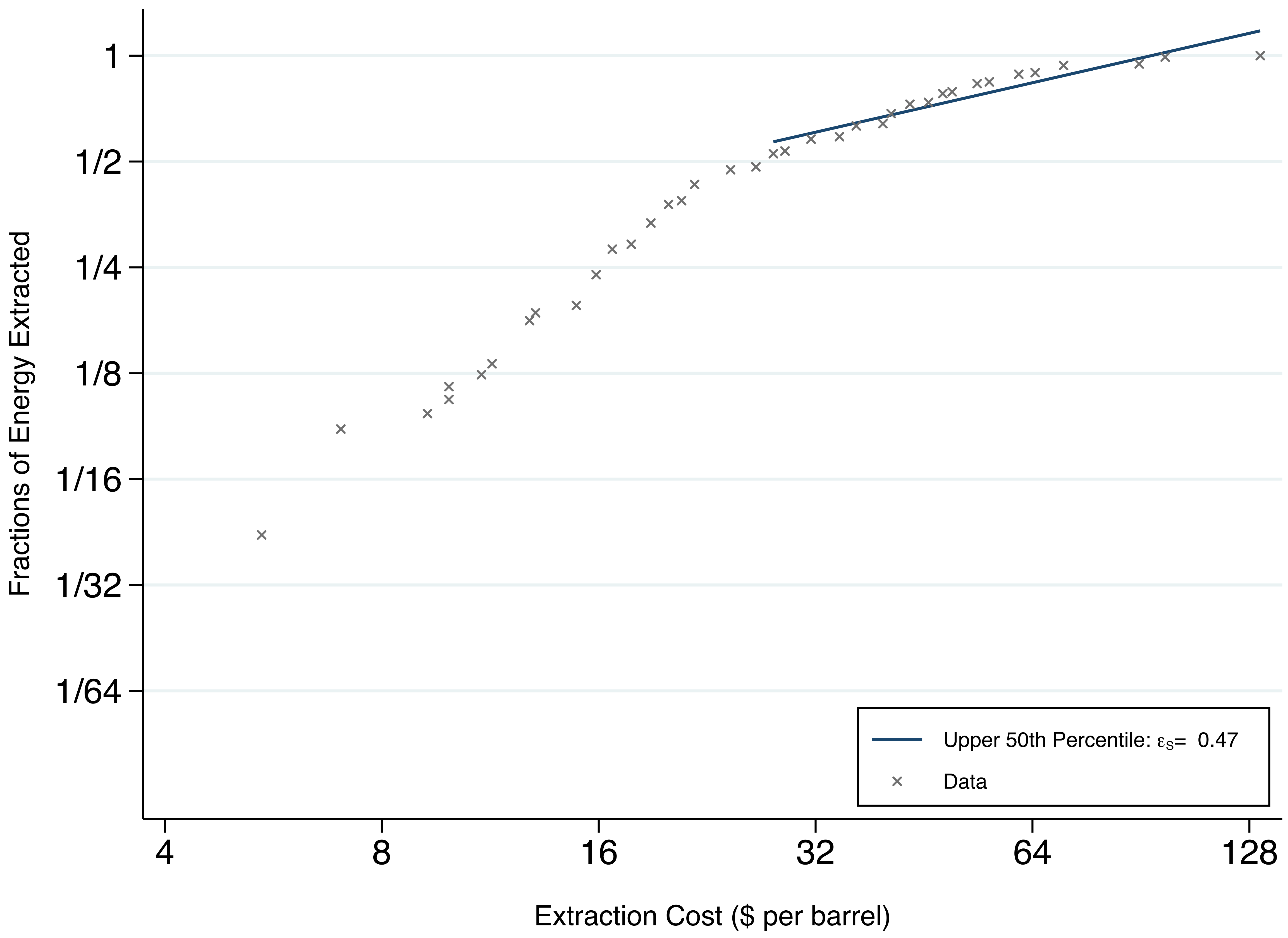
Calibration Strategy

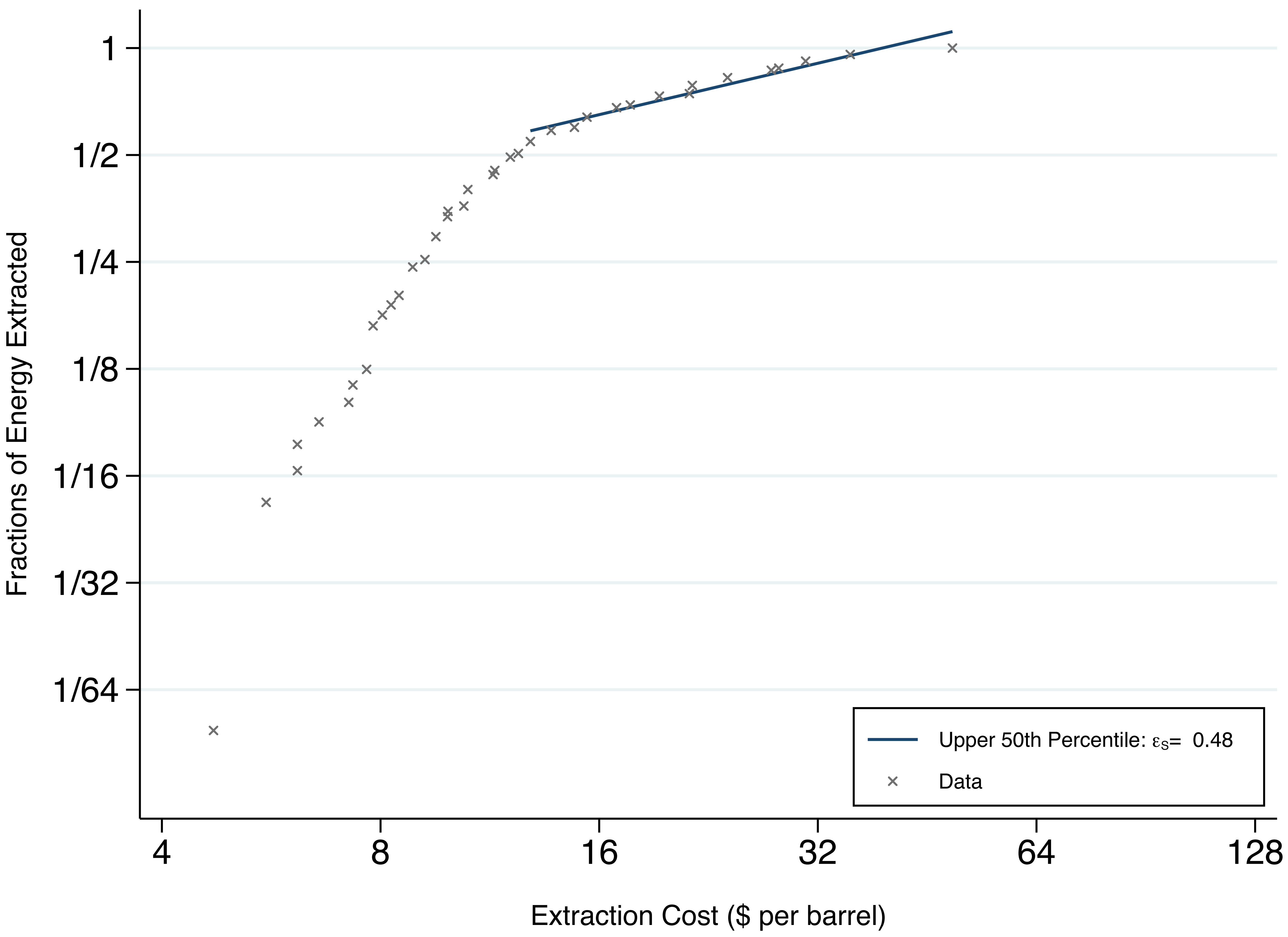
- Put back in the details from Kortum and Weisbach (2021)
- Impose functional forms for extraction and comparative advantage
  - constant supply elasticities, ϵ_S, ϵ_S^* and constant trade elasticity θ
- Calibrate to BAU using data above on carbon flows, for Home = OECD
  - can change the taxing coalition by simply plugging in new carbon flows matrix
- All results are relative to BAU competitive equilibrium, applying “hat algebra”
  - we normalize BAU energy price = 1

Calibrated Parameters

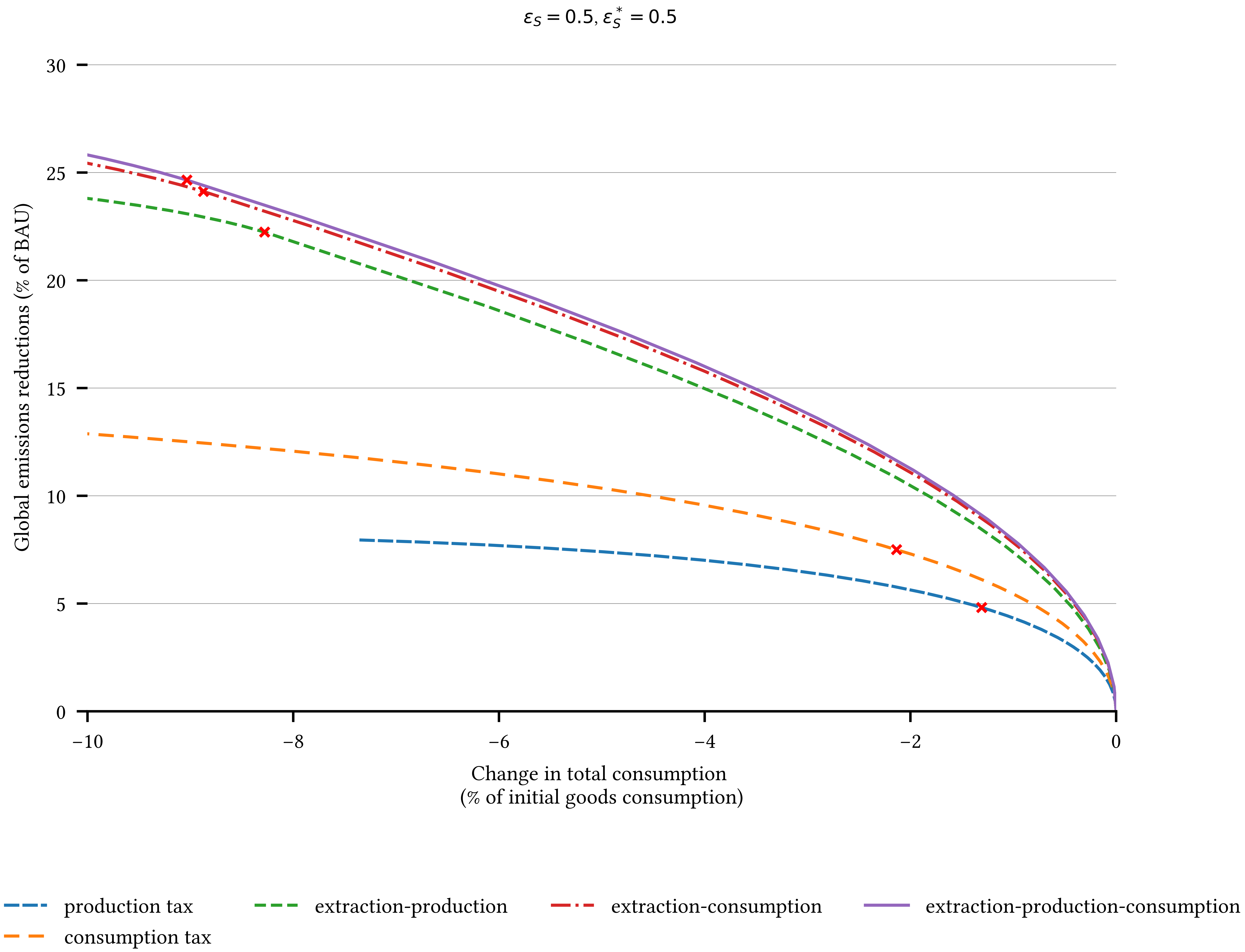
- Energy share in production $$1 - \alpha = 0.15$$
  - source: value of energy use and value added of production
- Elasticity of energy supply $$\epsilon_S = \epsilon_S^* = 0.5$$
  - oil fields from Asker, Collard-Wexler, and De Loecker (2018), but also try $\epsilon_S^* = 2$
- Elasticity of substitution in consumption $$\sigma = \sigma^* = 1$$
  - changing this parameter makes little difference
- Trade elasticity $$\theta = 4$$
  - source: Simonovska and Waugh (2014)

Calibration of Energy Supply Elasticity





OECD as Home (low elasticity)



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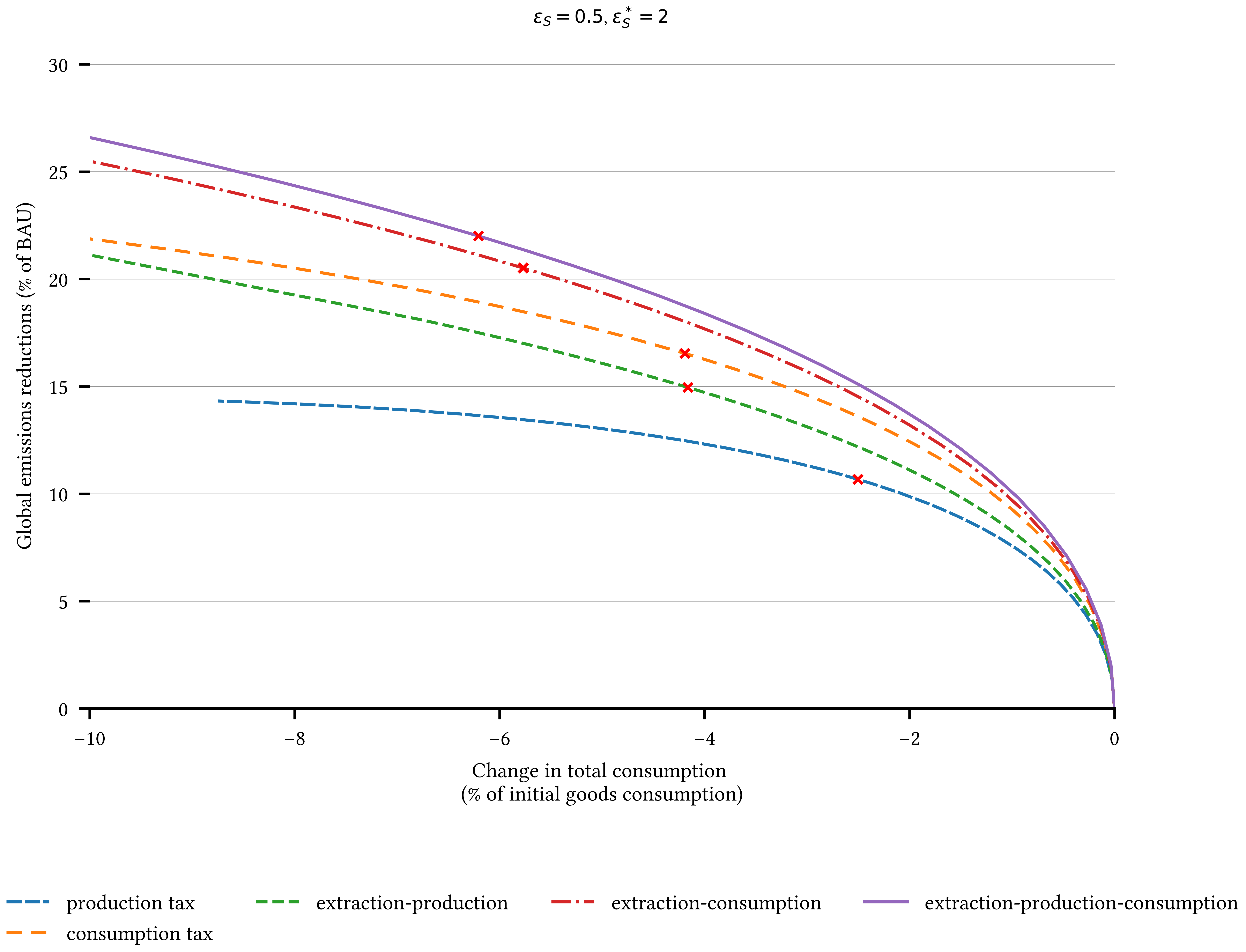
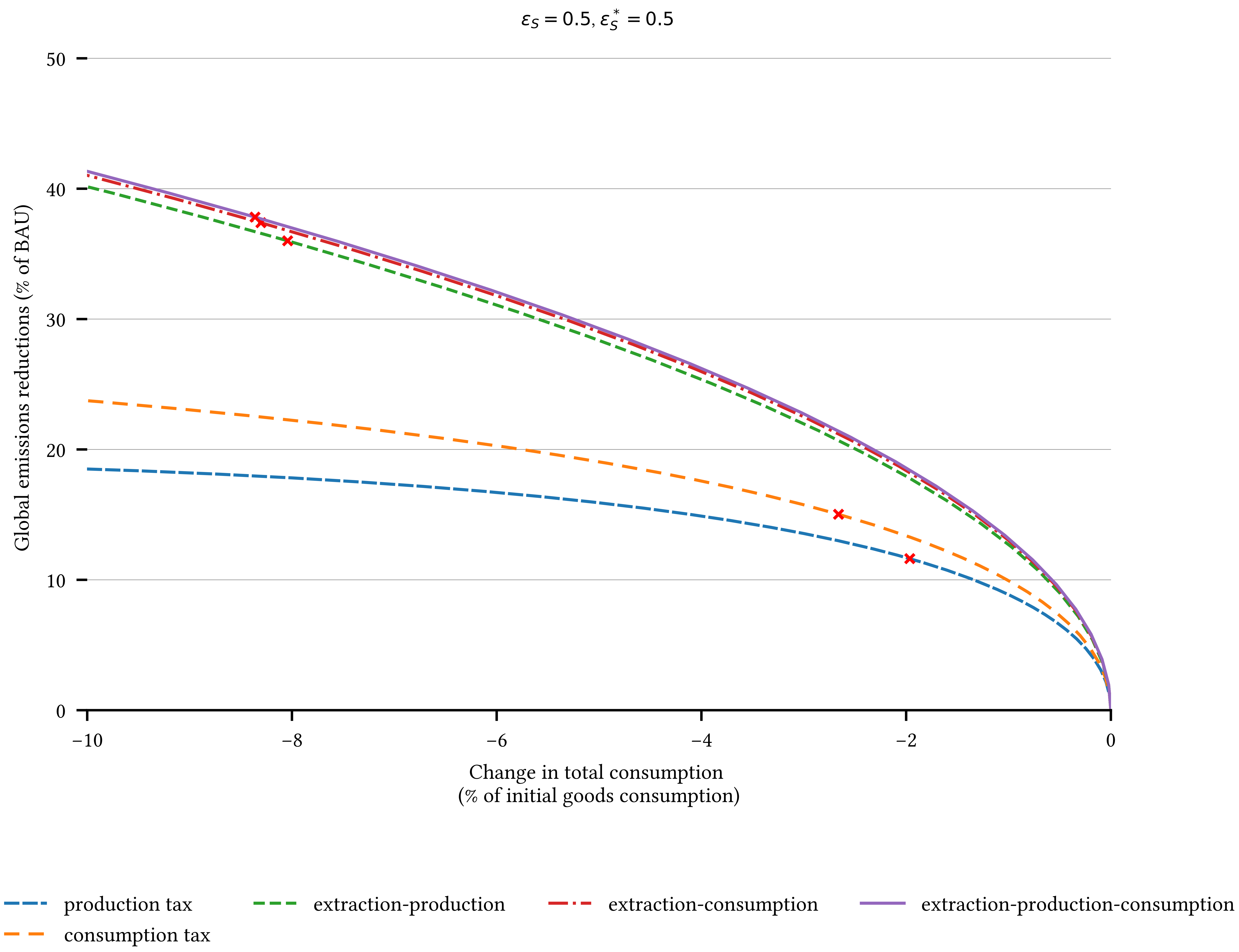


China Joins (low elasticity)



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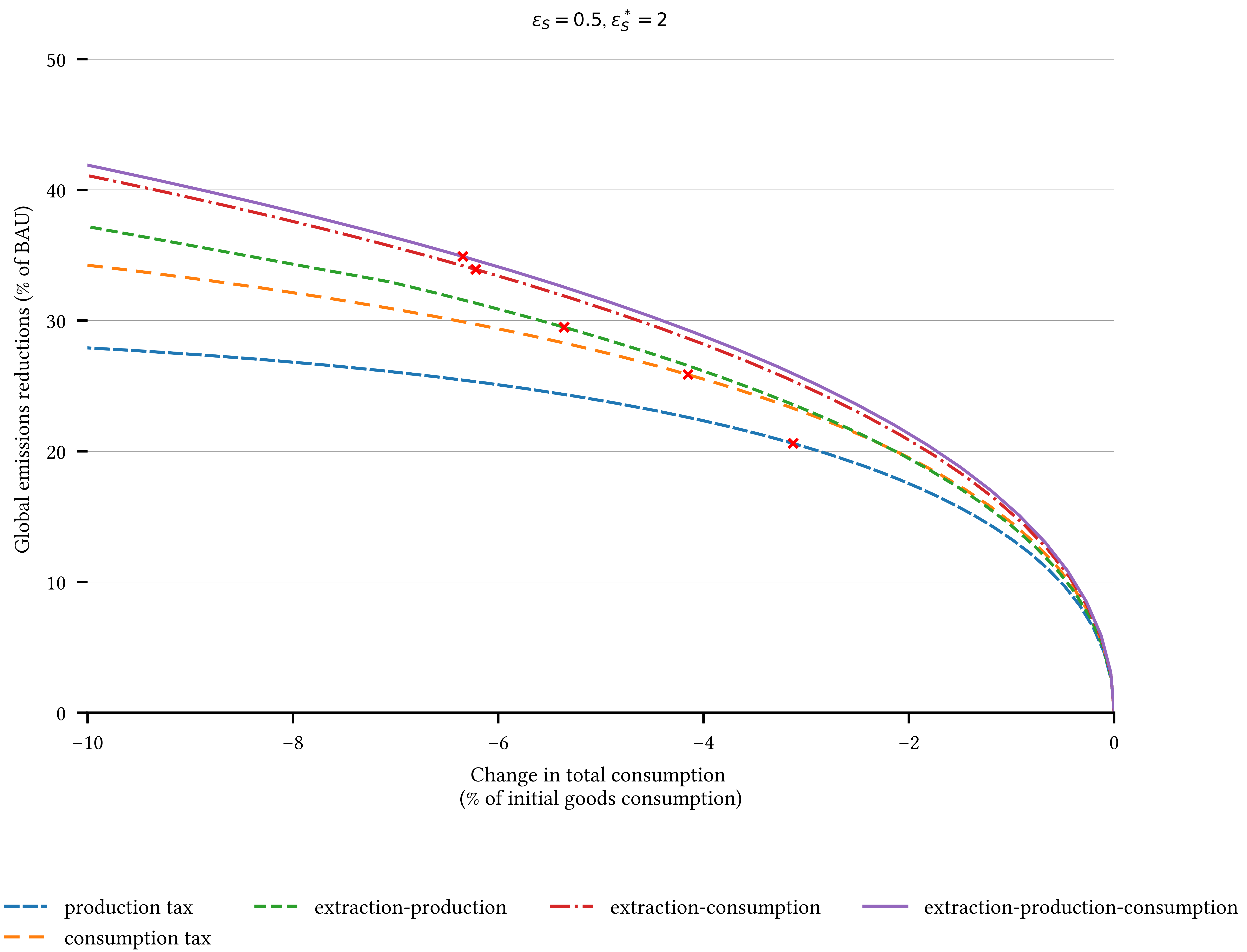

Conclusions

- There's scope to improve the design of a carbon tax
  - to lower the cost of achieving a given reduction in global emissions
- Might simply lower the border adjustment on energy
- Also consider dropping BAs on goods, or at least drop rebates on goods exports
- Empirical work can make these suggestions more precise quantitatively