Optimal Unilateral Carbon Policy

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- Emissions of CO_2 generate a *global externality*
    - harm doesn't depend on where emissions originate
- Optimal allocation can be implemented with a globally harmonized carbon price
    - little progress toward that ideal due to free-rider problem
- What can a coalition of countries "Home" do on its own? A stylized analysis!
    - solve for Home's ideal allocation in a DFS trade model, given Foreign price-taking behavior
    - analyze taxes and subsidies that implement this unilaterally optimal allocation

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  primal approach to derive optimal unilateral trade policy in DFS
- Follow Böhringer, Lange, and Rutherford (2014); Keen and Kotsogiannis (2014)
  policy can't reduce Foreign's welfare; must be Pareto improving

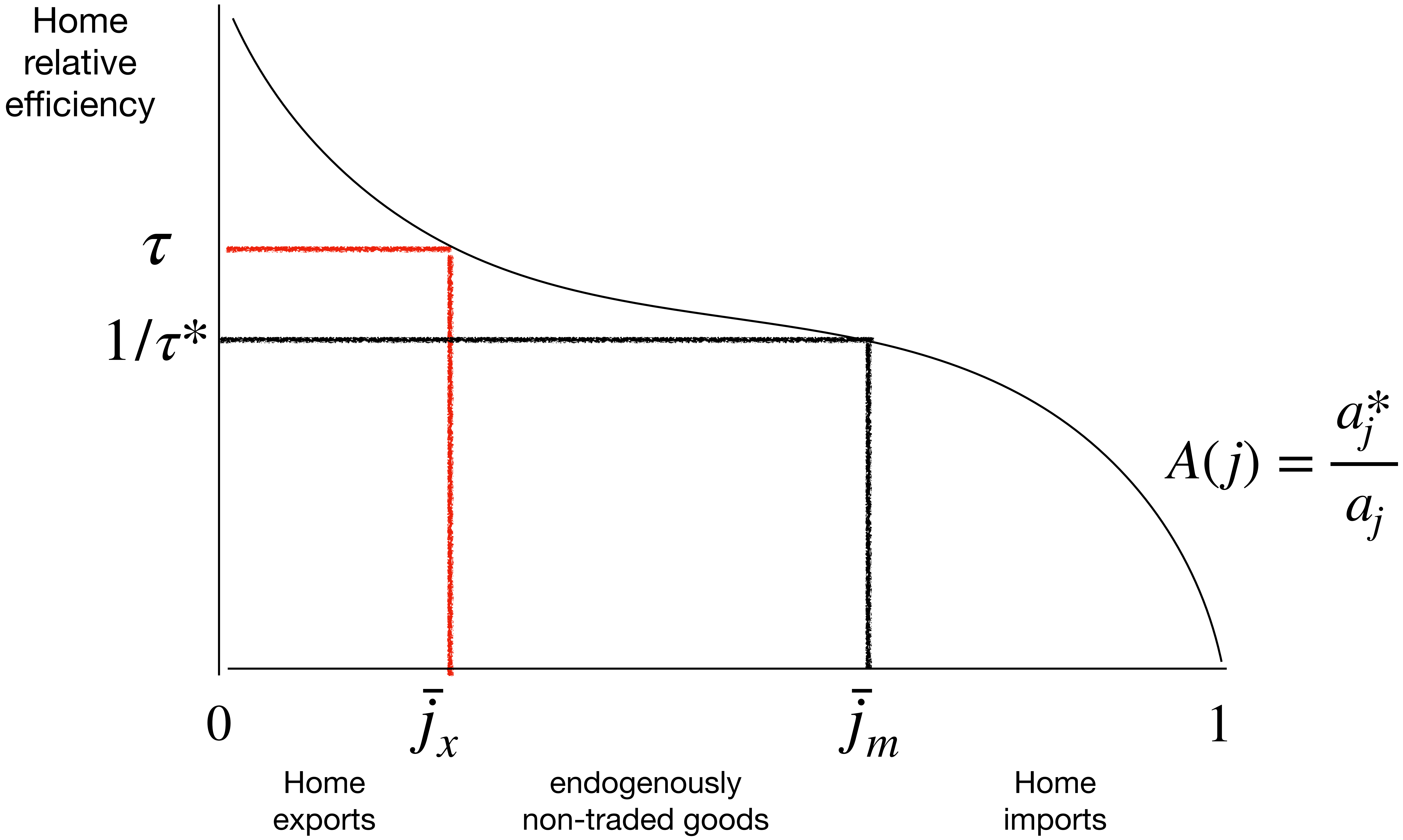
Preferences and Technology

- Home welfare quasi-linear; global social cost of carbon (SCC) $\varphi^W = \varphi + \varphi^*$

$$U = C_s + \int_0^1 u(c_j)dj + v(C_e^d) - \varphi Q_e^W$$

- Services produced 1-to-1 with labor, costlessly traded (numeraire)
- Goods produced with labor and energy with efficiency a_j, a_j^*; iceberg trade costs
- Fossil-fuels extracted at increasing labor cost $a(Q_e)$, $a^*(Q_e^*)$; $Q_e + Q_e^* = Q_e^W$

Goods Trade in BAU (SCC = 0)



Planner's Problem

- Planner wants to maximize global welfare (Pareto-improving policy)
    - but can't directly control activities in Foreign
- Decisions in Foreign guided by global energy price p_e
    - in Home guided by shadow value of energy λ_e
- Expected unit production costs in Foreign and Home $a_j^* g(p_e), \;\; a_j g(\lambda_e)$
    - function $g(p)$ combines energy cost (p) and labor cost (1); $g'(p)$ dictates energy intensity

Solution Strategy

- Massive Lagrangian!
- First solve the inner problem as in CDVW (optimize for each good j)
- Then solve the outer problem to determine aggregates $p_e,\ \lambda_e,\ Q_e\ C_e^d$
- Present results in reverse order
  - outer problem is like Markusen, with key policy implication
  - inner problem for Home consumption is like CDVW
  - inner problem for Foreign consumption is more novel

Solution to Outer Problem

- Energy price splits the Pigouvian wedge

extraction wedge consumption wedge

$$\left(p_e - (\lambda_e - \varphi^W)\right) \frac{\partial Q_e^*}{\partial p_e} = (\lambda_e - p_e) \left| \frac{\partial C_e^{z*}}{\partial p_e} \right| + \int_{j_s}^{j_x} \left(\tau a_j g(\lambda_e) - a_j^* g(p_e) \right) \left| \frac{\partial x_j}{\partial p_e} \right| dj$$

extraction wedge consumption wedge export wedges

$$C_e^{z*} = C_e^{d*} + C_e^{y*}$$

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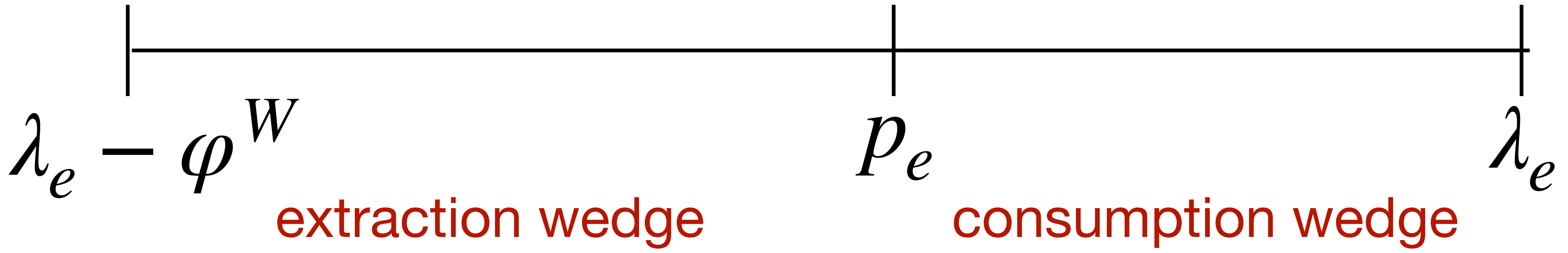

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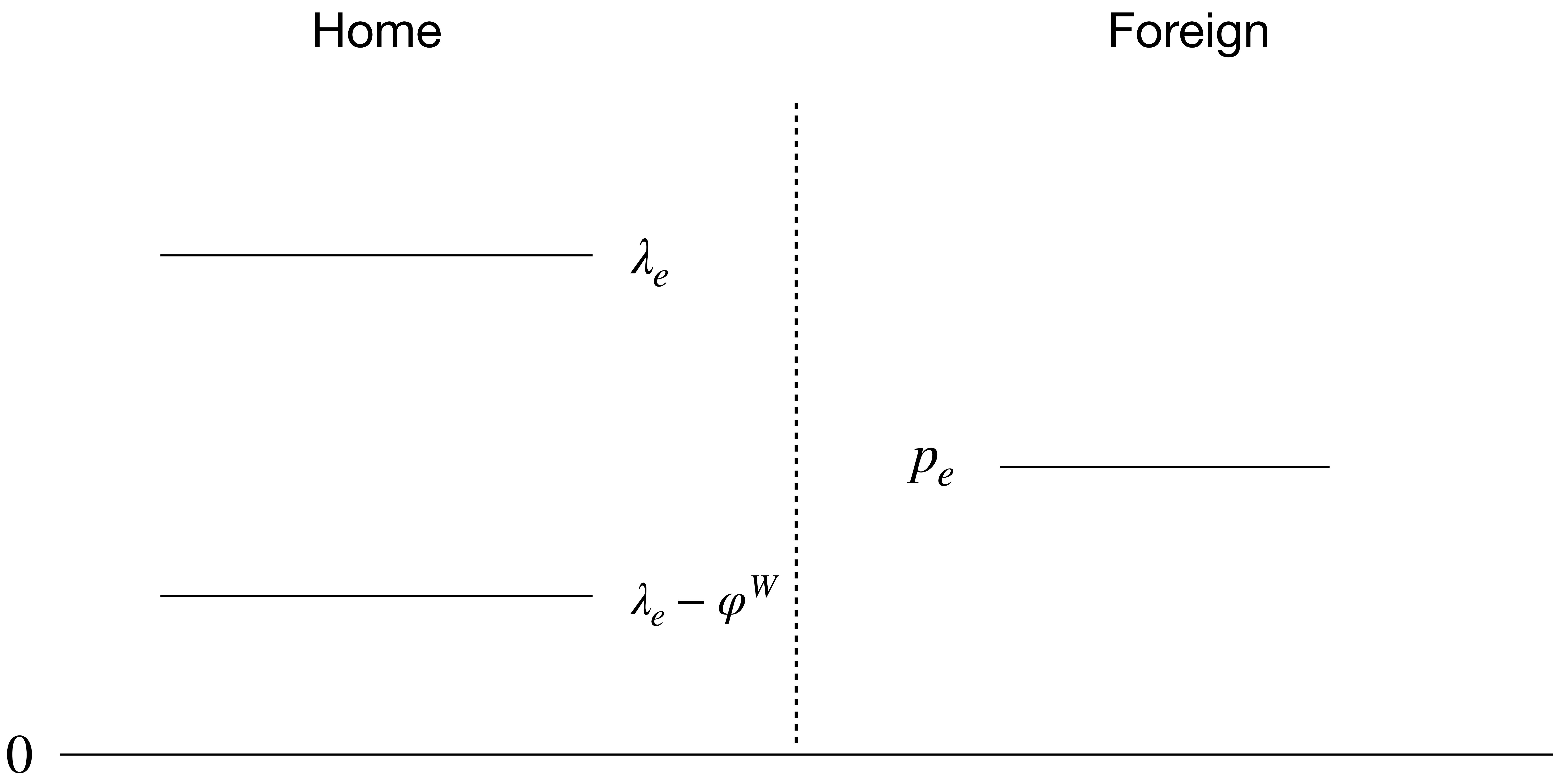
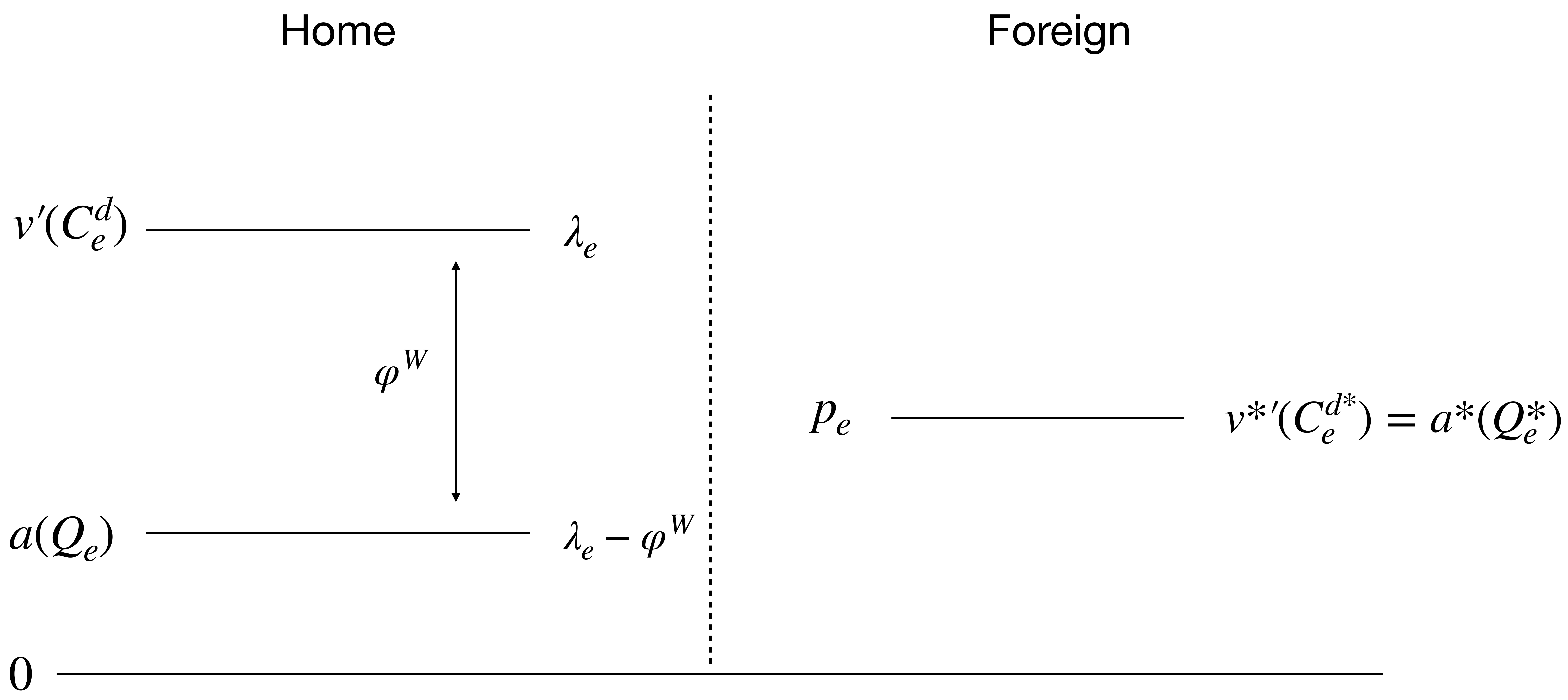
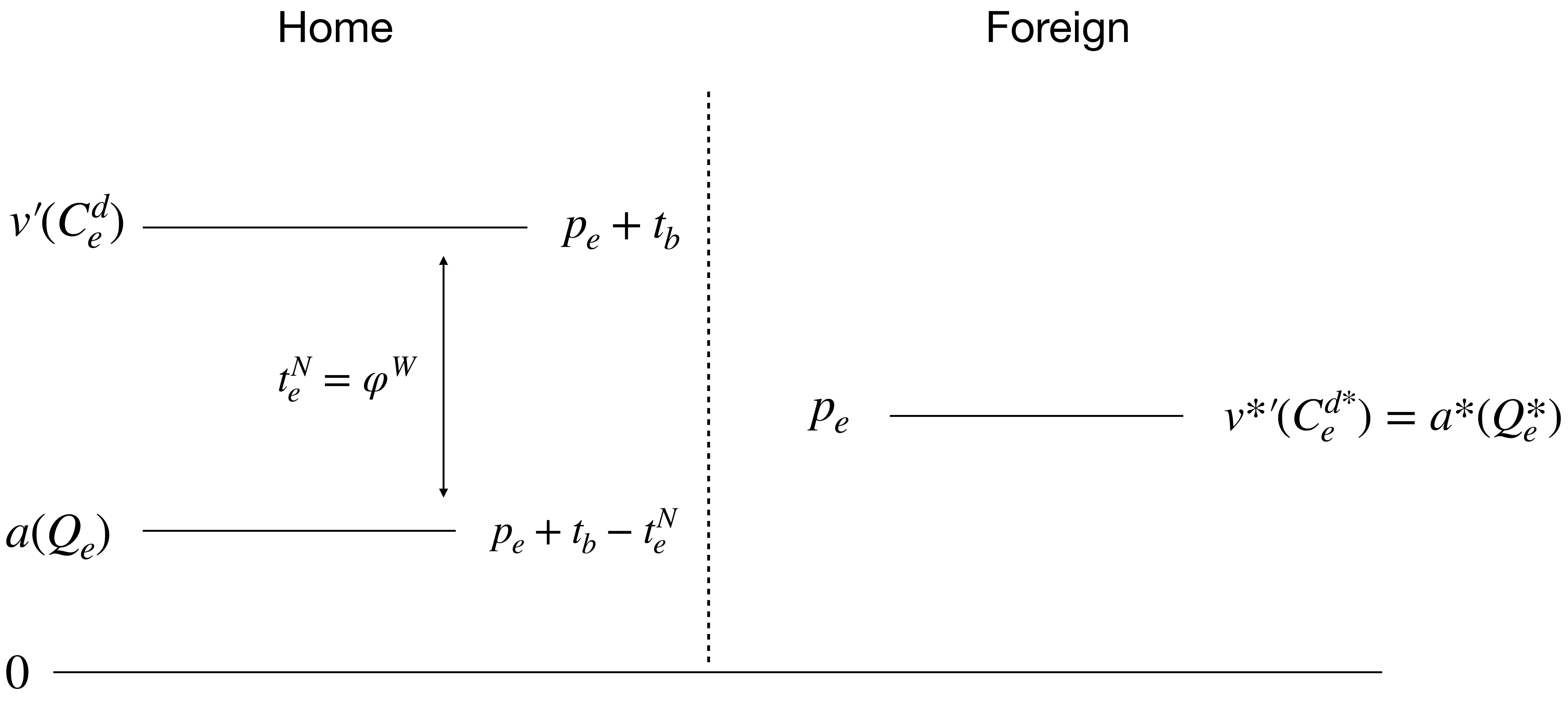
Valuing Energy



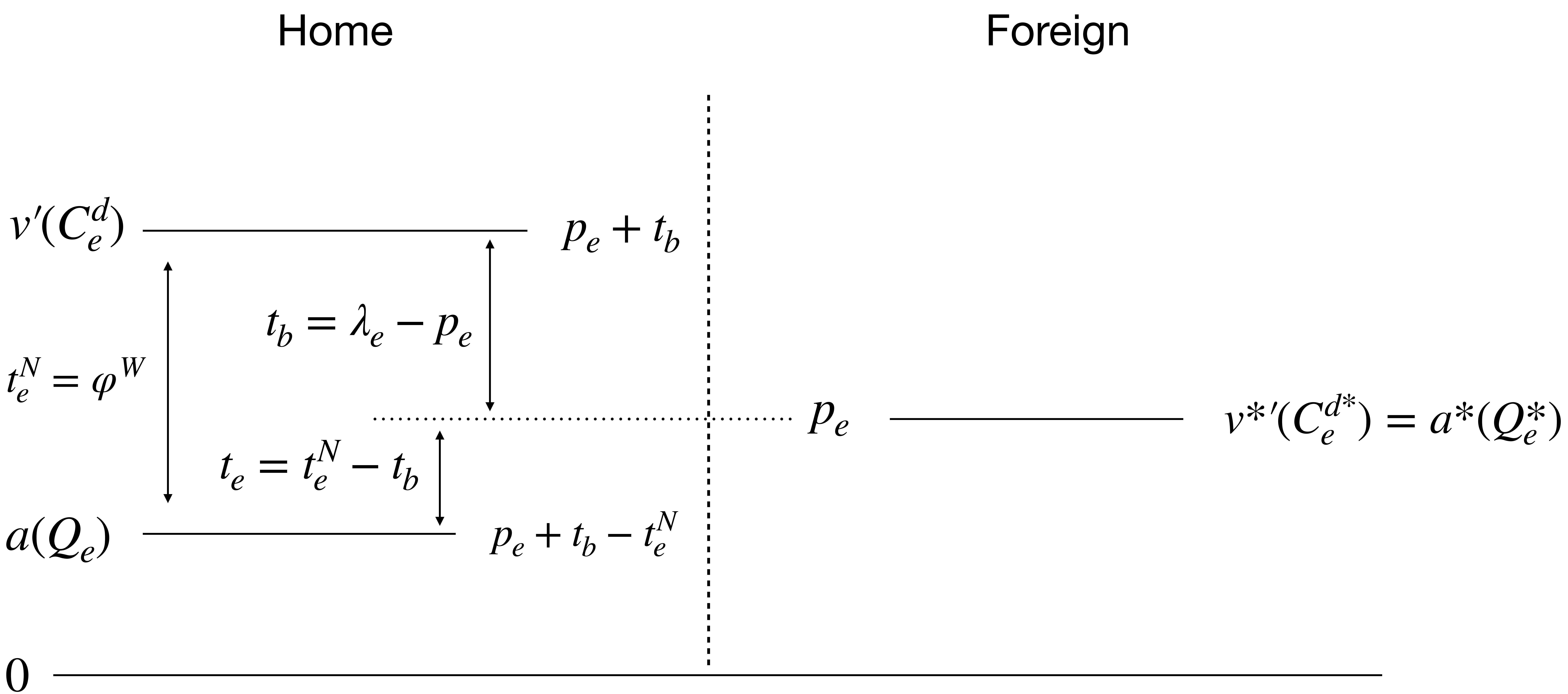
Supply and Demand



Implement with Taxes



Tax both Supply and Demand



Solution to Inner Problem

- Energy intensity

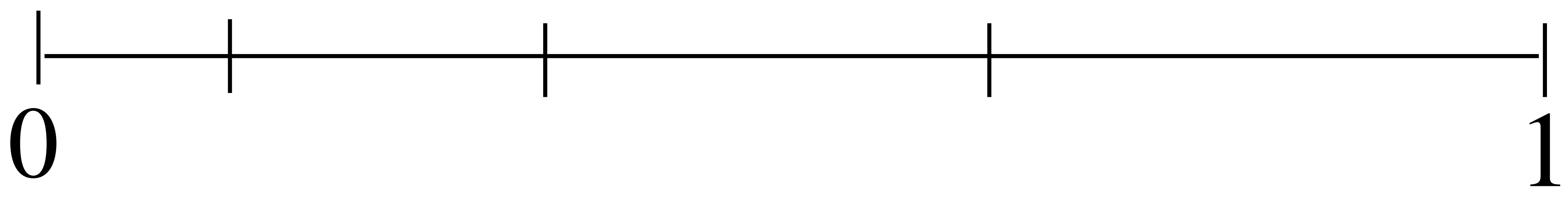
$$k_j^y = k_j^m = k_j^x = k(\lambda_e)$$

- Home consumption

$$u'(y_j) = a_j g(\lambda_e) \qquad u'(m_j) = \tau^* a_j^* g(\lambda_e)$$

$$j < j_m = \bar{j}_m \qquad j_m < j$$

- Foreign consumption



$$u^{*\prime}(x_j) = \tau a_j g(\lambda_e) \qquad u^{*\prime}(x_j) = a_j^* g(p_e) \qquad u^{*\prime}(y_j^*) = a_j^* g(p_e)$$

$$j < j_s \qquad j_s \leq j < j_x \qquad j_x < j$$

- Extensive margins of trade

$$A(j_m) = \frac{1}{\tau^*} \qquad A(j_s) = \tau \frac{g(\lambda_e)}{g(p_e)} \qquad A(j_x) = \tau \frac{g(\lambda_e)}{g(p_e) + (\lambda_e - p_e) g'(p_e)}$$

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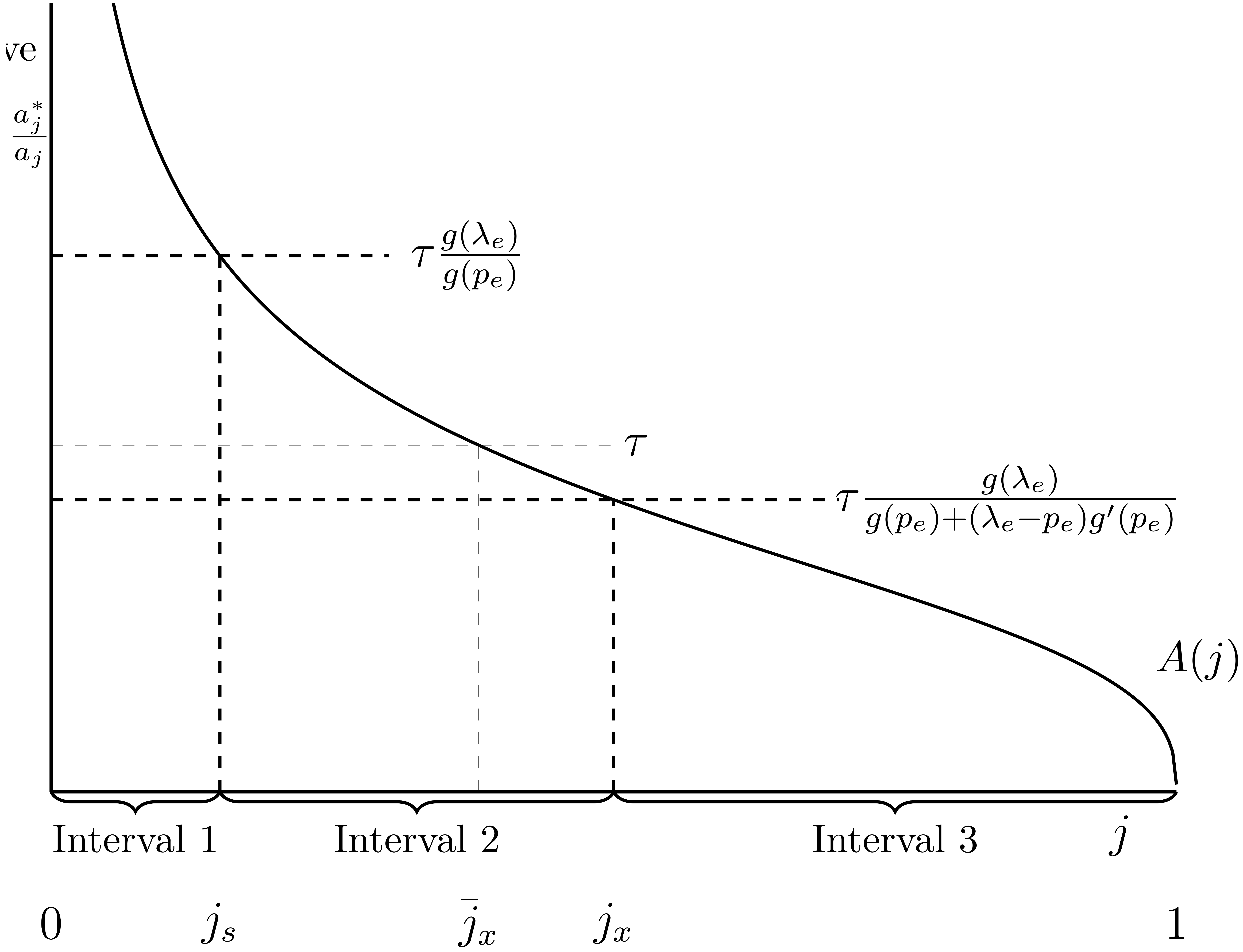
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$A(j)$
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- Border adjustments (per unit of CO_2)
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- Applies to imports and exports of energy, imports of goods (but not exports of goods)
  - keep import margin unchanged from BAU; CDVW logic
- It's partial: some tax remains on energy extraction, not just consumption
  - lower border adjustment means higher extraction tax, raising global energy price
  - low BA optimal if Foreign supply response low or demand response high; Markusen logic

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  - exports in which Home’s comparative advantage is weak
- Exporters still face carbon tax, retaining incentive for clean production
  - competitiveness ensured through subsidies for marginal exports
  - subsidy is per unit exported so doesn’t undercut carbon tax; Fischer and Fox logic
  - subsidy expands the Home’s export margin from BAU; can even lead to cross hauling

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- EU’s Emission Trading System and Carbon Border Adjustment Mechanism (CBAM)
  - carbon price hits producers: should shift burden to extraction by subsidizing energy imports!
  - CBAM follows the optimal unilateral policy: BA on imports with no rebate on exports
  - even closer if marginal exporters got free permits; mimics an output subsidy for exports

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Quantitative Version

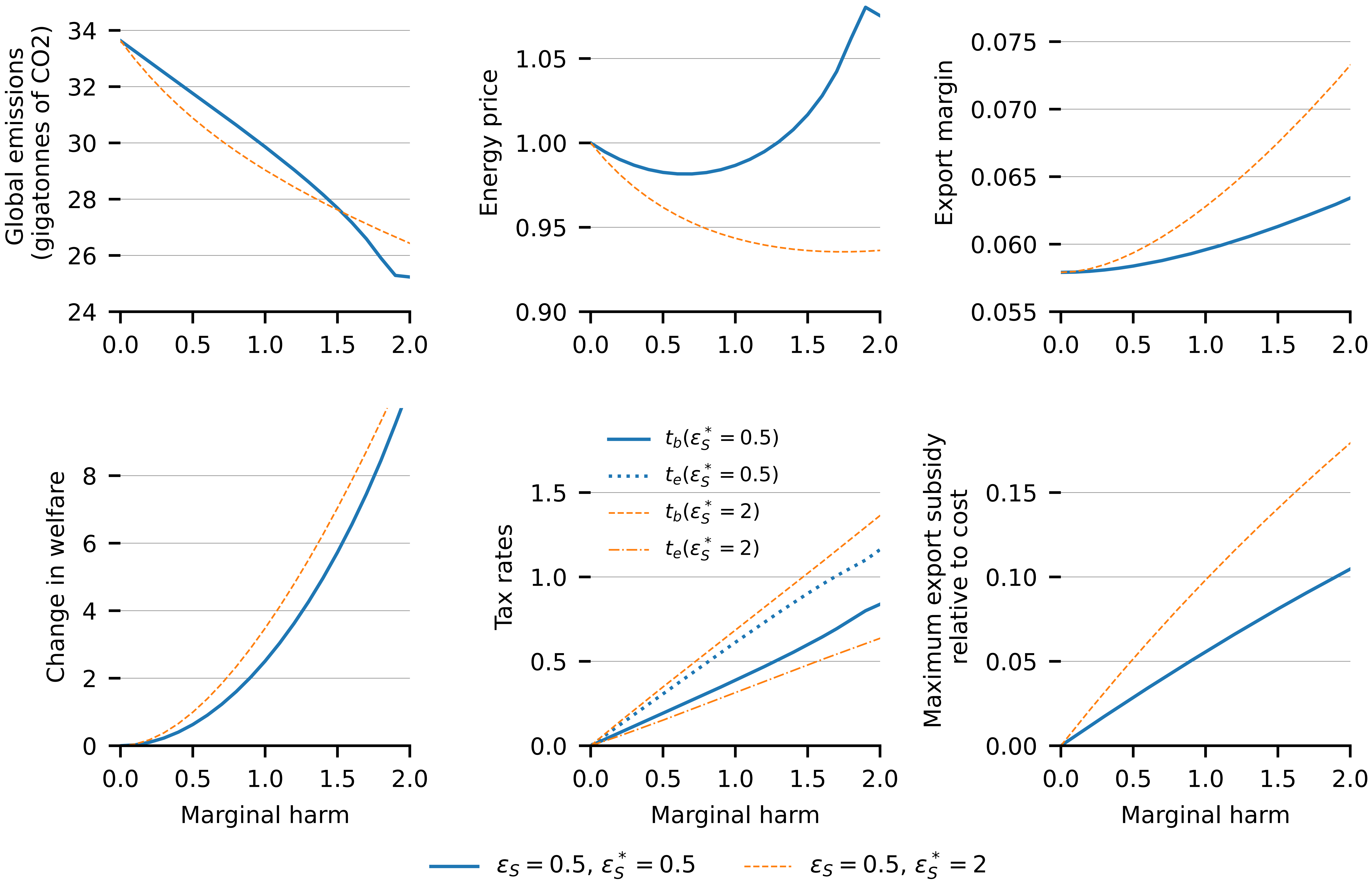
- Choose convenient functional forms with constant elasticities
- Calibrate to actual carbon flows, taking Home = OECD
- Choose a few additional parameters for trade elasticity, etc.
- Compute optimal policy for different values of global SCC
    - value of $\varphi^W = 1$ is approximately $150/ton of CO2

Carbon in the World

- Gigatonnes of CO_2 in 2018 (IEA and OECD TECO$_2$) with Home as the OECD

	Home	Foreign	Direct	Total
Home	$C_e^y = 8.7$	$C_e^m = 2.5$	$C_e^d = 2.5$	$C_e = 13.7$
Foreign	$C_e^x = 1.0$	$C_e^{y*} = 16.7$	$C_e^{d*} = 2.2$	$C_e^* = 19.9$
Direct	$C_e^d = 2.5$	$C_e^{d*} = 2.2$		
Total	$G_e = 12.2$	$G_e^* = 21.4$		$C_e^W = 33.6$
Extraction	$Q_e = 9.3$	$Q_e^* = 24.3$		$Q_e^W = 33.6$

Optimal Policy for the OECD



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    - combination of BAs matters, and trade can expand the reach of policy
- Practical policy prescription: combine supply-side and demand-side taxes
- Much is left to be explored with richer quantitative models!