“Alternative Vertical Market Structures and CBAMs”

Ian Sheldon (Ohio State University)
Steve McCorriston (University of Exeter)

Track Session:
“Agri-Food Trade: Is There A Role For Carbon Border Adjustment Mechanisms (CBAMs)?”

AAEA Annual Meetings
July 28-30, 2024, New Orleans, LA

EU CBAM Mechanism

- EU has introduced "Fit for 55 Package" designed to meet 2030 target of reducing GHG emissions by 55% compared to 1990 (European Commission, 2021)
- Changes to EU's emission trading system (ETS) combined with CBAMs on defined imports:
  - Progressive reduction of free allowances to sectors with carbon *leakage* risk, e.g., fertilizers*, iron and steel, aluminum, chemicals, and cement
  - Importers of covered products required to purchase CBAM "certificates", price reflecting EU emission allowances, surrendered to cover embodied emissions
- No refunds on exports

* For N production, 3.5-10.3 $kgCO_2$ equiv./kg of N (Walling and Vaneeckhaute, 2020)

Vertical Market Structure

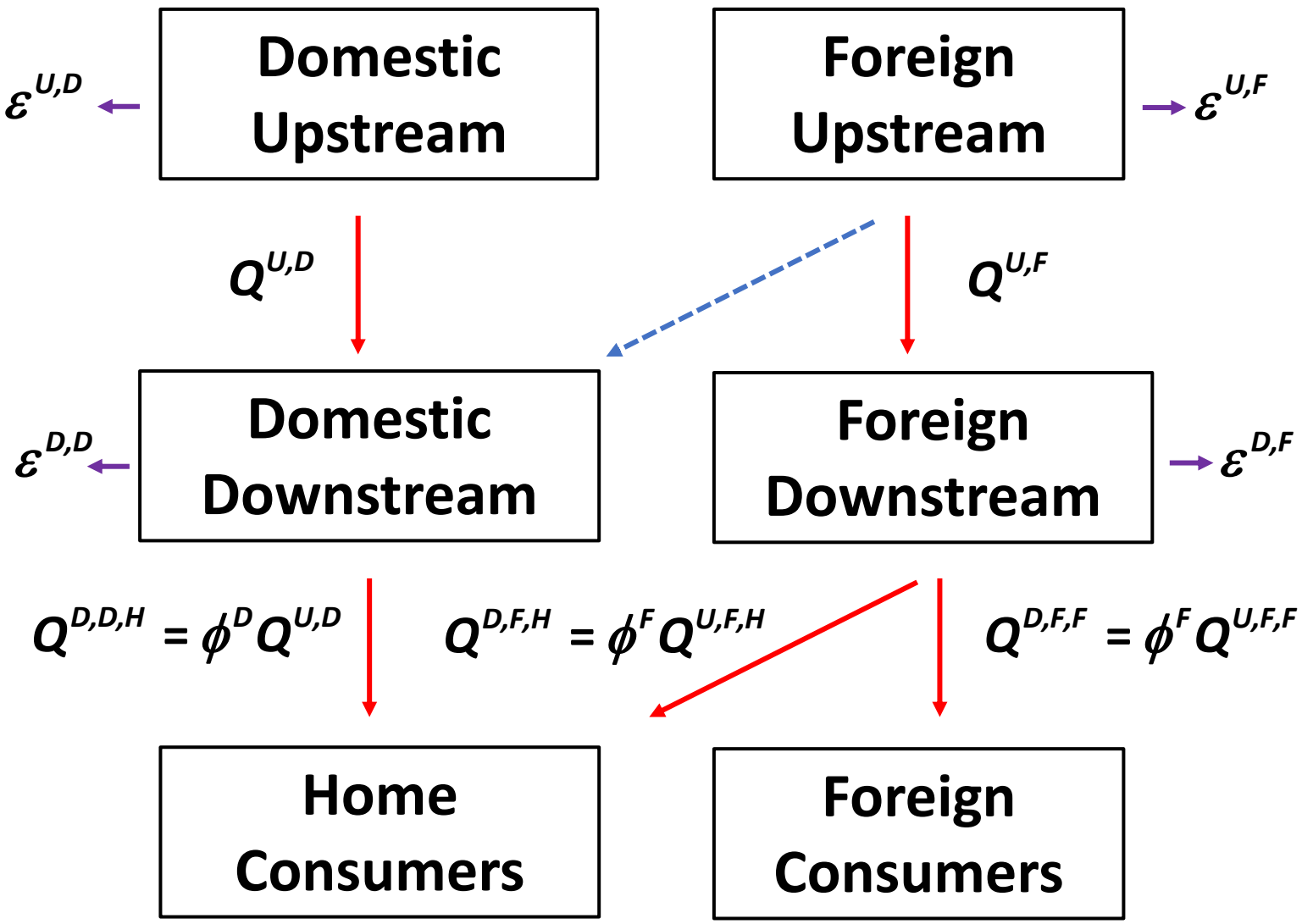
- **Key issues in analyzing CBAMs in vertical markets:**
  - **Input-output technology**
  - **GHG emissions at successive stages, e.g., electricity generation and fertilizer production**
  - **Horizontal market competition (Fowlie *et al*., 2016)**
  - **Vertical market competition, i.e., double marginalization, pass-through and pass-back (Weyl and Fabinger, 2013)**
- **Approach: build successive oligopoly model incorporating trade/climate policy (McCorriston and Sheldon, 2010)**
- **Policy(ies): domestic carbon price c_p^D combined with t^{CBAM} targeted at embodied carbon in imports**

Vertical Markets Model

- Domestic and foreign upstream production of intermediate (electricity) used in downstream production (fertilizer)
- Restrict analysis to downstream product being traded, i.e., foreign downstream product exported to domestic market
- Linear inverse (derived) demand system, home consumers treating domestic/foreign products as differentiated
- Leontief-type technology, ϕ is input-output coefficient
- θ^S captures "intensity of competition" (Ritz, 2024) as perceived by firms at stage *S*:

$$\theta^S = \frac{\left(1 + \frac{\partial q^S_{-i}}{\partial q^S_i}\right)}{n^S}, \; i = 1,\ldots,n^S, \; \theta^S \in [0,1]$$

Vertical Market Structure



Carbon Costs

- Assume carbon cost functions have specific form
- Focusing on downstream production:

$$c_P^D \varepsilon^{D,D}(Q^{D,D,H}) = c_P^D \varepsilon^{D,D}(\alpha^D + \beta^D Q^{D,D,H})$$

$$c_P^F \varepsilon^{D,F}(Q^{D,F,H} + Q^{D,F,F}) = c_P^F \varepsilon^{D,F}[\alpha^F + \beta^F (Q^{D,F,H} + Q^{D,F,F})]$$

where $c_P^D \varepsilon^{D,D}(Q^{D,D,H})' = \beta^D c_P^D \varepsilon^{D,D}$

and $c_P^F \varepsilon^{D,F}(Q^{D,F,H} + Q^{D,F,F})' = \beta^F c_P^F \varepsilon^{D,F}$

- Similar functions can be defined for upstream production

CBAMS and Carbon Leakage

- CBAMs are adapted border tax adjustments (BTAs)
- BTA analysis about *competitive equality*, e.g., see Poterba and Rotemberg (1995), McCorriston and Sheldon (2005)
- CBAM analysis focuses on *leakage, e.g.,* (Böhringer *et al*., 2018), but typically ignores market structure
- Allowing for vertical market structure, domestic carbon tax has multi-market effect on leakage *L*:

$$L = -\left[\frac{\{\varepsilon^{D,F}.d(Q^{D,F,H}+Q^{D,F,F})\}+\{\varepsilon^{U,F}.dQ^{U,F}\}}{\{\varepsilon^{D,D}.dQ^{D,D,H}\}+\{\varepsilon^{U,D}.dQ^{U,D}\}}\right]$$

- Sheldon and McCorriston (2017) only implicitly capture upstream leakage in analysis of CBAMs in North American aluminum sector

Definition of CBAMS

- CBAMs targeted at imports of foreign downstream product
- Designed to correct for domestic carbon price c_p^D , with possible options:

(i) $CBAM = c_P^D$; (ii) $CBAM = (c_P^D - c_P^F)$;

(iii) $CBAM = c_P^D \varepsilon^{D,D}(Q^{D,D,H})$; (iv) $CBAM = (c_P^D - c_P^F)\varepsilon^{D,D}(Q^{D,D,H})$;

(v) $CBAM = (c_P^D - c_P^F)\varepsilon^{D,F}(Q^{D,F,H} + Q^{D,F,F})$

- (i)-(iv) assume foreign emissions are unknown, CBAMs not fully reflecting foreign carbon costs

(v) is "true" CBAM given knowledge of $\varepsilon^{D,F}(Q^{D,F,H} + Q^{D,F,F})$

Solving Model *Case 1*

- **Inverse demand functions:**

$$P_1^H = a_1^H - b_1 Q^{D,D,H} - KQ^{D,F,H}$$

$$P_2^H = a_2^H - b_2 Q^{D,F,H} - KQ^{D,D,H}$$

$$P^F = a^F - b^F Q^{D,F,F}$$

- **Profit functions for representative firm(s):**

$$\pi_i^{D,D,H} = \left[P_1^H - P_I^D - c_P^D \varepsilon^{D,D} (Q^{D,D,H}) \right] q_i^{D,D,H}$$

$$\pi_j^{D,F} = \pi_j^{D,F,H} + \pi_j^{D,F,F}, \text{ where}$$

$$\pi_j^{D,F,H} = \left[P_2^H - P_I^F - c_P^f \varepsilon^{D,F} (Q^{D,F,H} + Q^{D,F,F}) - t^{CBAM} \right] q_j^{D,F,H}$$

$$\pi_j^{D,F,F} = \left[P^F - P_I^F - c_P^f \varepsilon^{D,F} (Q^{D,F,H} + Q^{D,F,F}) \right] q_j^{D,F,F}$$

Solving Model *Case 1*

- **Derive aggregate first-order conditions, and substitute in inverse demand functions:**

$$a_1^H - P_I^D - \left[b_1(1+\theta^{D,D,H}) + \beta^D c_P^D \varepsilon^{D,D}(1+\theta^{D,D,H}) \right] Q^{D,D,H} - KQ^{D,F,H} - c_P^D \varepsilon^{D,D}$$

$$a_2^H - P_I^F - t^{CBAM} - \left[b_2(1+\theta^{D,H,F}) + \beta^F c_P^F \varepsilon^{D,F}(1+\theta^{D,H,F}) \right] Q^{D,F,H} - KQ^{D,D,H}$$
$$- c_P^F \varepsilon^{D,F} - \beta^F c_P^F \varepsilon^{D,F} Q^{D,F,F} \theta^{D,H,F}$$

$$a^F - P_I^F - \left[b_2(1+\theta^{D,F,F}) + \beta^F c_P^F \varepsilon^{D,D}(1+\theta^{D,H,F}) \right] Q^{D,F,F} - KQ^{D,F,H}$$
$$- c_P^F \varepsilon^{D,F} - \beta^F c_P^F \varepsilon^{D,F} Q^{D,F,H} \theta^{D,F,H}$$

- **Re-arrange into matrix form**

Vertical Markets Model *Case 1*

Downstream Only

- **Equilibrium solution:**

$$\begin{bmatrix} \chi_1 & K & 0 \\ K & \chi_2 & (1+\theta^{D,H,F})c_P^F\varepsilon^{D,F} \\ 0 & (1+\theta^{D,F,F})c_P^F\varepsilon^{D,F} & \chi_3 \end{bmatrix} \begin{bmatrix} Q^{D,D,H} \\ Q^{D,F,H} \\ Q^{D,F,F} \end{bmatrix} = \begin{bmatrix} a_1^H - c_P^D\varepsilon^{D,D} - P_I^D \\ a_2^H - c_P^F\varepsilon^{D,F} - P_I^F - t^{CBAM} \\ a^F - c_P^F\varepsilon^{D,F} - P_I^F \end{bmatrix}$$

$$\chi_1 = \left[b_1(1+\theta^{D,D,H}) + \beta^D c_P^D \varepsilon^{D,D}(1+\theta^{D,D,H}) \right]$$

where:

$$\chi_2 = \left[b_2(1+\theta^{D,H,F}) + \beta^F c_P^F \varepsilon^{D,F}(1+\theta^{D,H,F}) \right]$$

$$\chi_3 = \left[b_2(1+\theta^{D,F,F}) + \beta^F c_P^F \varepsilon^{D,F}(1+\theta^{D,H,F}) \right]$$

Vertical Markets Model – *Case 2*

Upstream and Downstream

- **Equilibrium solution:**

$$\begin{bmatrix} E_1 & \phi^F K & 0 \\ \phi^D K & E_2 & (1+\theta^{U,F,F})c_P^F \varepsilon^{U,F} \\ 0 & (1+\theta^{U,F,H})c_P^F \varepsilon^{U,F} & E_3 \end{bmatrix} \begin{bmatrix} Q^{U,D} \\ Q^{U,F,H} \\ Q^{U,F,F} \end{bmatrix} = \begin{bmatrix} a_1^H - c_P^D \varepsilon^{D,D} - P_A^D \\ a_2^H - c_P^F \varepsilon^{D,F} - P_A^F - t^{CBAM} \\ a^F - c_P^F \varepsilon^{D,F} - P_A^F \end{bmatrix}$$

$$E_1 = \left[\theta^F \chi_1 (1+\theta^{U,D}) + \beta^{U,D} c_P^D \varepsilon^{U,D} (1+\theta^{U,D}) \right]$$

where:

$$E_2 = \left[\phi^F \chi_2 (1+\theta^{U,F,H}) + \beta^{U,F} c_P^F \varepsilon^{U,F} (1+\theta^{U,F,H}) \right]$$

$$E_3 = \left[\phi^F \chi_3 (1+\theta^{U,F,F}) + \beta^{U,F} c_P^F \varepsilon^{U,F} (1+\theta^{U,F,F}) \right]$$

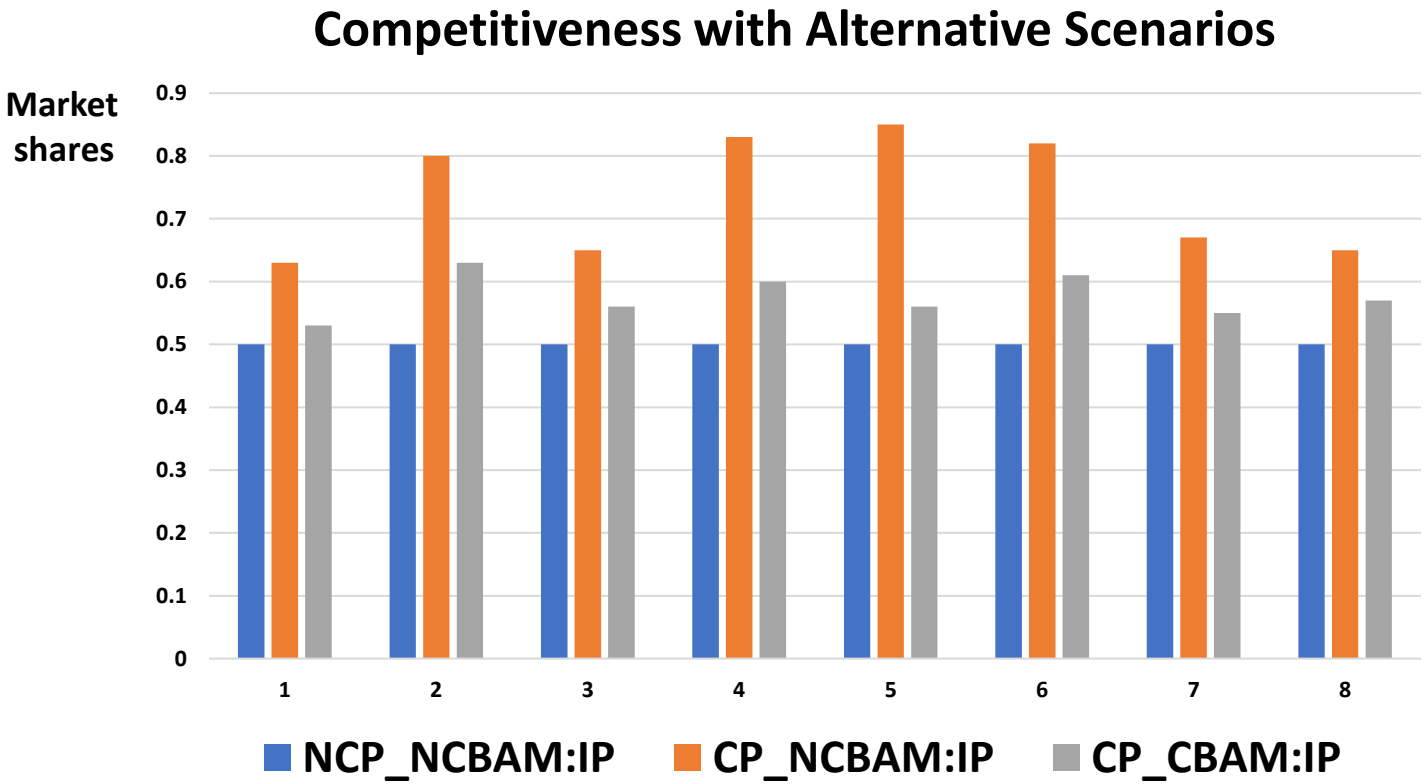
Vertical Markets Model: Example

- Across home and foreign markets: (i) symmetric market shares at each stage, and (ii) $\varepsilon^{U,D} = \varepsilon^{U,F}$, $\varepsilon^{D,D} = \varepsilon^{D,F}$
- Carbon prices $c_P^D \geq c_P^F$, and $t^{CBAM} = (c_P^D - c_P^F)$
- Carbon leakage defined as: $\dfrac{\Delta Q^F - \Delta Q^D}{Q^F + Q^D}$

  (static oligopoly setting, i.e., no entry/exit of firms)
- Scenarios:

1. $\phi = 1$; $\theta = 1$	5. $\phi = 0.2$; $\theta^D = 0.2$; $\theta^U = 0.6$
2. $\phi = 0.2$; $\theta = 1$	6. $\phi = 0.2$; $\theta^D = 0.6$; $\theta^U = 0.2$
3. $\phi = 1$; $\theta = 0.5$	7. $\phi = 1$; $\theta^D = 0.2$; $\theta^U = 0.6$
4. $\phi = 0.2$; $\theta = 0.5$	8. $\phi = 1$; $\theta^D = 0.6$; $\theta^U = 0.2$

Competitiveness and CBAMs

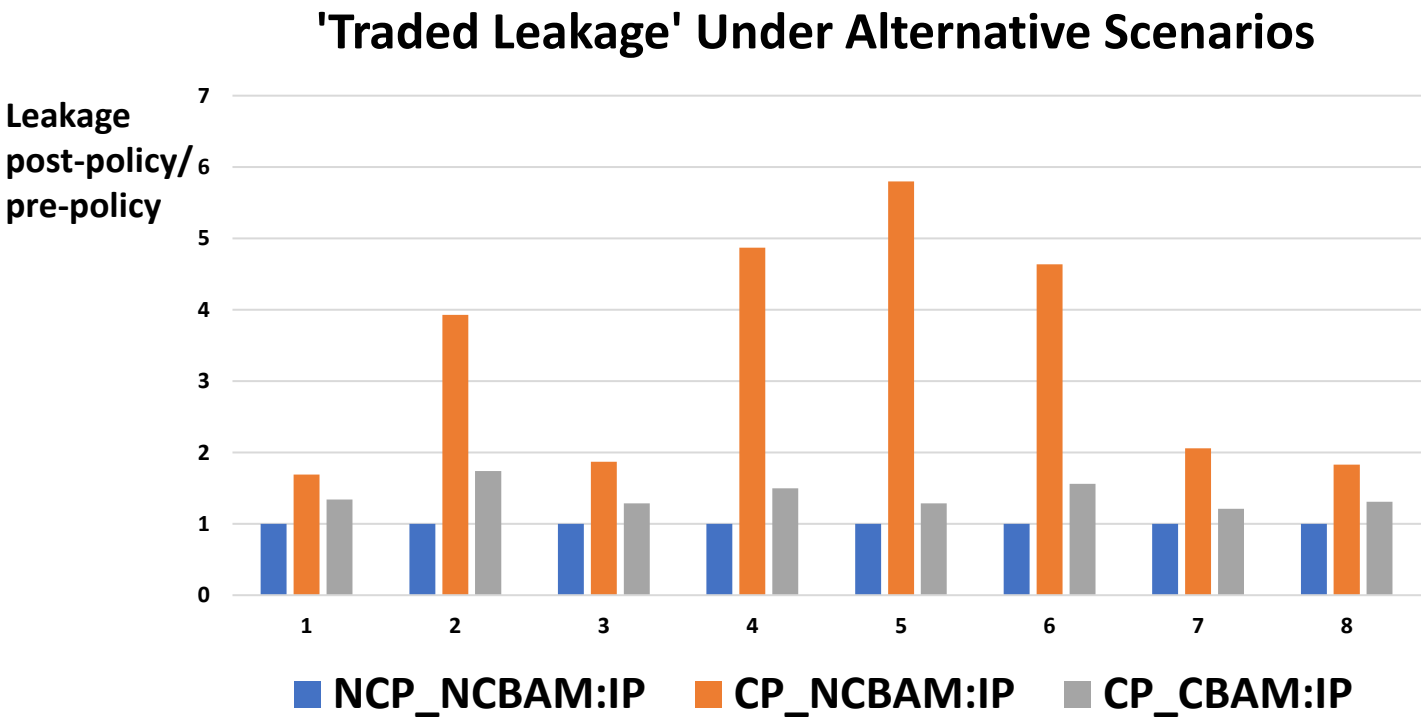


Domestic firms lose competitiveness with carbon price, not restored with CBAM

Input-output structure matters given downstream firms face higher intermediate costs with carbon price imposed upstream

Loss of competitiveness greater with more intense competition at each stage, but matters less than input-output structure and passthrough of carbon price

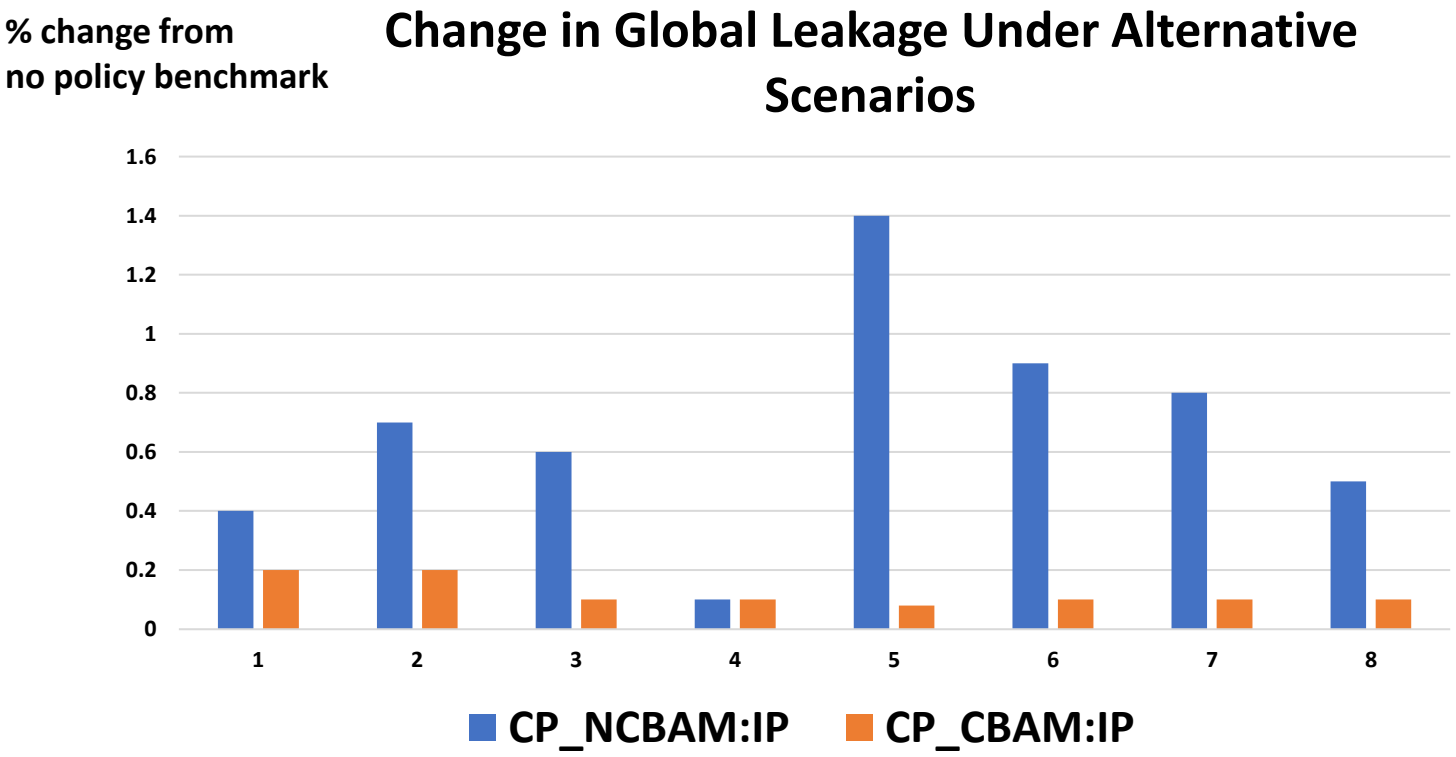
Leakage and CBAMs



Leakage here only due to home country trade in downstream product

Similar drivers, with input-output structure mattering most

Leakage and CBAMs



Changes in leakage relatively small due to (i) the rest of the world is large relative to imports by the home country, (ii) plus adding on rest of the world upstream emissions minimizes impact of changes in imports by home country

Summary and Conclusions

- Under revised EU climate policy, “dirty” industries will no longer receive free allowances, carbon leakage being targeted with CBAMs
- Repeated focus by EU Commission on challenge of extending CBAMs along complex value chains
- Objective in paper to analyze CBAMs in context of vertical market structure/imperfect competition
- Analysis important in several dimensions: complexity of value chains; successive oligopoly and pass-through/pass-back; definition of CBAMs
- Next step(s): expand vertical market structures beyond example, and calibrate with actual data