25% of CO2 Emissions from Fossil Fuels are from Production of Goods for Export (The US is still the world's biggest emitter of CO2, not China)

Mt CO2/y. Excludes non-CO2 GHGs.
How to Allocate Emissions between Co-Products?
Co-Product Example 1

Mexico

US

LIGHT FUEL OIL
ETHYLENE GASOLINE

Mexico

GASOLINE
Co-Product Example 2

China

EU

STEEL

STEEL SLAG

China
Co-Product Example 3

Turkey

EU

BORIC ACID

Turkey

BORIC OXIDE
How to Allocate Emissions between Co-Products?
**Importer’s Profit**

\[
\max_{q \geq 0, \ i \in \{V,M,S\}} \ (x - yq)q - (p_a + \theta)q - tq\gamma_i(l)
\]

**Supplier’s Profit**

\[
\max_{p_a \geq 0, \ e \in \{e_H,e_L\}} \ q^* (p_a + p_b - c(e)) - I(e)
\]
Allocation Schemes

- **Value (V)**
  \[ \gamma_V(\ell) = e \frac{qp_a}{qp_a + qp_b} = e \frac{pa}{pa + pb} \]

- **Mass (M)**
  \[ \gamma_M(\ell) = e \frac{q\beta_a}{\beta_a q + \beta_b q} = e \frac{\beta_a}{\beta_a + \beta_b} \]

- **Substitution (S)**
  \[ \gamma_S(\ell) = e - e_b \]

Flexibility for importer to choose one of the above.

where \( \ell \doteq [e, e_b, p_a, p_b, \beta_a, \beta_b] \). Set \( \beta_a = \beta_b = 1 \) wlog.

*Source: Scope 3 Accounting and Reporting Standards, WRI*
Research Question

Effect of the *allocation scheme* on

- emissions
- importer’s and supplier’s profit
- trade quantity
- consumer surplus
- social welfare?
Proposition

Given flexibility, the importer selects the allocation scheme that maximizes

- emissions.
- supplier’s profit.
- consumer surplus.

Flexibility decreases welfare if and only if the social cost of emissions is above a threshold.
Supplier sets \( p_a \) and then Importer chooses \( \gamma_i, i \in \{V, M, S\} \)

**Proposition**

Giving the importer flexibility to choose an allocation scheme

- may decrease emissions
- may decrease the importer’s profit
- increases the supplier’s profit
Supplier sets $p_\alpha$ and then Importer chooses $\gamma_i, i \in \{V, M, S\}$

Example where flexibility reduced emissions and the profit of the importer.
Supplier sets $p_a$ and then Importer chooses $\gamma_i, i \in \{V, M, S\}$

<table>
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**Proposition**

If the allocation is based on Mass or Substitution, emissions decrease with the tax rate $t$. (With discrete choice of $e$, emissions may increase with the tax rate $t$.)

If the allocation is based on Value, emissions may *increase* with the tax rate $t$.

**Intuition:**

Under Value-based allocation, as tax rate increases, supplier is motivated to reduce $p_a$ in order to reduce the effective tax and sell more.
Supplier sets $p_a$ and then Importer chooses $\gamma_i, i \in \{V, M, S\}$

\[ p_a|_M - p_a|_V > t(\gamma_V (p_a|_V) - \gamma_M (p_a|_M)) \]
Supplier sets \( p_a \) and then Importer chooses \( \gamma_i, i \in \{V, M, S\} \)

**Proposition**

If the allocation is based on Mass or Substitution, emissions decrease with the tax rate \( t \).
(With discrete choice of \( e \), emissions may increase with the tax rate \( t \).)

If the allocation is based on Value, emissions may *increase* with the tax rate \( t \).

**Intuition:**

Under Value-based allocation, as tax rate increases, supplier is motivated to reduce \( p_a \) in order to reduce the effective tax and sell more.
Supplier sets $p_a$ and then Importer chooses $\gamma_i$, $i \in \{V, M, S\}$

**Lemma**

Let the difference in total emissions be $D \doteq TE_V - TE_M$.

\[ \frac{\partial D}{\partial x} < 0, \quad \frac{\partial D}{\partial c} < 0, \quad \frac{\partial D}{\partial p_b} > 0 \]

**Remark**

Increasing the importer’s market $x$ and the supplier’s cost $c$ decreases emissions under value-based allocation relative to mass-based allocation.

Increasing the supplier’s selling price for co-product B, i.e. $p_b$, increases emissions under value-based allocation relative to mass-based allocation.
Proposition

Suppose that the emissions allocation is value-based or flexible and that firms can write complete contracts. Then, the emissions tax is ineffective.

Corollary

Flexibility maximizes

- total emissions
- firms’ profits
- consumer surplus.

Flexibility decreases social welfare.

Intuition

The importer chooses value-based allocation. The optimal contract specifies a fixed transfer payment $T$ to the supplier, the joint-profit-maximizing emissions intensity and quantity, and sets $p_a = 0$. Effective emission tax is zero.
Policy Implication

Value-based allocation should account for all payments and non-financial assistance that the importer provides to the supplier, not just the wholesale price per unit:

\[ \gamma V = e \frac{\overline{p}_{a}}{\overline{p}_{a} + p_{b}} \]

where \( \overline{p}_{a} \equiv p_{a} + \frac{T}{q} \), total compensation per unit purchased.
Proposition

Suppose that Value-based allocation accounts for the ‘total compensation per unit purchased’.

If the supplier incurs no fixed cost of production, $F(e) = 0$, then flexibility maximizes emissions.

However, if $F(e) > 0$ then flexibility may reduce emissions.
Contracting to maximize joint profit

An example where flexibility reduced emissions.
Take-Aways

- Flexibility for the importer to choose an allocation scheme may *reduce*
  - emissions.
  - importer’s profit.
  - trade quantity.
  - consumer surplus.

- Flexibility increases the supplier’s profit.

- Under Value-based allocation, emissions may increase with the tax rate.

- With Value-based allocation as currently implemented, an emission tax is *ineffective*
  under complete contracts. (Firms will minimize $p_a$)
Supplier sets $p_a$ and then Importer chooses $\gamma_i$, $i \in \{V, M, S\}$

Consider the case of allocation flexibility. Suppose $\gamma_M(\cdot) < \gamma_S(\cdot)$

Proposition

The importer prefers value-based allocation to mass-based allocation when

- her market is small
- her costs are high
- the supplier’s costs are low
- tax rate is high

Formally,

\[
\min(\gamma_V, \gamma_M) = \begin{cases} 
\gamma_V = \frac{ep_a^*}{p_a^* + p_b} & \text{if } x - \theta + c < 3p_b + te \min \left\{ 1 - \frac{c}{4p_b}, \frac{1}{2} \right\} \\
\gamma_M = \frac{c}{2} & \text{if } x - \theta + c > 3p_b + te \max \left\{ 1 - \frac{c}{4p_b}, \frac{1}{2} \right\}
\end{cases}
\]
The importer prefers

- **Value** if and only if
  \[ p_a < p_b \quad \text{and} \quad e > e_b \left( 1 + \frac{p_a}{p_b} \right) \]

- **Mass** if and only if
  \[ p_a \geq p_b \quad \text{and} \quad e > 2e_b \]

- **Substitution** if and only if
  \[ e \leq e_b \min \left\{ 1 + \frac{p_a}{p_b}, 2 \right\} \]