Potential carbon leakage risk: A cross-sector cross-country assessment in the OECD area

Julio G. Fournier Gabela[1] & Florian Freund[1]
[1]Institute of Market Analysis

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A unilateral race to climate neutrality?

- Achieving climate targets requires more stringent mitigation policies incl. the participation of **all sectors** (Rogelj et al. 2018; Wollenberg et al. 2016).
- However, in a fragmented global climate regime, unilateral mitigation policies affecting sectors' production costs increase **carbon leakage risk**

➡ **Lose-lose situation**: few (or negative) GHG emission savings at (high) economic cost

➡ Also happens in **downstream sectors** via inputs

➡ Major barrier to sectors' **acceptance** of more stringent climate policy (Grosjean et al. 2018)

Sectoral carbon leakage risk assessments

- *Ex-post*, e*x-ante* w/ economic models, e*x-ante* w/ EITE metric (Sato et al. 2015; Martin et al. 2014)
- However, while most studies report economy-wide carbon leakage rates, sector-level assessments typically focus on energy-intensive sectors
- Furthermore, because studies focus on the effects of particular climate policies on particular units, it is challenging to compare results across studies

Our study

- Uses the EITE metric to estimate potential carbon leakage risk in **all sectors** in **all OECD countries** under three different (but comparable) climate policy scenarios
- Main findings:
  - potential carbon leakage risk in **downstream sectors** as high as in “directly targeted” sectors
  - **AFOLU+** and **transport** sectors have, on average, a higher potential carbon leakage risk than energy-intensive sectors
  - high risk variability across OECD countries

The EITE metric

- Sector's emission intensity (proxy for relative carbon cost impact)

$$ei_j^{d\,(TOT)} = \frac{\left(direct\_emi_j^d + \widehat{indirect\_emi_j^d}\right) \cdot carbon\_price}{gross\_value\_added_j^d} \qquad (1)$$

→ Use of GVA suggested by Sato et al. (2015)

- Sector's trade intensity (proxy for trade responsiveness)

$$te_j^d = \frac{exports_j^{d\,(non-OECD)} + imports_j^{d\,(non-OECD)}}{x_j^d + imports_j^{d\,(non-OECD)}} \qquad (2)$$

→ Excluding intra-OECD trade suggested by Martin et al. (2014)

- Sector's carbon leakage risk:

$$eite_j^{d\,(TOT)} = ei_j^{d\,(TOT)} \cdot te_j^d \qquad (3)$$

→ Simultaneous use of 2 components suggested by several authors

EE-MRIO model

- To estimate indirect emissions, we use an environmentally-extended (**EE**) multi-regional input-output (**MRIO**) model
- We begin by defining sectors' production GHG emissions :
  - $\mathbf{total\_emi \equiv direct\_emi + indirect\_emi \leftrightarrow rx \equiv cx + mZ}$ (4)
- where,
  - $\mathbf{x} = [x_j^d]$ is a vector of output, $\mathbf{Z} = [z_{ij}^{od}]$ is a matrix of (global) intermediate demand
  - $\boldsymbol{r} = [r_j^d]$, $\boldsymbol{c} = [c_j^d]$, $\boldsymbol{m} = [m_i^o]$ are total, direct and indirect GHG emission coefficients

EE-MRIO model

- Assuming that $m_i^o = r_j^d$ (Hertwich & Wood, 2018), replacing **r** and **m** by $\hat{\mathbf{m}}$ in equation 4, and re-arranging yields:

$$\widehat{\boldsymbol{indirect\_emi}} = \hat{\mathbf{m}}\mathbf{Z} = \mathbf{c}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{Z} \qquad (5)$$

- where,
  - **I** a (NP x NP) identity matrix, and $\mathbf{A} = \boldsymbol{Zx}^{-1}$ is a coefficient matrix, and $(\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse matrix

Climate policy scenarios

Scenario name	Domestic climate policies imply
Total	carbon costs on **all** domestic sectors' GHG emissions
Direct	carbon costs on domestic sectors' **direct** GHG emissions
Indirect	carbon costs on domestic sectors' **indirect** GHG emissions

Data

- **Economic:** GTAP-MRIO database (Carrico et al. 2020)
  - based on GTAP 10A: 141 countries and 65 economic sectors for 2014
- **Direct GHG emissions:** GTAP CO_2 and non-CO_2 GTAP databases (Lee 2008; Chepeliev 2020)
  - we use cradle-to-gate emissions only
  - databases exclude LULUC emissions
- Uniform benchmark carbon price: \$30/tCO_2e

GTAP sectors: EI vs. TE under the “total” scenario

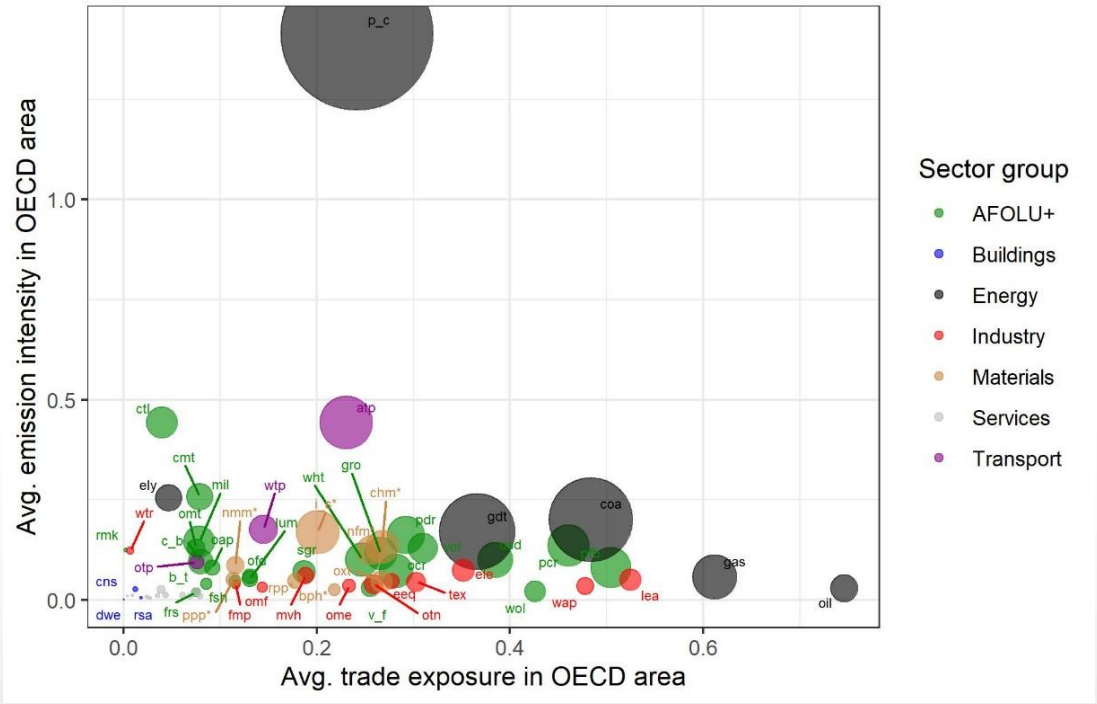

Figure 1 Emission intensity vs. trade exposure under the “total” scenario, OECD country averages by sector. Note: The circles’ area is proportional to the cross-country variation (standard deviation) of the EITE metric in the OECD area.

GTAP sectors: Top 10 according to carbon leakage risk (avg. OECD)

	Policy scenario								
	Total			Direct			Indirect		
No.	Sector	Sector group	EITE value	Sector	Sector group	EITE value	Sector	Sector group	EITE value
1	Petroleum & coal products	Energy	0.424 (0.771)	Petroleum & coal products	Energy	0.262 (0.772)	Petroleum & coal products	Energy	0.161 (0.174)
2	Coal	Energy	0.125 (0.232)	Coal	Energy	0.106 (0.222)	Processed rice	AFOLU+	0.042 (0.034)
3	Air transport	Transport	0.106 (0.089)	Gas manufacture & distribution	Energy	0.076 (0.162)	Vegetable oils & fats	AFOLU+	0.035 (0.026)
4	Gas manufacture & distribution	Energy	0.095 (0.190)	Air transport	Transport	0.073 (0.062)	Ferrous metals	Materials	0.033 (0.047)
5	Processed rice	AFOLU+	0.055 (0.055)	Gas	Energy	0.023 (0.035)	Air transport	Transport	0.032 (0.028)
6	Gas	Energy	0.044 (0.088)	Plant-based fibers	AFOLU+	0.019 (0.025)	Chemical products	Materials	0.029 (0.028)
7	Ferrous metals	Materials	0.040 (0.060)	Cereal grains not elsewhere classified (n.e.c.)	AFOLU+	0.019 (0.022)	Metals n.e.c.	Materials	0.029 (0.021)
8	Paddy rice	AFOLU+	0.039 (0.044)	Paddy rice	AFOLU+	0.019 (0.018)	Leather products	Industry	0.025 (0.013)
9	Plant-based fibers	AFOLU+	0.039 (0.051)	Wheat	AFOLU+	0.018 (0.025)	Bovine meat products	AFOLU+	0.021 (0.022)
10	Chemical products	Materials	0.038 (0.034)	Bovine animals, horses & other equines	AFOLU+	0.017 (0.028)	Paddy rice	AFOLU+	0.021 (0.033)

7-sectors : EITE component contribution (avg. OECD)

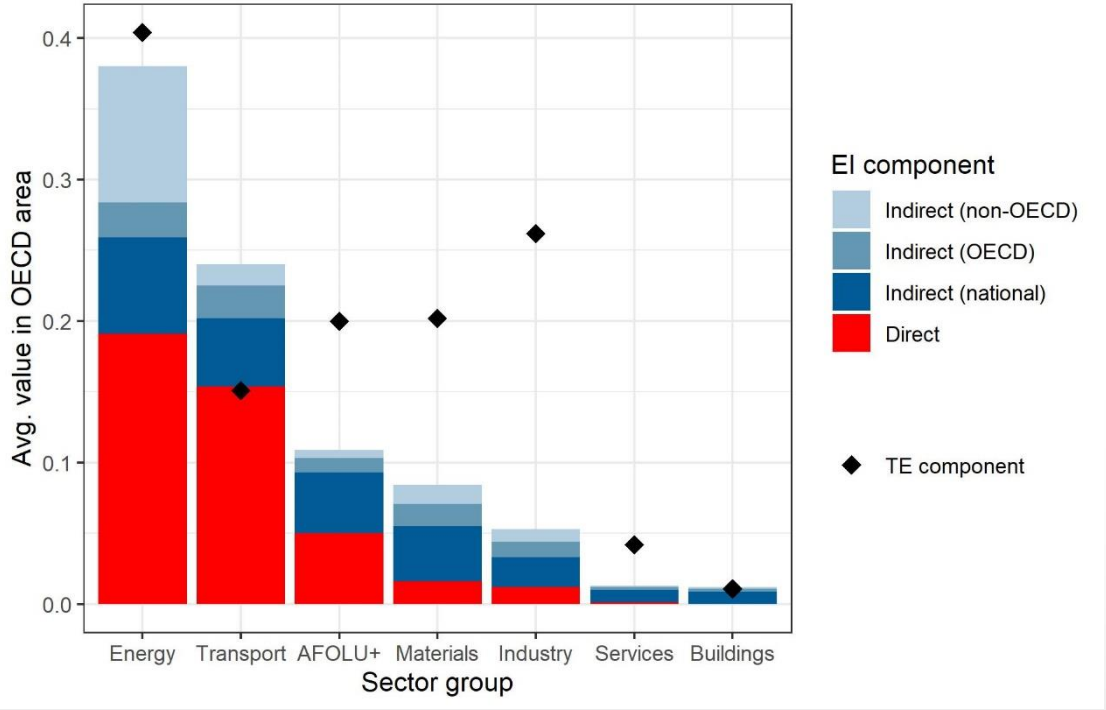

Figure 2 Average value of EITE components in OECD countries, by sector group. Note: averages are calculated by taking the mean of the EITE component value over sectors belonging to the sector group in OECD countries.

7-sectors: Cross-country variation

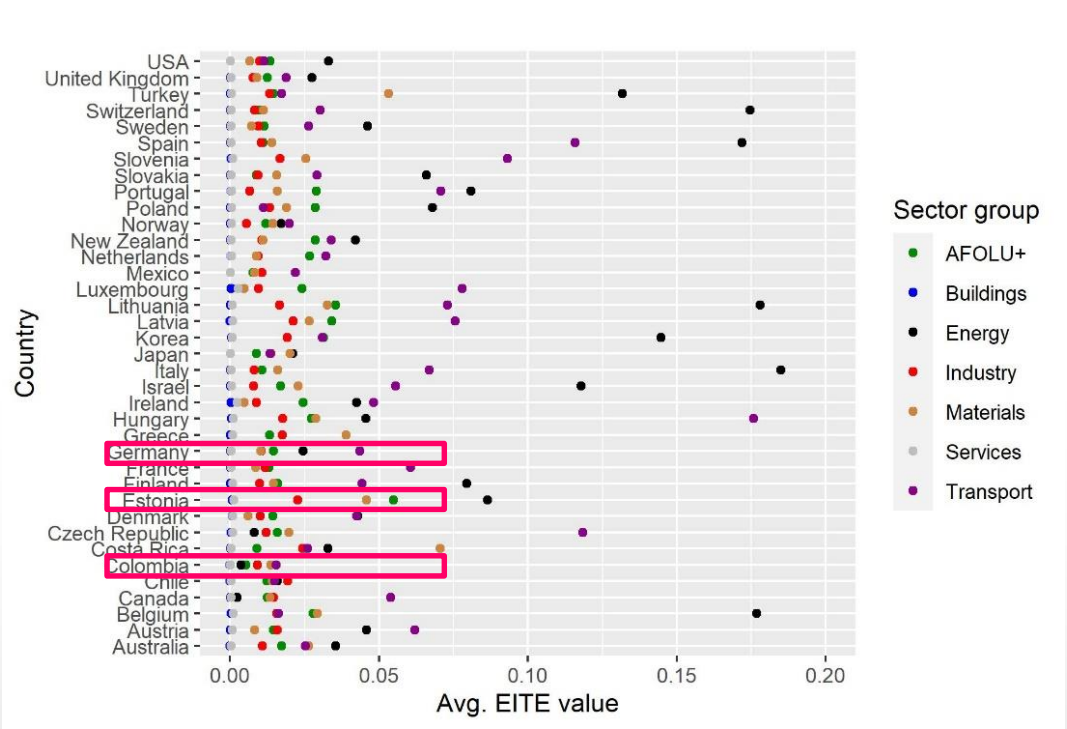

Figure 3 Average EITE value under the "total" scenario, by OECD country. Notes: to improve visualization, this figure does not show the following EITE values belonging energy: Slovenia (1.454), Luxemburg (0.726), Latvia (0.556), France (0.302), Netherlands (0.264), and Greece (0.232). Averages are calculated by taking the mean of the EITE value over sectors belonging to the sector group in OECD countries.

Conclusions

Our results suggest that:

- sectors traditionally excluded from climate policy could have a relatively high carbon leakage risk under all climate policy scenarios
- carbon leakage risk has a high cross-country variability

Developing anti-leakage mechanisms, at least for the most vulnerable sectors, is crucial to increase their acceptance of more stringent climate policies

Thanks for your attention!

Further questions and comments?

julio.fournier@thuenen.de

Appendix: Bibliography

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Appendix: The Z-matrix

$$\mathbf{Z} = \begin{pmatrix} \mathbf{Z}^{11} & \mathbf{Z}^{12} & \cdots & \mathbf{Z}^{1P} \\ \mathbf{Z}^{21} & \mathbf{Z}^{22} & \cdots & \mathbf{Z}^{2P} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{Z}^{P1} & \mathbf{Z}^{P2} & \cdots & \mathbf{Z}^{PP} \end{pmatrix}$$

Appendix: Names and description of the GTAP variables used in the EE-MRIO model

Data type	Variable name	Description
Economic	VDFM	Intermediates - Firms' domestic purchases at market prices
	VIFM	Intermediates - Firms' import purchases at market prices
	VXMD	Trade - Bilateral exports at market prices
	VDPM	Household domestic purchases at market prices
	VDGM	Government domestic purchases at market prices
	VST	Trade - Exports for international transportation at market prices
	VFM	Endowments - Firms' purchases at market prices
	VIPM	Household import purchases at market prices
	VIGM	Government import purchases at market prices
Environmental	MDF	Emissions from domestic product in current production, MtCO2
	MIF	Emissions from imports in current production, MtCO2
	NCQO	Emissions associated with output in 2014, mil tCO2.eq
	NCQE	Emissions associated with endowment in 2014, mil tCO2.eq
	NCQF	Emissions associated with intermediate use in 2014, mil tCO2.eq

Appendix: Emission intensity vs. trade exposure under different scenarios, OECD country averages by sector

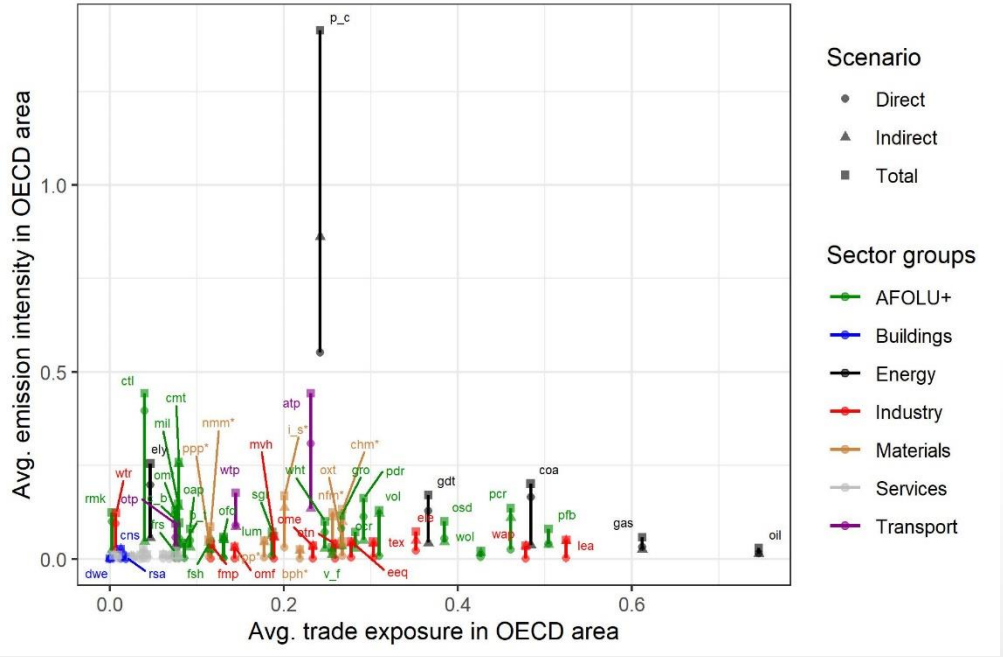

Figure 2 Emission intensity vs. trade exposure under different scenarios, OECD country averages by sector.

Appendix: Average EITE value in OECD countries for different scenarios, by sector group

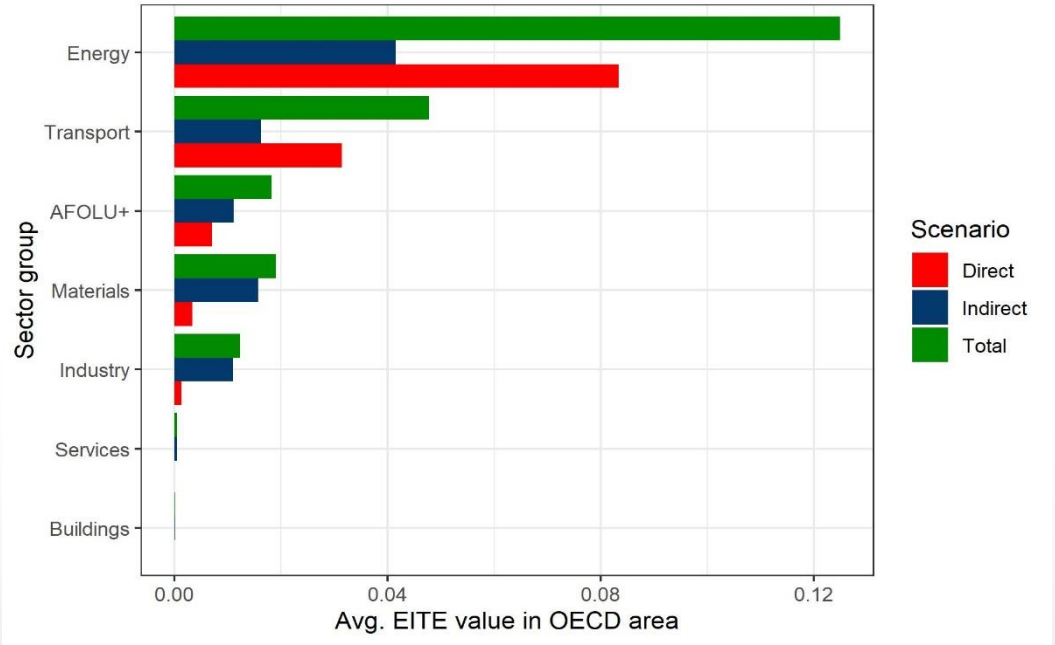

Figure 4 Average EITE value in OECD countries for different scenarios, by sector group. Note: averages are calculated by taking the mean of the EITE value over sectors belonging to the sector group in OECD countries.