A CBAM in the EU agricultural sector

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Introduction

EU climate policy

- **EU ETS** (since 2005): cap-and-trade covering power, industry, and intra-EU aviation
  - **CBAM** (phased in 2023–2025): importers must purchase certificates equivalent to the EU carbon price
- **EU ETS2** (from 2028): extends carbon pricing to buildings, road transport, and additional fuels
- **And Agriculture?**
  - Covered only by the **Effort Sharing Regulation** — national targets but no carbon pricing
    - After 2028, one of the few sectors without comprehensive GHG coverage
    - EU 2050 carbon neutrality goal requires substantial agricultural emission reductions
  - **Regulation on Deforestation-free Products** (since 2023): applies to cattle, cocoa, coffee, palm oil, rubber, soya, and wood

Our work

- Using CEPII's MIRAGE CGE model, simulate the consequences of carbon pricing in the agricultural sector in the EU27.
- Revision of MIRAGE land-use modeling
- Analyze leakage through international trade, as well as the potential role of a Carbon Border Adjustment Mechanism (CBAM).
- Because of our focus on international leakage, we neglect issues related to the challenges inherent to taxing this sector (European Commission and Directorate-General for Climate Action et al. 2023) ⇒ We assume emissions are perfectly observable and can be taxed at the farm level

Model

MIRAGE model

- Multi-sector, multi-region computable general equilibrium (CGE) model
  - Database GTAP 11 + GTAP-Power extension: base year 2017, 76 sectors, 160 regions
  - Single year comparative statics version
- **Production**
  - Factors: unskilled and skilled labor, capital, land, natural resources
  - Intermediate consumption
  - Electricity generation with renewables, nuclear, and fossil fuels
  - Nested CES production for all sectors except agriculture
- **Demand**
  - Representative household: LES-CES, calibrated with country-level demand price and income elasticities
  - Trade: Armington assumption (elasticities from Fontagné, Guimbard, and Orefice 2022)
  - Trade costs: tariffs (including AVE of TRQs) and transport costs
    - AVE of non-tariff measures and iceberg trade costs are not included in this version

Agricultural sector setup

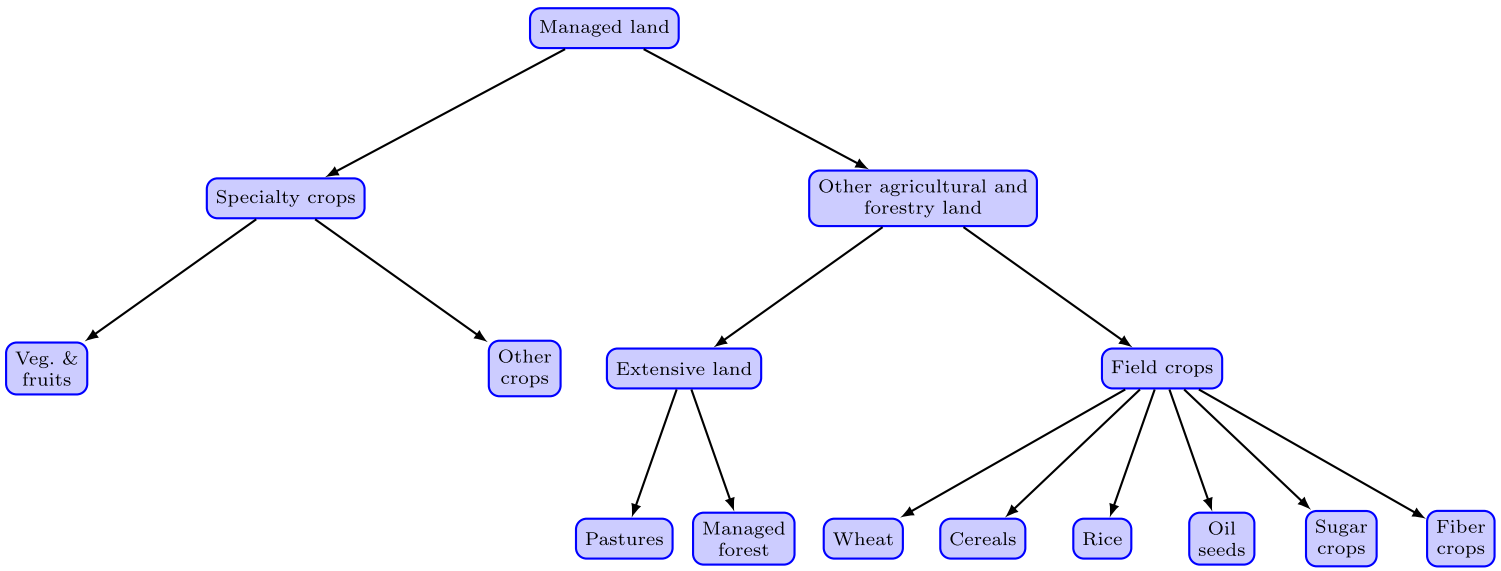
Comprehensive revision of MIRAGE agricultural sector modeling

- Land-use allocation representing physical quantities, based on a multinomial logit approach
  - Crops, including pastures, are produced through a combination of:
    - Land
    - Fertilizers and chemical products ⇒ The only input that affects yields
    - Other intermediate inputs ⇒ Inputs applied proportionally to area
    - Other value added components
  - The livestock sector is modeled as a proportional combination of:
    - Feed: Imperfect substitution among various crops
    - Other intermediate inputs and value added

Land representation

- Initial areas represent physical areas, calculated as harvested areas adjusted for multiple cropping (using SPAM).
- Cropping intensity is assumed to remain constant.
- Managed land can be expanded into natural land.
  - Not all countries have available, productive, natural land. Extension elasticities based on Miranda, Britz, and Börner (2024).
  - Extension is assumed to take place on a mix of forest and grassland. The mix is based on the land use transitions that occurred between 2005 and 2014 from the LUH2 database (Hurtt et al. 2020).

Managed land nesting



Emission accounting

- Covers most GHGs: CO_2, CH_4, N_2O, and fluorinated gases (GTAP-nonCO2 database, CO_2e)
- Agricultural GHG emissions
  - Fluxes
    - Livestock (GTAP): enteric fermentation, manure management, manure left on pastures, manure applied to soils
    - Crops: rice cultivation (FAOSTAT), burning crop residues (GTAP), crop residues (GTAP), use of synthetic fertilizers (GTAP)
    - LU: cultivation on organic soils (FAOSTAT)
  - Stocks (amortized over 20 years)
    - LUC: changes in soil organic carbon (SOC) emissions, loss/gain from deforestation and afforestation
    - LUC emissions are not covered by ETS and CBAM, but are accounted for simulation.
- No explicit abatement technologies; only input substitution (e.g., fertilizer)

Aggregation

Description | Agri-food sectors | Regions

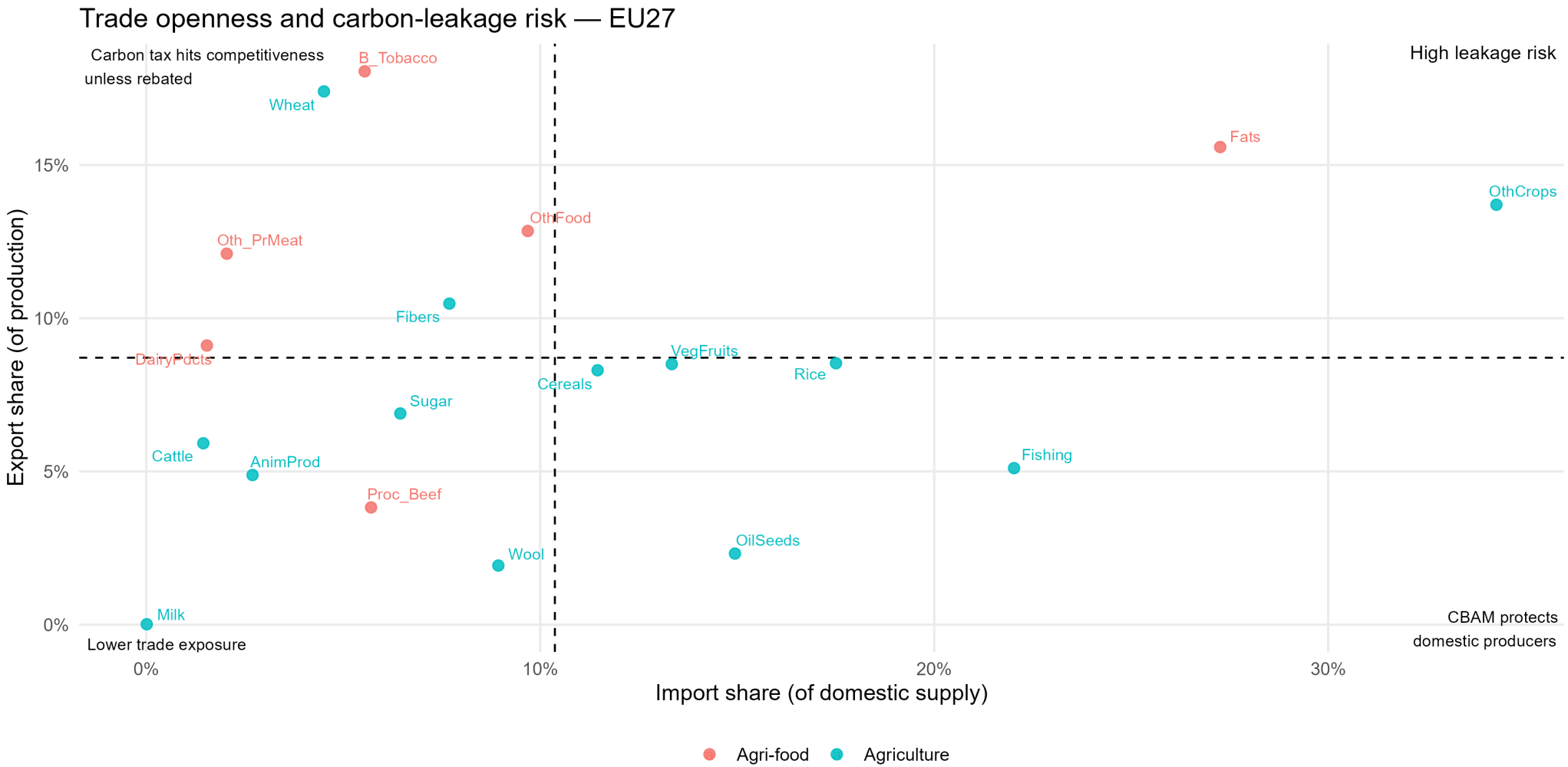
39 sectors

- Agri-food: 14 agricultural sectors and 8 food sectors.
- Energy sectors: coal, oil, gas, refined oil, and electricity (generated with different sources).
- Industry sectors: aggregated, except for chemistry sector separated to represent fertilizers.
- Services: transportation and other services.

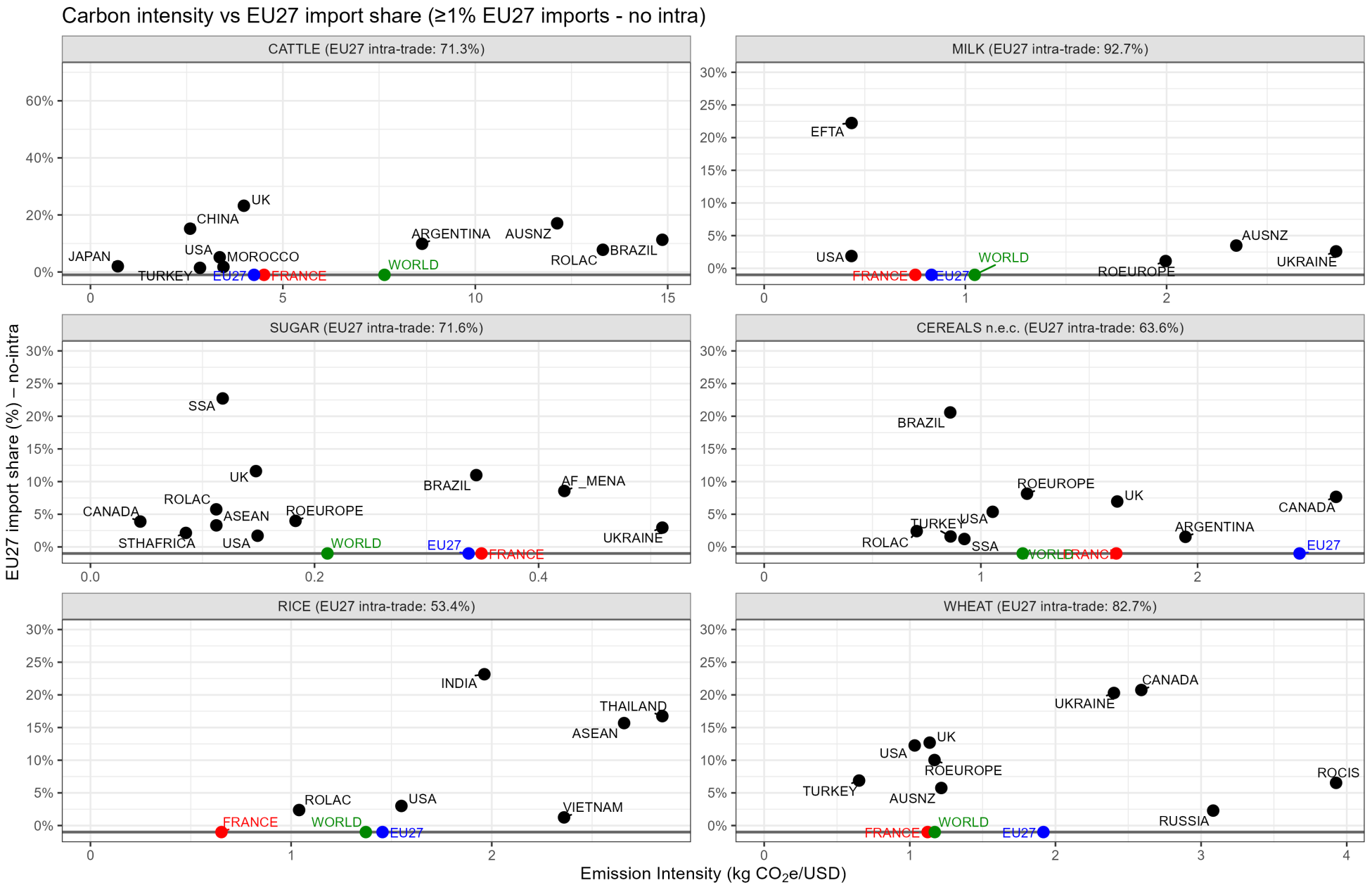
29 regions

- All major trade partners of the EU27 in the agri-food sectors.
- Major exporters in the agricultural and agri-food sectors.

Stylized facts



Note: Import share = Imports / (Production + Imports − Exports)
Export share = Exports / Production
Quadrant split at means (EU27): import share = 10.4%, export share = 8.7%.



Note: Trade in CATTLE corresponds to processed beef (Proc_Beef); Trade in MILK corresponds to dairy products (DairyPdcts).

Scenarios

Scenarios

- **Baseline**
- Agricultural policies as in 2017 in GTAP 11
- Trade policies (MAcMap 2022, sanctions on Russia [including the 2025 50% tariff on agri-food imports], US-China trade war before 2022)
- Carbon policies (ETS1 and ETS2, 100 $ / t CO_2e)
- **Scenarios**
  - **S1**: ETS-ag (100 $ / t CO_2e) in the climate club for agricultural sector emissions not covered by EU-ETS1 and 2, excluding land-use change emissions
  - **S2**: ETS-ag + CBAM scope 1
  - **S3**: ETS-ag + CBAM scope 3
  - **S4**: ETS-ag + CBAM scope 3 with export rebates
  - **S5**: Carbon consumption tax at average emission footprint
- **Club**
  - Not just EU policy: a climate club including EFTA countries

Scopes

Notation: $\mathcal{C} = \{\text{EU27}, \text{EFTA}\}$, club carbon tax $\tau_{\mathcal{C}}$; e_{jr} endogenous emission intensity; $L_{ir,js}$ Leontief inverse.

- **Scope 1** — direct emissions + immediate upstream for selected sectors:

$$t_{jrs}^{\text{CBAM}_1} = \max(\tau_{\mathcal{C}} - \tau_r, 0) \left(e_{jr} + \mathbf{1}_{j \in \mathcal{I}^1} \sum_{i \in \mathcal{I}_j^1} e_{ir} \frac{IC_{ijr}}{Q_{jr}} \right)$$

  Upstream linkages: cattle→processed beef, milk→dairy, paddy rice→milled rice, sugar crops→refined sugar, other animals→other meat

- **Scope 3** — all upstream agricultural emissions outside the club:

$$t_{jrs}^{\text{CBAM}_3} = \sum_{i \in \mathcal{A},\, r' \notin \mathcal{C}} \max(\tau_{\mathcal{C}} - \tau_{r'}, 0)\, e_{ir'} L_{ir',jr} \frac{P_{jr}^Y}{P_{ir'}^Y}$$

- **Export rebate** (S4) — rebates embedded carbon costs on club exports to avoid competitiveness loss
- **Consumption tax** (S5) — applies $\tau_{\mathcal{C}}$ to the average emission footprint of consumption regardless of origin; no incentive to reduce e_{ir} or restructure value chains Formal details

Ad valorem equivalent taxation (%)

Sector	Tariff	Carbon tax	CBAM scope 1	CBAM scope 3	Export rebate	Consumption tax
Paddy rice	19.5	24.4	23.1	24.6	24.6	31.9
Wheat	28.0	14.1	12.6	14.1	14.6	17.9
Cereals	5.6	17.6	12.7	13.9	18.4	22.0
Vegetable fruits	5.5	1.0	2.3	2.7	1.1	1.7
OilSeeds	0.5	3.1	7.0	8.0	4.2	5.8
Sugar crops	7.8	6.5	4.6	5.3	7.3	10.5
Fibers	0.2	0.5	5.5	6.3	0.6	0.8
Other crops	0.5	0.9	3.0	3.9	1.5	3.1
Cattle	16.6	27.0	32.9	44.8	29.9	43.9
Other animals	8.7	5.5	5.1	6.9	7.3	8.2
Wool and silk	0.1	0.0	0.0	4.1	7.1	7.2
Processed beef	54.0	0.0	15.8	20.9	8.4	10.2
Processed oth meat	30.5	0.0	1.6	2.8	3.6	3.8
Oils and fats	4.2	0.0	0.0	6.6	2.3	2.7
Dairy products	33.3	0.0	1.4	6.1	3.2	3.1
Milled rice	25.3	0.0	12.2	14.1	4.9	5.1
Refined sugar	90.7	0.0	0.6	1.9	1.7	2.0
Other food	8.7	0.0	0.0	2.2	1.5	1.7
Beverage and tobacco	7.2	0.0	0.0	0.8	0.9	0.5
Milk	0.0	6.5	10.2	13.3	11.2	12.7

Comparison: producer price for carbon tax and export rebate, tariff-inclusive import price for CBAM, consumption price for

Results

Changes in emissions (Mt CO_2e)

		Territorial emissions			
Scenario	Region	GHG emission w/o LUC	LUC emissions	Total	Footprint
S1	EU27 & EFTA	-81.8	-72.0	-153.8	-102.3
	RoW	41.1	25.6	66.7	15.2
	World	-40.7	-46.3	-87.0	-87.0
S2	EU27 & EFTA	-71.1	-61.0	-132.0	-120.6
	RoW	14.6	10.7	25.2	13.8
	World	-56.5	-50.3	-106.8	-106.8
S3	EU27 & EFTA	-69.5	-57.4	-126.9	-124.6
	RoW	11.5	7.1	18.6	16.2
	World	-58.1	-50.3	-108.3	-108.3
S4	EU27 & EFTA	-57.9	-42.1	-100.0	-115.4
	RoW	-15.6	-12.7	-28.3	-12.9
	World	-73.5	-54.8	-128.3	-128.3
S5	EU27 & EFTA	-16.1	-12.1	-28.2	-30.1
	RoW	-2.0	-1.8	-3.8	-2.0
	World	-18.1	-13.9	-32.0	-32.0

Carbon leakage (outside the club)

Scenario	Leakage rate (%)	
	w/o LUC	w/ LUC
S1	50.3	43.4
S2	20.5	19.1
S3	16.5	14.6
S4	-26.9	-28.3
S5	-12.4	-13.5

$$\text{Leakage rate} = -\frac{\sum_{r \notin \mathcal{C}} \Delta E_r}{\sum_{r \in \mathcal{C}} \Delta E_r}$$

S1 S2 S3 S4 S5

- LUC emissions reduce leakage: club reforestation partially offsets production-driven emission shifts

Land use change by sector (%)

Region	Sector	Init. land area (million ha)	S1	S2	S3	S4	S5
EU27 & EFTA	Paddy rice	0.44	-10.01	-3.85	-3.30	-2.55	-0.24
	Wheat	23.97	-1.03	-0.90	-1.00	0.54	-0.01
	Cereals	27.82	-2.36	-1.85	-1.91	-1.36	-0.09
	Vegetable fruits	12.81	0.10	0.18	0.20	0.21	-0.04
	OilSeeds	16.38	1.23	1.87	2.74	2.46	-0.08
	Sugar crops	1.66	1.31	1.10	1.22	1.35	-1.24
	Fibers	0.36	0.58	2.03	2.13	2.08	-0.28
	Other crops	0.23	0.82	2.32	2.74	3.13	-0.82
	Pasture	71.35	-3.89	-3.69	-3.64	-3.45	-0.74
	Forestry	167.97	2.07	1.80	1.71	1.34	0.36
	Crop land	83.67	-0.84	-0.46	-0.33	0.25	-0.08
	Agricultural land	155.02	-2.25	-1.95	-1.86	-1.46	-0.39
RoW	Paddy rice	114.00	0.04	-0.04	-0.04	-0.05	0.00
	Wheat	171.92	0.26	0.30	0.31	0.07	-0.03
	Cereals	293.01	0.14	0.05	0.05	-0.04	-0.03
	Vegetable fruits	265.27	0.02	0.02	0.01	0.01	-0.01
	OilSeeds	260.90	0.01	-0.06	-0.15	-0.11	-0.01
	Sugar crops	29.23	0.03	0.07	0.05	0.01	-0.01
	Fibers	35.97	-0.05	-0.07	-0.04	-0.02	0.00
	Other crops	47.95	0.06	-0.06	-0.09	-0.09	-0.03
	Pasture	3309.16	0.03	0.01	0.01	-0.01	0.00
	Forestry	2752.27	-0.06	-0.03	-0.02	0.02	0.00
	Crop land	1218.26	0.08	0.04	0.02	-0.03	-0.02
	Agricultural land	4527.42	0.05	0.02	0.01	-0.02	-0.01

Forest area change (million ha)

From managed and natural forests

Region	S1	S2	S3	S4	S5
World	1.71	2.25	2.32	2.91	0.75
EU27 & EFTA	3.48	3.02	2.88	2.26	0.60
RoW	-1.77	-0.78	-0.56	0.65	0.15
Russia	-0.37	-0.35	-0.33	0.06	0.03
Brazil	-0.21	0.07	0.09	0.18	0.03
SSA	-0.18	-0.15	-0.19	-0.05	0.00
RoLAC	-0.14	-0.05	-0.03	0.09	0.01
Canada	-0.13	0.00	0.01	0.05	0.01
AusNZ	-0.13	-0.05	-0.03	0.07	0.03
USA	-0.08	-0.05	-0.04	0.00	0.00
UK	-0.07	-0.02	-0.01	0.02	0.00
Argentina	-0.05	0.04	0.06	0.07	0.01
China	-0.05	-0.03	-0.03	-0.01	0.00
Ukraine	-0.04	0.01	0.03	0.04	0.01
Turkey	-0.03	-0.03	-0.02	0.00	0.00
ASEAN	-0.01	0.00	0.02	0.02	0.00
Indonesia	-0.01	0.00	0.05	0.06	0.00

Impacts under carbon tax (S1, %)

Sector	Init. prod. ($bd)	Production	Exports	Imports	Consumption
Paddy rice	2.0	-11.6	-69.9	310.6	-0.2
Wheat	30.5	-6.0	-17.0	20.1	-0.3
Cereals	30.1	-8.0	-16.5	13.2	-0.3
Vegetable fruits	152.3	-1.6	-3.3	3.9	-0.5
OilSeeds	51.2	-2.3	-5.0	3.8	-0.3
Sugar crops	6.3	-5.1	-16.1	17.3	-5.3
Fibers	4.5	0.1	0.7	-0.5	0.0
Other crops	38.1	-3.9	-4.7	1.7	-1.1
Cattle	46.0	-26.3	-76.1	379.2	-12.4
Other animals	79.1	-6.2	-24.1	27.9	-3.6
Milk	84.6	-3.9	-29.9	40.8	-3.2
Wool and silk	5.3	5.1	29.7	-14.5	3.1
Processed beef	80.7	-7.6	-25.0	30.2	-3.9
Processed oth meat	152.2	-3.3	-12.1	14.8	-1.7
Oils and fats	56.7	-2.0	-2.4	0.9	-0.1
Dairy products	194.8	-1.7	-4.9	1.4	-0.9
Other food	552.5	-1.6	-2.5	1.5	-0.6
Beverage and tobacco	248.1	-0.6	-1.0	0.5	-0.2
Milled rice	3.7	-8.4	-18.8	17.3	-0.1
Refined sugar	18.7	-2.2	-4.7	3.5	-1.0

Agriculture and food impacts (%)

Sector	Indicator	S1	S2	S3	S4	S5
Agri	Production	-4.8	-4.1	-3.9	-3.1	-1.3
	Exports	-13.7	-17.1	-18.2	-1.1	1.3
	Imports	8.3	-4.1	-5.2	-2.6	-1.8
	Consumption	-1.5	-2.0	-2.1	-2.2	-2.4
Food	Production	-2.0	-2.0	-1.6	-0.8	-0.9
	Exports	-3.9	-5.3	-6.3	-0.1	0.3
	Imports	3.4	0.9	-7.5	-5.8	-1.3
	Consumption	-0.9	-1.1	-1.3	-1.4	-1.3

Conclusion

Conclusion

- EU agri-food sector is very sensitive to carbon taxation: leakage risk of ~51% (42% including LUC emissions) in case of carbon taxation
- Leakage risks exist both on the import and on the export sides
  - A CBAM can only prevent half of the leakage if not combined with an export rebate
  - With export rebates, the protection is complete
- A carbon consumption tax decreases emission little (no incentives to decarbonize production)
- Role of LUC emissions: Reduce leakage because of reforestation in the climate club

Thank You !

Any question ?

Multinomial logit

Variable profit per hectare for crop i:

$$\pi_i = P_i^Y y_i(x_i^v) - P_i^v x_i^v$$

A land owner maximises per-hectare land rents over crop shares s_i:

$$\pi = \sum_i s_i \pi_i - \sum_i P_i^p b_i s_i - P^e \underbrace{\left(\sum_i c_i s_i + \alpha^{-1} \sum_i s_i \log s_i \right)}_{\text{Management cost fn.}}$$

The management cost captures the efficiency cost of concentrating work on fewer crops (synchronised planting/harvesting, risk diversification, etc.).

First-order condition:

$$\boxed{s_i = \frac{\exp \tilde{\pi}_i}{\sum_j \exp \tilde{\pi}_j} = \exp(\tilde{\pi}_i - \phi)}$$

where $\tilde{\pi}_i = \alpha(\pi_i - P_i^p b_i - P^e c_i)/P^e$ and $\phi = \log \sum_i \exp \tilde{\pi}_i$.

← Back to Agricultural sector setup

Formally — notation

- r, s: origin–destination countries
- i, j: origin–destination sectors
- $\mathcal{C} = \{\mathrm{EU27}, \mathrm{EFTA}\}$: members of the climate club that apply the common carbon tax $\tau_{\mathcal{C}}$
- P^{Y}_{ir}: producer-output price; P^{D}_{js}: final demand price before local taxes
- e_{jr}: emission intensity of production (endogenous: vary with input use)

← Back to Scopes

Formally — Scope 1

$$t_{jrs}^{\mathrm{CBAM}_1} = \max\left(\tau_{\mathcal{C}} - \tau_r, 0\right)\left(e_{jr} + \mathbf{1}_{j\in\mathcal{I}^1}\sum_{i\in\mathcal{I}_j^1} e_{ir}\frac{IC_{ijr}}{Q_{jr}}\right)$$

- τ_r: carbon tax in the exporting country r
- IC_{ijr}/Q_{jr}: ratio of intermediate consumption to production

← Back to Scopes

Formally — Scope 3

$$t_{jrs}^{\mathrm{CBAM}_3} = \sum_{i \in \mathcal{A}, r' \notin \mathcal{C}} \max\left(\tau_{\mathcal{C}} - \tau_{r'}, 0\right) e_{ir'} L_{ir',jr} \frac{P_{jr}^{Y}}{P_{ir'}^{Y}}$$

- $L_{ir,js}$: Leontief inverse matrix (endogenous)
- Applied only to agri-food sectors; L is value-based and converted to quantities by the price ratio.

← Back to Scopes

Formally — Export rebate

$$x_{js} = \sum_{i \in \mathcal{A}, r} \left[\underbrace{\mathbf{1}_{r \in \mathcal{C}} \tau_{\mathcal{C}}}_{\text{carbon-tax rebate}} + \underbrace{\mathbf{1}_{r \notin \mathcal{C}} \max\left(\tau_{\mathcal{C}} - \tau_r, 0\right)}_{\text{CBAM duty drawback}} \right] e_{ir} L_{ir,js} \frac{P^Y_{js}}{P^Y_{ir}}$$

- x_{js} is a rebate per unit of producer output for club exporters.

← Back to Scopes

Formally — Consumption tax

$$t_{js}^{\text{Cons}} = \tau_{\mathcal{C}} \sum_{i \in \mathcal{A}, r} e_{ir} L_{ir,js} \frac{P_{js}^{D}}{P_{ir}^{Y}}$$

- Applies the club carbon price on the average emission footprint of good j consumed in s, irrespective of origin.
- Applied on all final demand (households, government, and investment good)
- No incentives for producers: just apply at consumption level
- Same footprint formula as export rebate if no taxes in non-club members
  - But different values because a consumption tax does not provide incentives to reduce e_{ir} or to adjust value chains ($L_{ir,js}$) to reduce the footprint, while a CBAM does

← Back to Scopes

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