Clean on Arrival? Environmental Non-Tariff Measures and the Carbon Content of Trade

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What is Environmental NTM?

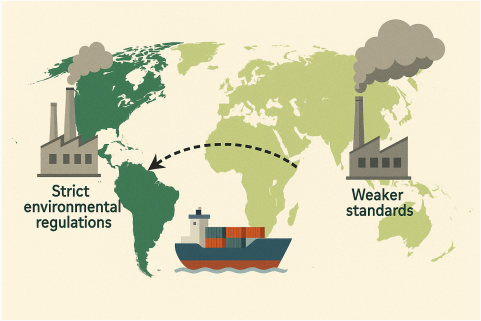
- Non-tariff trade policy instruments with environmental objectives.
- Regulate products or production processes to protect the environment or health.
- Influence trade through technical standards, labeling, or certification rather than prices.
- Can raise compliance costs for exporters but promote global diffusion of green standards.

Examples of Environmental NTMs

WTO Category	Description	Environmental Examples
TBT	Technical Barriers to Trade	Energy-efficiency labels, chemical restrictions (REACH), vehicle emission standards
SPS	Sanitary and Phytosanitary Measures	Limits on pesticide residues, GMO restrictions, quarantine rules
Export Measures	Export controls or bans	Ban on unprocessed timber or recyclable waste exports
Quantity/Price Controls	Import quotas, taxes	Quotas on ozone-depleting substances, carbon border taxes
Voluntary Schemes	Eco-labels, green procurement	EU Ecolabel, organic certification

Why Environmental NTMs on CO_2?

- Same product, different embodied CO_2 across countries
- Carbon leakage by stricter environmental regulation
- Rising environmental NTMs beyond taxes/ETS
- Question
  - Do stricter importer standards reduce the carbon content of imports?
  - relevant to trade effects?
  - sectoral heterogeneity?



This Paper

- Multi-sector Ricardian model with bilateral product standards that affect costs and emissions.
- Empirics
  - WIOD + CO_2 linked to WTO EDB
  - environmental NTMs
    identification via importer–exporter NTM gap
  - IV using neighbors' NTMs
- Findings
  - stricter importer standards lower embodied CO_2
  - negative trade effects.
  - effects concentrated in cleaner sectors

Contribution: Bridging Trade, Standards, and Emissions

- **Connecting NTMs to environmental outcomes**
  - Kee, Nicita, and Olarreaga (2009); Disdier, Fontagné, and Mimouni (2008); Copeland and Taylor(2003) on pollution haven effect linked to trade restrictiveness.
  - extension of this line by examining how *environmental* NTMs (Bellelli and Xu, 2022, WTO EDB) affect the carbon content of traded goods.
- **Integrating product standards into quantitative trade models**
  - multi-sector Ricardian frameworks (Eaton and Kortum, 2002; Caliendo and Parro, 2015)
  - bilateral product standards as technology-shifting frictions following Duan et al. (2021).
- **Extending gravity-style estimation to embodied emissions**
  - Aichele and Felbermayr, 2015; Peters et al., 2011; Shapiro, 2021
  - a bilateral emissions equation linking NTM stringency gaps to imported carbon intensity using WIOD data

Theoretical Framework

- World of N countries i, n and J sectors j.
- Iceberg trade cost $d_{ni}^j \geq 1$ ($d_{nn}^j = 1$).
- Environmental product standards (proxy for NTMs):

$$s_n^j \geq 0, \quad s_i^j \geq 0, \quad \text{bilateral standard } s_{ni}^j \equiv \frac{s_n^j}{s_i^j}.$$

- Emissions tax in source i: $t_i > 0$.
- Heterogeneous productivity (Eaton–Kortum): $A_i^j(\omega)$ Fréchet with (T_i^j, θ^j).

Key idea. Destination standards s_n^j tighten compliance for foreign suppliers: raise marginal costs via $\psi_{ni}^j(\cdot)$ and lower emissions per dollar via elasticity parameter $\phi^j > 0$.

Households and Final Demand

Preferences in country n (Cobb–Douglas):

$$U(C_n) = \prod_{j=1}^{J} \left(C_n^j\right)^{\alpha_n^j}, \qquad \sum_j \alpha_n^j = 1.$$

Budget $\sum_j P_n^j C_n^j = I_n \;\Rightarrow$

$$C_n^j = \frac{\alpha_n^j I_n}{P_n^j}.$$

CES price for composite j:

$$P_n^j = \left(\int p_n^j(\omega)^{\,1-\sigma^j} \, d\omega \right)^{\frac{1}{1-\sigma^j}}.$$

Implications

- Demand shares α_n^j pin sectoral spending $X_n^j = P_n^j Q_n^j$.
- Trade and technology determine P_n^j, hence the composition of demand.

Production, Abatement, and Emissions Elasticity

Two-stage technology for an intermediate ω in sector j (source i for destination n):

$$y_{ni}^{j}(\omega) = A_{i}^{j}(\omega)\,(s_{ni}^{j})^{-\eta_{i}^{j}}\left[l_{ni}^{j}(\omega)\right]^{\gamma_{i}^{j}}\prod_{k=1}^{J}\left[m_{ni}^{k,j}(\omega)\right]^{\gamma_{i}^{k,j}}, \quad \gamma_{i}^{j}+\sum_{k}\gamma_{i}^{k,j}=1.$$

Net output after abatement $q_{ni}^{j} = (1-\epsilon_{ni}^{j})\,y_{ni}^{j}$.

Emissions and intensity. With emissions proportional to potential output and more responsive under stricter destination standards, the emissions intensity (emissions per unit revenue) simplifies to

$$e_{ni}^{j} \;\equiv\; \frac{z_{ni}^{j}}{p_{ni}^{j}q_{ni}^{j}} \;=\; \frac{(s_{ni}^{j})^{-\phi^{j}}}{(s_{ni}^{j})^{-\phi^{j}}+1}\;\cdot\;\frac{1}{t_{i}}, \qquad \phi^{j}>0.$$

Comparative statics.

$$\frac{\partial e_{ni}^{j}}{\partial s_{ni}^{j}}<0, \qquad \frac{\partial e_{ni}^{j}}{\partial t_{i}}<0.$$

Stricter destination standards and higher source emission taxes reduce emissions per dollar.

Trade Costs, Prices, and EK Aggregation

Unit cost (excluding emissions):

$$c_i^j = \kappa_i^j \, w_i^{\gamma_i^j} \prod_k \left(P_i^k\right)^{\gamma_i^{k,j}},$$

Compliance/emissions objects fold into ψ_{ni}^j, so delivered price draw:

$$p_{ni}^j(\omega) = d_{ni}^j \, \psi_{ni}^j \left(A_i^j(\omega)\right)^{-\frac{1}{(s_{ni}^j)^{-\phi^j}+1}}.$$

EK with Fréchet productivities $\Rightarrow$ sectoral expenditure share:

$$\pi_{ni}^j = \frac{T_i^j \left(d_{ni}^j \psi_{ni}^j\right)^{-\theta^j}}{\Phi_n^j}, \qquad \Phi_n^j = \sum_m T_m^j \left(d_{nm}^j \psi_{nm}^j\right)^{-\theta^j}.$$

Interpretation

- $s_{ni}^j \uparrow$ raises ψ_{ni}^j (compliance cost) $\Rightarrow$ lowers π_{ni}^j.
- Standards thus act through *cost* (competitiveness) and *intensity* (per-dollar emissions).

Emissions in Trade and Sufficient Statistics

Emissions embodied in n's imports from i (sector j):

$$E_{ni}^j = e_{ni}^j \, \pi_{ni}^j \, X_n^j \;=\; \underbrace{\frac{(s_{ni}^j)^{-\phi^j}}{(s_{ni}^j)^{-\phi^j}+1} \cdot \frac{1}{t_i}}_{\text{intensity}} \cdot \underbrace{\frac{T_i^j \left(d_{ni}^j \psi_{ni}^j\right)^{-\theta^j}}{\Phi_n^j}}_{\text{expenditure share}} \cdot X_n^j.$$

Two channels of s_{ni}^j on E_{ni}^j

1. *Direct*: lowers emissions intensity e_{ni}^j via $\phi^j > 0$.
2. *Indirect*: raises compliance cost ψ_{ni}^j, reducing π_{ni}^j.

Log-linear approximation (holding t_i, d_{ni}^j, T_i^j, Φ_n^j fixed within FE):

$$\ln E_{ni}^j \;\approx\; -\phi^j \ln s_{ni}^j \;+\; \ln X_n^j \;+\; \text{(terms absorbed by FE)}.$$

Prediction: tighter destination standards ($s_n^j \uparrow$ relative to s_i^j) reduce embodied emissions in n's imports.

Empirical Equation Mapped from the Model

$$\ln E^{j}_{nit} = \gamma_0 - \phi^{j}\left(\ln s^{j}_{nt} - \ln s^{j}_{it}\right) + \gamma_1 \ln(1+\tau^{j}_{nit}) + \gamma_{nt} + \gamma_{it} + \gamma_{nij} + \varepsilon^{j}_{nit}$$

- $\phi^{j} > 0 \Rightarrow$ stricter importer vs exporter standards $\Downarrow$ embodied emissions.
- High-dimensional FE absorb multilateral resistance, technology, demand, and t_i variation.
- τ^{j}_{nit} controls for tariffs; robustness: IV using neighboring countries' NTM prevalence.

Model takeaways

1. Standards lower emissions per dollar (intensity) and shift sourcing (shares).
2. Effects are stronger where trade/substitution elasticities are larger and abatement is more responsive (ϕ^{j} high).

Robustness check

- trimming top/bottom 3%
- quartile splits
- instrumental variables approach
  - environmental NTMs of the two closest neighbors (Kee & Nicita (2022)-style).
  - strong first stage (under-ID and Cragg–Donald tests) across specs
- alternative outcomes (gross energy use/emission-relevant use)

Data Sources & Construction

WIOD (2009–2014)

- MRIO & environmental accounts for sector–country CO_2.
- Leontief inverse $(I - A)^{-1}$ for supply-chain CO_2 per \$.
- 43 countries, 22 manufacturing industries.

WTO EDB $\rightarrow$ Environmental NTM Index (Belleli & Xu,2022)

- based on Trade Policy Reviews and **Members' notifications**
- 90 % = TBT, SCM, Agriculture, SPS, ILP
- trade-related sample of policies
- environmental issues (climate change, air pollution, biodiversity loss, land degradation, hazardous waste management, or deforestation)

WIOD: Embodied CO_2 Construction

1. Compute technical coefficients A and Leontief inverse $(I - A)^{-1}$.
2. Build sector–country vectors of CO_2/gross output from environmental accounts.
3. Obtain supply-chain CO_2 per \$: multiply emission intensities by $(I - A)^{-1}$.
4. Apply to bilateral import uses by sector to get E^j_{nit} (embodied in imports).

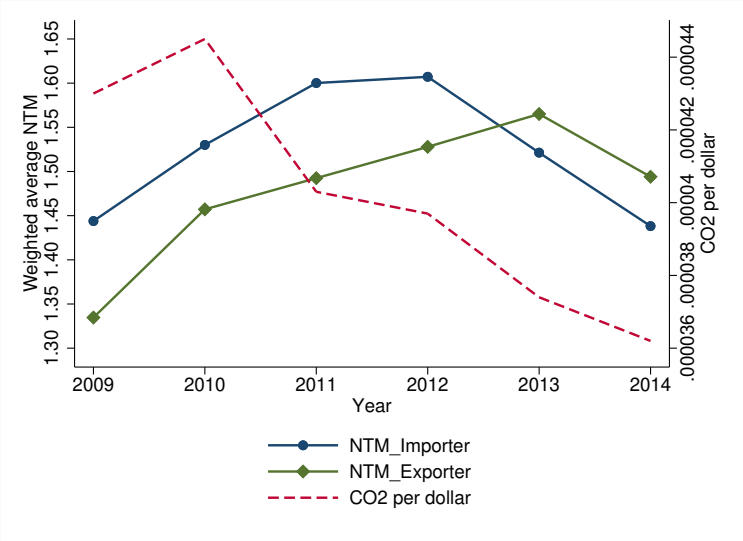
NTM Index: Construction

- **Breadth** (log-scaled): sector coverage, objective coverage, keyword frequency.
- **Depth** (log-scaled): action-verb intensity (weak/moderate/strong weighted avg).
- **Score** $\in [0, 3]$: product of breadth and depth; annual country–sector measure.
- Harmonization across TBT/SPS/SCM/ILP/agriculture-related notifications and TPRs.

Bilateral Gap Used in Estimation

$\texttt{lnScore_diff}^{j}_{nit} = \ln s^{j}_{nt} - \ln s^{j}_{it}$ (importer minus exporter).

Environmental NTMs and Carbon Intensity



Carbon Intensity across Industries

Top 5 (Highest)	Carbon Intensity
Basic metals	0.0000761
Coke and refined petroleum products	0.0000598
Fabricated metal products	0.0000580
Chemicals and chemical products	0.0000570
Rubber and plastic products	0.0000516
Bottom 5 (Lowest)	**Carbon Intensity**
Basic pharmaceutical products	0.0000253
Food, beverages, and tobacco	0.0000249
Crop and animal production	0.0000246
Fishing and aquaculture	0.0000232
Forestry and logging	0.0000143

Baseline Results

- **Carbon intensity**
  - $\phi^j > 0$ and significant.
  - Full sample: 1pp increase in NTM gap $\Rightarrow \approx$0.03% lower CO_2 intensity.
  - Stronger for **clean** industries (below-median intensity); insignificant for dirty.
  - consistent with Brännlund et al. (2015), Ederington et al. (2005)

- **Trade volumes**
  - negative in full sample (10% sig.)
  - **strongly negative for clean** industries; no effect for dirty.

Baseline Results: CO_2 Content of Trade

	Carbon Intensity			Trade		
	Full	Clean	Dirty	Full	Clean	Dirty
lnScore_diff	-0.00030***	-0.00045***	-0.00020	-0.0028*	-0.0075***	0.0011
	(0.00011)	(0.00014)	(0.00016)	(0.00149)	(0.00193)	(0.00215)
ln(1+Tariff)	0.00642*	0.00768*	-0.0101	0.142***	0.161***	0.0836
	(0.00379)	(0.00407)	(0.00780)	(0.0545)	(0.0570)	(0.123)
Importer–Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Exporter–Year FE	Yes	Yes	Yes	Yes	Yes	Yes
IEI FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	114,344	55,812	57,282	117,638	55,812	57,282
R^2	0.997	0.998	0.983	0.896	0.901	0.983

The Effects of NTM on Carbon Emissions per Dollar of Output

	lnScore_diff			Weighted NTM		
	Full	Clean	Dirty	Full	Clean	Dirty
	(1)	(2)	(3)	(1)	(2)	(3)
NTM	1.39e-06	2.29e-06	6.47e-07	-0.000664	-0.000975	0.000143
	(9.14e-07)	(1.94e-06)	(4.35e-07)	(0.000564)	(0.000695)	(0.000144)
ln(Intariff+1)	0.000109	0.000136	3.73e-05*	4.15e-05	5.39e-05*	-1.85e-05
	(8.25e-05)	(0.000113)	(2.20e-05)	(2.42e-05)	(3.03e-05)	(1.84e-05)
Fixed Effects:						
Importer-Year	YES	YES	YES			
Exporter-Year	YES	YES	YES			
Imp.-Exp.-Ind.	YES	YES	YES			
Exporter-Industry FE				YES	YES	YES
Year FE				YES	YES	YES
Observations	117,638	55,812	60,576	3,138	1,427	1,503
R-squared	0.976	0.974	0.983	0.923	0.984	0.984

Robustness Check: Trimming Top/Bottom 3%

	Carbon Intensity			Trade		
	Full	Clean	Dirty	Full	Clean	Dirty
lnScore_diff	-0.000308***	-0.000440***	-0.000232	-0.00202	-0.00678***	0.00189
	(0.000116)	(0.000148)	(0.000157)	(0.00148)	(0.00192)	(0.00219)
ln(1+Tariff)	0.00586	0.00750	-0.0108	0.139***	0.159***	0.0498
	(0.00414)	(0.00456)	(0.00797)	(0.0537)	(0.0560)	(0.131)
Importer–Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Exporter–Year FE	Yes	Yes	Yes	Yes	Yes	Yes
IEI FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	108,717	53,967	53,496	112,746	55,215	56,287
R^2	0.992	0.981	0.976	0.894	0.901	0.900

Robustness Check: Quartiles of Carbon Intensity

	Carbon Intensity				Trade			
	25th	25–50th	50–75th	75th	25th	25–50th	50–75th	75th
lnScore_diff	-0.00060***	-0.00013	-0.00018	-0.000048	-0.0070***	-0.00727**	0.0022	-0.0011
	(0.00020)	(0.00018)	(0.00018)	(0.00024)	(0.0026)	(0.0028)	(0.0031)	(0.00301)
ln(1+Tariff)	0.00945**	0.00223	0.0022	-0.0056	0.257***	-0.149	0.205	-0.0491
	(0.0047)	(0.0066)	(0.0076)	(0.0117)	(0.0595)	(0.132)	(0.151)	(0.192)
Importer–Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exporter–Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IEI FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	28,128	27,599	27,521	27,820	28,128	27,599	27,521	31,114
R^2	0.999	0.910	0.909	0.975	0.895	0.918	0.904	0.912

Robustness Check: IV Estimates (2SLS)

	Carbon Intensity			Trade		
	Full	Clean	Dirty	Full	Clean	Dirty
lnScore_diff	-0.00240*	-0.00367**	-0.000718	-0.0345**	-0.00487	-0.0432
	(0.00142)	(0.00156)	(0.00208)	(0.0171)	(0.0164)	(0.0305)
ln(1+Tariff)	0.00713*	0.00871**	-0.0100	0.153***	0.160***	0.0946
	(0.00385)	(0.00413)	(0.00782)	(0.0549)	(0.0575)	(0.124)
FE (all)	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	114,344	55,812	57,282	117,638	55,812	60,576

Robustness Check: Alternative Outcomes

	Gross Energy Intensity			Emission-relevant Energy		
	Full	Clean	Dirty	Full	Clean	Dirty
lnScore_diff	-0.000241**	-0.000391**	-0.000059	-0.000194*	-0.000353**	-0.000110
	(0.000117)	(0.000153)	(0.000151)	(0.000112)	(0.000142)	(0.000154)
ln(1+Tariff)	0.00641	0.00851*	-0.00879	0.00694*	0.00880**	-0.00995
	(0.00419)	(0.00465)	(0.00693)	(0.00391)	(0.00432)	(0.00736)
FE (all)	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	117,638	55,411	61,084	117,638	55,227	61,323
R^2	0.996	0.997	0.982	0.996	0.997	0.983

Conclusion

- Theoretically, bilateral product standards lower emissions intensity of imports via abatement effectiveness & cost channels.
- Evidence: tighter importer standards $\Rightarrow$ lower embodied CO_2 in imports.
- Environmental NTMs can act as *de facto* import-side climate instruments.
- Effects are **sectorally asymmetric**: strong in clean sectors, limited in heavy industry.
- Leakage risk persists in dirty sectors without complementary policies.
- Standards + technology/abatement support for carbon-intensive sectors.

Thank you!