Trade and the Environment

ECON 871

Inroduction

Trade and environmental policy are tightly linked.

- Trade can affect the environment through many different channels.
- Trade policy is seen as a way to potentially lower global emissions.

Plan for Today: Broad overview of these two things.

Quick Note on Data

One of the most commonly used data sources for **trade + environment** studies is the **World Input Output Database (WIOD)**.

- Multi-region input-output table.
- Combines national input-output tables, international trade data, and pollution emissions data to provide measures of economic and environmental activity comparable across countries and industries.
- Many pollutants: CO_2, NO_x, CH4, N_2O, CO, NH_3, etc.

Quick Note on Data

Other data sources:

- WIOD measures greenhouse gas emissions using data from the **International Energy Agency**.
- For air pollution, WIOD data comes primarily from the Emission Database for Global Atmospheric Research (EDGAR)
- For the United States, the EPA has even more detailed data available.
  - GHG emissions by detailed location (facility level).
  - Paired with demographic information, etc.

Globalization and the Environment

Two key questions:

1. How does trade affect the environment?
2. How can trade policy affect environmental outcomes?

Globalization and the Environment

Trade can affect the environment in many ways.

We can break these down into two main channels, with a bunch of sub-channels.

1. Growth/Real Income Effects.
2. Reallocation Effects.

Growth Effects of Trade on Environment

Generally understood that **trade increases real income**. This can have competing effects:

- More income $\rightarrow$ more output $\rightarrow$ **more pollution**.
- But, if environmental quality is **a normal good**, more income will also lead to more demand for environmental quality.
  - Increased regulation $\rightarrow$ less pollution.

Growth Effects of Trade on Environment

In the early 1990s, Grossman and Krueger (1995) wrote one of the first **trade + environment** papers.

Hypothesis: Economic growth brings an initial phase of deterioration of environmental quality, followed by a subsequent phase of improvement.

- Inverted U-shaped relationship between real income per capita and environmental quality in a country.
- Referred to as an “Environmental Kuznets Curve” or EKC (original Kuznets curve is about relationship between income per capita and inequality.

Growth Effects of Trade on Environment

Empirical relevance of the EKC is somewhat inconclusive:

- Grossman and Krueger (1995) show it appears to be true in the data for many pollutants.
- Many other indicators of environmental damage that don't necessarily generate an EKC.
- Identification is tough—countries different across so many dimensions
  - Importantly, including economic and environmental regulations.

Reallocation Effects

Focus, today, on the reallocation channels instead.

- Trade and FDI can affect the **location of production**, which can interact with environmental regulations:
    - *Pollution haven hypothesis*—countries w/lower environmental standards have comparative advantage in dirtier industries.
    - *Pollution offshoring hypothesis*—countries w/stricter environmental standards will offshore dirtiest parts of production.
    - Direct effects of transporting goods across countries on emissions.
- **Technique effects**—trade reallocates production toward more productive firms, which tend to be cleaner.
    - This can lead to lower pollution.
    - Technique can also be affected by environmental regulation.

Pollution Haven Hypothesis

Some evidence that relatively more stringent pollution policy contributes to a comparative disadvantage in pollution production.

Recent Example: Tanaka, Teshima and Verhoogen (2022), study the effect of a tightening of U.S. air quality standards for lead in 2009 on the relocation of battery recycling to Mexico.

- In 2009, U.S. tightened the National Ambient Air Quality Standard (NAAQS) for lead by a factor of 10.
- No change in the standard in Mexico.
- Track the location of battery recycling, ambient lead levels, trade of used batteries, and health outcomes.

Pollution Haven Hypothesis

Tanaka et al. (2022) have five main findings:

1. Revised air quality standards **reduced ambient lead concentrations around U.S. battery recycling plants.**
2. Used lead acid battery exports from the U.S. to Mexico increased by 4x after the policy was enacted (2009-14).
3. Growth of value added and output in Mexican battery-recycling plants increased sharply, growing by 243.2 percent between 2008 and 2013, relative to 62.2 percent in 2003-08.
4. Average incidence of low birthweight increased significantly near Mexican battery-recycling plants.
5. Health effects were concentrated among mothers in hospitals run by the Mexican Ministry of Health (MH), who tend to be of lower socioeconomic status than mothers in other public or private hospitals.

Pollution Offshoring Hypothesis

Also limited evidence of pollution offshoring in the data.

Example: Cole, Elliott, Okubo and Zhang (2021)

- Study 4000 Japaneese firms between 2009 and 2013.
- Find that composition of Japanese **imports** have become dirtier and the carbon embodied within Japanese imports is larger and has growtn more rapidly than the carbon embodied within exports.
- Find a relatively large reduction in pollution intensity of firms that begin outsourcing relative to firms that do not.

Consensus is that Relocation Effects are Small

Despite these important counter examples, general consensus has been that the effects of pollution haven/offshoring behavior on overall emissions is small.

This finding comes from decompositions of emissions into emissions due to:

1. **Scale:** total production.
2. **Composition:** breakdown of “clean” vs “dirty” sectors.
3. **Technique:** emissions intensity of production.

Technique channel found to be more important than scale or composition.

Pollution Decomposition

Shapiro and Walker (2018) performs this decomposition for U.S. emissions between 1990 and 2008. Start by defining total manufacturing pollution, Z, as:

$$Z = \sum_s z_s = \sum_s x_s e_s = X \sum_s \kappa_s e_s$$

- Total pollution equals the sum of pollution from each manufacturing product, s:

$$\sum_s z_s$$

- z_s equals manufacturing output times emission intensity:

$$\sum_s x_s e_s$$

- x_s equals total output times the product's share of output:

$$\sum_s X \frac{x_s}{X} e_s = \sum_s X \kappa_s e_s$$

Pollution Decomposition

In vector notation, this decomposition becomes:

$$Z = X\kappa'\mathbf{e}$$

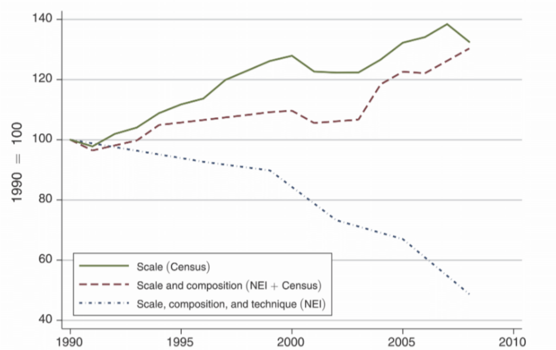
Totally differentiating and dividing through by Z, this becomes:

$$\underbrace{\frac{dZ}{Z}}_{\%\Delta\text{emissions}} = \underbrace{\frac{dX}{X}}_{\text{scale}} + \underbrace{\frac{d\kappa}{\kappa}}_{\text{composition}} + \underbrace{\frac{de}{e}}_{\text{technique}}$$

Take this to the data with annual data on:

- Pollution (total, and by industry) from the EPA's National Emissions Inventory
- Production (total, and by industry) from the Census Annual Survey of Manufacturers

Pollution Decomposition



Pollution Decomposition

- The **green line** shows the scale effect.
  - Hold emissions intensity and composition fixed at 1990 levels.
  - What would emissions look like if you only allow scale of production to change over time?
- The **red line** shows the *additional* change in emissions if you allow for sectoral composition to change.
  - Hold emissions intensity constant at 1990 levels.
  - What do emissions look like if you only allow scale and composition changes?
- The **blue line** shows *additional* change in emissions allowing for technique changes.
  - Now, allow emissions intensity to change over time.

Takeaway: Technique contributed the most to emissions decline between 1990 and 2008.

Technique Effect

The **technique channel** of emissions reductions is a reduction of **emissions intensity of output**, or, emissions per unit of output.

There is less evidence as to exactly what has caused this deline in emissions intensity. A few possibilities:

- **Reallocation of production** toward lower-polluting plants.
- **Improvements in abatement technology** likely spurred by environmental regulation.
- **Outsourcing** could also play a role.

Technique and Heterogeneous Firms

The reallocation channel is based on the observation that **more productive firms tend to be cleaner**.

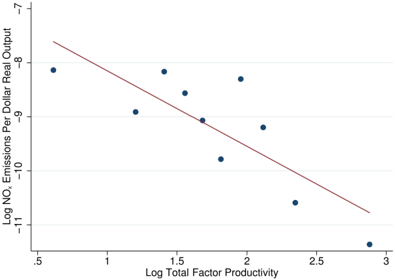


FIGURE 1 Emission Rates and Firm Productivity.

NOTES: Figure from Shapiro and Walker (2018). This figure plots the relationship between plant-level total factor productivity and NO_x pollution per unit of output for U.S. manufacturing in 1990. The plant-level productivity measure is constructed from the U.S. Annual Survey of Manufacturers, using a total factor productivity index measure. The sample is divided into 10 deciles based on this plant-level productivity measure. The circles represent the mean values of log productivity and log pollution per unit of real output within each decile, weighting the decile mean by plant-level inventory-adjusted, real output. The plot is accompanied by a linear fit, relating plant-specific emissions intensities to total factor productivity at the same plant. The line is fit to the entire sample, not simply the decile means.

Technique and Heterogeneous Firms

Several papers have developed Melitz-type models, where reducing trade barriers reallocates production into the more productive, hence, less polluting firms.

Simple Framework: Consider the following setup...

- Suppose each industry i has a continuum of firms on the interval $[0, n_i]$.
- Emissions of firm n are denoted $z_i(n)$.
- Then, we can write **total industry emissions** as:

$$Z_i = \int_0^{n_i} z_i(n)dn$$

Technique and Heterogeneous Firms

Next, we can define the **emissions intensity** of industry i as:

$$E_i = \frac{Z_i}{S_i} = \int_0^{n_i} e_i(n)\varphi_i(n)dn$$

- S_i is the scale of output in industry i, which is the sum of value added, $v_i(n)$ across firms.
- $e_i(n) \equiv z_i(n)/v_i(n)$ is the emission intensity of firm n.
- $\varphi_i(n) \equiv v_i(n)/S_i$ is firm n's share of value added in industry i.

Technique and Heterogeneous Firms

From the last slide, we have emissions intensity of industry i:

$$E_i = \frac{Z_i}{S_i} = \int_0^{n_i} e_i(n)\varphi_i(n)dn$$

Decompose this, by taking logs and differentiating the above:

$$\hat{E}_i = \underbrace{\int_0^{n_i} \hat{e}_i(n)\theta_i(n)dn}_{\text{A}} + \underbrace{\int_0^{n_i} \hat{\varphi}_i(n)\theta_i(n)dn}_{\text{B}} + \underbrace{n_i\left[\theta_i(n_i) - \phi_i(n_i)\right]\hat{n}_i}_{\text{C}}$$

- Where $\theta_i(n) \equiv z_i(n)/Z_i$ is firm n's share of emissions in industry i.

Technique and Heterogeneous Firms

$$\hat{E}_i = \underbrace{\int_0^{n_i} \hat{e}_i(n)\theta_i(n)dn}_{\text{A}} + \underbrace{\int_0^{n_i} \hat{\varphi}_i(n)\theta_i(n)dn}_{\text{B}} + \underbrace{n_i \left[\theta_i(n_i) - \phi_i(n_i)\right] \hat{n}_i}_{\text{C}}$$

- **A** is a weighted average of firm-level changes in emission intensity.
  Captures within-firm changes in emissions intensities.

- **B** is a weighted average of firm-level changes in value added.
  Captures reallocation effects. Industry emissions fall if the share of value added from relatively clean firms rises.

- **C** is a selection effect driven by entry and exit.
  Emissions rise if the emission intensity of an entering firm is higher than the average emission intensity of the industry.

Empirical Evidence

Theoretical mechanisms are pretty well understood, but there is less conclusive empirical evidence as to what is driving the technique effects.

- Quantitative models suggest environmental regulation has had a larger effect than trade.
- Limited quasi-experimental evidence have mixed findings on the trade channel.
- Offshoring may also play a role:
  - Firm-level emissions intensity go down if the most polluting parts of production are shifted offshore.
  - Again, relatively little empirical evidence on the importance of offshoring in affecting emission intensities.

Trade Policy and the Environment

Very brief overview of the relationship between trade and the environment.

The next question is, can trade **policy** affect environmental outcomes?

Focus on two main points, but there is lots more that has been done and more to do:

- Current tariff policy **subsidizes** trade in high-polluting industries.
- Multilateral environmental trade policies will work better than unilateral ones.

Trade Policy and the Environment

Shapiro (2021) describes a new fact about trade policy: in most countries, import tariffs and non-tariff barriers are **substantially lower on dirty industries than on clean industries.**

To arrive at this fact, he calculates the **embodied carbon content of trade** of an industry s as:

- Direct emissions of industry s.
- Emissions generated during the production of *intermediate goods* used to produce s.
- Calculates this using data from Exiobase (global multiregion input-output table similar to the WIOD).

Trade Policy and the Environment

He then estimates the following for each country:

$$\tau_{js} = \alpha E_{js} + \mu_j + \varepsilon_{js}$$

- τ_{js} is the tariff/NTB on product s from country j
- E_{js} is the average embodied emissions for industry s in country j.
- μ_j is a country fixed effect that captures the average rate of protection in country j.

Trade Policy and the Environment

Specification from the last slide:

$$\tau_{js} = \alpha E_{js} + \mu_j + \varepsilon_{js}$$

The coefficient of interest, α can be interpreted as the **implicit carbon tariff**—the tax on imports of embodied carbon.

- For example, $\alpha = 40$ would imply that an additional \$40 of import duties is collected for each additional ton of CO2 emitted.
- Shapiro (2021) estimates an α of **-85 to -120** implying that current trade policy actually *subsidizes* carbon at a rate of \$85 to \$120 per ton.

Trade Policy and the Environment

TABLE I

CLEANEST AND DIRTIEST MANUFACTURING INDUSTRIES IN THE GLOBAL DATA

	CO_2 rate (tons/\$) × 1000 (1)	Import tariff rate (2)	Nontariff barriers (3)
Panel A: Cleanest industries			
Pork processing	0.34	0.10	0.37
Meat products n.e.c.	0.36	0.10	0.37
Sugar refining	0.37	0.20	0.42
Wood products	0.37	0.01	0.03
Motor vehicles	0.40	0.03	0.05
Mean of cleanest five industries	0.37	0.09	0.25
Panel B: Dirtiest industries			
Bricks, tiles	1.54	0.02	0.02
Coke oven products	1.64	0.01	0.01
Iron and steel	1.74	0.01	0.02
Phosphorus fertilizer	1.93	0.02	0.11
Nitrogen fertilizer	2.53	0.02	0.11
Mean of dirtiest five industries	1.88	0.02	0.05

Notes. CO_2 rates are measured in metric tons of CO_2 per thousand dollars of output, calculated by inverting a global multiregion input-output table from Exiobase. Dollars are deflated to real 2016 values using the U.S. GDP deflator. Global refers to the mean value across all countries, weighted by the value of output; industries are ordered based on global emissions; n.e.c. means not elsewhere classified. Import tariffs are ad valorem and measured in 2007 CEPII Macmap data. Nontariff barriers are ad valorem, from Kee, Nicita, and Olarreaga (2009).

Trade Policy and the Environment

This carbon “subsidization” has held over time. (Slightly different specification than before.)

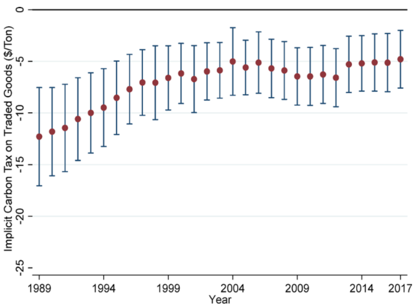


FIGURE III

Correlation between U.S. Import Tariffs and CO_2 Emission Rates

The implicit carbon tax is the coefficient from a regression of import tariffs on CO_2 emission rates, as in equation (1). The graph shows a separate regression for each year. Emissions intensity is estimated from 2007 input-output tables and applied to all years. Circles show the coefficient estimates, bars show robust 95% confidence intervals. Regressions use instrumental variables; total CO_2 is instrumented with direct CO_2.

Trade Policy and the Environment

Also holds across countries, with some countries worse than others.

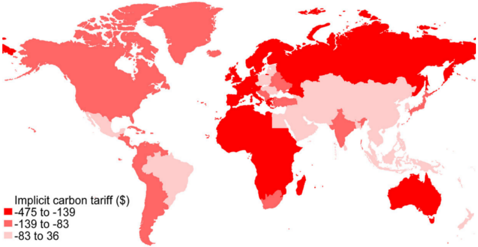


FIGURE V

Implicit Carbon Tax on Traded Goods, by Country

The implicit carbon tax is the coefficient from a regression of import tariffs plus NTBs (ad valorem equivalent) on CO_2 emission rates and a constant, separately for each country. The data correspond to Figure IV. The graph includes five rest-of-the-world groups, one per continent.

Trade Policy and the Environment

Shapiro (2021) attempts to figure out why there is this negative correlation.

- The only covariate that eliminates the relationship between carbon emissions and tariff rate is a measure of “upstreamness” of the industry.
- Tariffs tend to be lower on upstream goods than downstream, and these upstream industries tend to be dirtier.
  - Simple explanation—firms pressure governments for low tariffs on inputs, high tariffs to protect production.
- Related to a separate literature on **tariff escalation**.

Trade Policy and the Environment

Shapiro (2021) then uses a quantitative model to assess how counterfactual trade policies would affect CO2 emissions and social welfare.

- Model features input-output links, trade imbalances, CO2 emissions, tariffs, NTBs,
- **Counterfactual:** What would happen if each country implemented a single tariff per trading partner equal to the baseline bilateral tariff (tax clean and dirty goods the same way):
  - Modest increase in global real income (0.65%).
  - Reduce global carbon emissions by 3.6%.
  - Example of how a trade policy reform can reduce carbon emissions with no long-run aggergate global cost.

Trade Policy and the Environment

Current tariffs are not helping emissions, but can tariff policy actually reduce emissions?

Basic Idea: Strict environmental standards put domestic producers at a competitive disadvantage.

- Cheaper to produce in “dirtier” ways (e.g., coal vs solar).
- Import tariffs can help level the playing field within the country, making domestic industry more competitive.
- Also can incentivize foreign countries to produce in cleaner ways if tariffs are based on emissions of products.

One problem is something known as **leakage**.

- Suppose U.S. demand for Chinese steel declines because of environmental regulation. This causes Chinese steel prices to decline, which increases demand by other countries.

Trade Policy and the Environment

Climate change is a **global problem**.

- Each unit of carbon emission creates a global externality.
- For these reasons, governments have tried to reach international climate agreements.
- Global climate agreements have not been very effective in bringing down global carbon emissions:
  - Kyoto Protocol (1997)
  - Paris Climate Accord (2015)
- **Main Problem:** Free-riding.
  - Countries can recieve the benefits of a cleaner environment without contributing to the costs if they rely on other countries to reduce emissions.

Trade and Climate Policies

Hsiao (2021) explores how effective import tariffs can be at curbing global carbon emissions.

- Dynamic empirical framework.
- Applies the framework to studying the palm oil industry.
  - Responsible for 5% of global CO_2 emissions from 1990-2016.
  - 84% of production occurs in Indonesia and Malaysia.
  - Large source of export revenue, so little incentive to regulate internally.
- Finds that import tariffs can be effective at reducing emissions, but requires that global efforts are:
  - Coordinated (multilateral rather than unilateral).
  - Committed to (strong enforcement).

Trade and Climate Policies

Table 5: Counterfactual experiments

	%	$1B	ΔW ($1B)				ΔW ($1B)			
	ΔE	ΔW	CS	PS	G	E	EU	CI	OI	IM
Domestic regulation										
Full commitment	39.62	115	-207	-70	194	198	-21	0	74	62
30-year commitment	32.63	95	-157	-58	147	163	-17	3	67	41
10-year commitment	7.87	26	-30	-18	35	39	-4	3	18	8
Tariffs: all importers										
Full commitment	38.92	108	-165	-65	143	195	-3	24	138	-51
30-year commitment	31.84	89	-123	-53	105	160	-3	20	113	-41
10-year commitment	7.49	22	-25	-17	27	38	0	5	29	-12
Tariffs: EU, China, India										
Full commitment	15.20	39	-87	-22	72	76	-8	0	64	-18
30-year commitment	11.68	30	-61	-16	49	58	-6	1	49	-14
10-year commitment	2.13	6	-12	-3	11	11	-1	0	9	-3
Tariffs: EU only										
Full commitment	6.10	15	-28	-9	22	30	-8	6	25	-8
30-year commitment	5.03	12	-23	-7	17	25	-7	4	21	-6
10-year commitment	1.27	3	-6	-2	5	6	-1	1	5	-2

Each row is one experiment. Columns show changes relative to business as usual in emissions (E) and social welfare (W). I break welfare into consumer surplus (CS), producer surplus (PS), government revenue (G), and emissions (E), as well as welfare for the EU (EU), China and India (CI), other importers (OI), and Indonesia and Malaysia (IM). Each is a net present value from the initial period. The EU, China/India, other importers, and Indonesia/Malaysia bear 1%, 17%, 80%, and 2% of the social costs of carbon, respectively, based on pooled estimates from Ricke et al. (2018).

Trade and Climate Policies

Key Takeaways: Tariffs can be effective, but coordination and commitment matter.

- **First Best:** Indonesia and Malaysia internally regulate the industry, which reduces emissions by 40 percent.
- Tariffs by **all importers with full commitment** is almost as good as the first-best.
- As coalition of countries imposing tariffs decreases, emissions reductions are reduced. Leakage and trade diversion.
- Commitment is a substitute for coordination—smaller coalitions with full commitment are as good as coordination with no commitment.

Trade and Climate Policies

Two other types of policy proposals that leverage trade policy to target climate issues:

Policy 1: Carbon Border Taxes (Unilateral)

- Tariffs based on the carbon content of imported products.
- EU is phasing in this type of policy starting in January.
- **Goal:** Level the playing field for domestic producers if they are less competitive due to stricter environmental regulation; incentivize ROW to generate less carbon emissions.

Policy 2: Climate Club (Multilateral, Nordhaus (2015))

- One/a few climate-conscious countries establish climate club.
- Core club-members use tariffs collectively to incentivize other countries to join.
- **Idea:** If you would benefit from free trade with the club members, you pay a "climate fee" to join the club, where the climate fee is strict environmental regulation.

Trade and Climate Policies

Farrokhi and Lashkaripour (2021) develop a multi-country, multi-industry quantitative trade model that can incorporate both of these policy proposals.

- Unilateral carbon border tax adjustment cannot come close to replicating CO2 reductions attainable under global climate cooperation.
- Climate club proposal is much more effective.
  - Hinges on both the U.S. and the EU committing to the climate club as core members.

Conclusion

Broad overview of the literature on trade and emissions/climate change.

- Lots more that we didn't cover.
- Recommend reading the Copeland et al. (2021) for a more detailed overview if you're interested.
- One other strand that is developing is about **adaptability**.
  - As temperatures change, for example, agricultural productivity in certain regions will change.
  - Trade will need to help reallocate production, change structure of supply chains.

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