The environmental bias of trade policy

Shapiro (2021), *The Quarterly Journal of Economics*

Env Climate discussion group S2

July 31, 2023

Research questions

1. Do dirty industries already face higher tariffs and NTBs?
   (NTBs include policy barriers to trade that are not tariffs, such as price regulations, product standards, quantity restrictions like quotas, or others)
2. Why have countries imposed more protection on clean than dirty industries?
3. How would counterfactual trade policies affect CO_2 emissions and social welfare?

Outline of the paper

- document a new fact — **trade policy's environmental bias**
  - regression of tariff (or ad valorem NTB) rates on CO2 intensity
- analyze its causes
  - consider explanations based on 20 variables suggested by theoretical and empirical research
  - address potential endogeneity: instrument a particular political economy explanation with its value from the 10 smallest other countries (i.e. deal-takers plausibly)
  - highlight the covariance of "upstreamness" (of an industry in global value chains) and trade policy
- analyze its consequences
  - a partial equilibrium back-of-the-envelope (rough, using simplified assumptions) calculation of global implicit subsidy in trade policy
  - a quantitative general equilibrium model to assess how counterfactual trade policies would affect CO2 emissions and social welfare

Contributions

- important policy implications (discuss later)
- 1st to report the association of tariffs or NTBs with the pollution emitted to produce different goods
- 1st to quantify the environmental consequences of harmonizing trade policy between clean and dirty goods
- introduces tariffs and NTBs as a new setting to study political economy and the environment
- 1st nonparametric evidence of "tariff escalation", 1st evidence of NTB escalation & 1st empirical link between tariff escalation and the environment

Data (1)

cross-section for 2017 or the closest available year

- trade policy
  - French Centre d'Etudes Prospectives et d'Informations (CEPII) + Market Access Map (Macmap) database: six-digit Harmonized System code version of tariff rates $\Rightarrow$ official policy, statutory rates
  - Census Bureau's Imports of Merchandise files: tariffs on US imports $\Rightarrow$ actually paid duties, effective rates
  - Kee, Nicita, and Olarreaga (2009) on the dollar (i.e., ad valorem) equivalent of NTBs
- pollution emissions
- political economy

Data (2)

cross-section for 2017 or the closest available year

- trade policy
- pollution emissions
  - direct CO_2 emissions = emissions from burning fossil fuels to produce output ⇒ consider the rows for the coal extraction, oil extraction, and natural gas extraction industries from the input-output table (in dollar terms): **(country-industry-specific) direct emission rate = coal, oil, and gas input expenditures × the tons of CO2 emitted per dollar of fossil fuel burned**
  - indirect CO_2 emissions = emissions from burning fossil fuels to produce intermediate goods ⇒ inverting the input-output matrix permits calculation of total emissions = sum of direct and indirect
- political economy

Formal calculation: a single closed economy

For a single closed economy, S — number of industries, A — $S \times S$ input-output table where

- each row lists the industry supplying input
- each column lists the industry demanding outputs
- each entry describes the dollars of input from the row industry required to produce \$1 of output for the column industry

x — $S \times 1$ column vector describing each industry's gross output, d — $S \times 1$ vector describing each industry's final demand, including exports. By an accounting identity:

$$\underbrace{x}_{\text{gross output}} = \underbrace{Ax}_{\text{value of its output used for intermediate goods in all industries}} + \underbrace{d}_{\text{value of its output used for final demand}}$$

Thus, the total amount of intermediate inputs required to produce \$1 of final demand:

$x = (I - A)^{-1} d$

Formal calculation: multiply open economies

N — number of countries, S — number of industries, A — $NS \times NS$ multi-region input-output table

- each row lists the country-industry supplying input
- each column lists the country-industry demanding outputs
- each entry describes the dollars of input from the row country-industry required to produce \$1 of output for the column country-industry

x — $NS \times 1$ column vector = gross output, d — $NS \times 1$ vector = final demand. Similarly, by an accounting identity:

$$\underbrace{x}_{\text{gross output}} = \underbrace{Ax}_{\text{value of its output used for intermediate goods in all country-industries}} + \underbrace{d}_{\text{value of its output used for final demand}}$$

Thus, the total amount of intermediate inputs required to produce \$1 of final demand: $x = (I - A)^{-1}d$. (Leontief inverse $L = (I - A)^{-1}$)

Data (3)

cross-section for 2017 or the closest available year

- trade policy
- pollution emissions
  - Exiobase:
    - provides a global multi-region input-output table, which reports the **direct CO2 emissions** per million euros of output for every country-industry
    - allow computation of total (direct + indirect) emissions rates:
      L_{ijst} — the dollars of output from industry s in country i required to produce \$1 of output from industry t in country j
      E_{is}^{direct} — the reported CO_2 emitted from the coal, oil, and natural gas used directly in this country-industry
      $\Rightarrow$ **total emission rates** $E_{jt} = \sum_{i,s} L_{ijst} E_{is}^{direct}$
- political economy

Data (4)

cross-section for 2017 or the closest available year

- trade policy
- pollution emissions
- political economy — "Why do different industries face different trade policies?"
  1. explanation involving optimal tariffs and the terms of trade — **optimal tariffs (classically given by the inverse of foreign export supply elasticity) could correlate with CO_2 intensity:** higher on more differentiated industries, and clean industries may be more differentiated.
  2. explanation involving political economy — organized interest groups lobby to obtain trade protection

  - Exiobase: some political economy variables are available separately for each country-industry, and a larger set for each industry in U.S. data
  - add a measure of "local" air pollution emissions and damages (local external costs could lead to policies like low tariffs and NTBs on dirty industries that seek to relocate polluting activity elsewhere)

Upstreamness

- most important variable
- each industry's "upstreamness" = the average economic distance of an industry from final use
- interpretation: the mean position of an industry's output in a vertical production chain, or the share of an industry's output sold to relatively upstream industries

Econometrics: Trade policy and CO_2 Intensity

To measure differences in trade policy between clean and dirty industries:

$$t_{js} = \alpha E_{js} + \mu_j + \varepsilon_{js} \tag{1}$$

t_{js} — the mean import tariff rate or ad valorem NTBs that destination country j imposes on goods in industry s
s — the foreign industry which produced the good in the global data (not the domestic industry which consumed it)
E_{js} — the mean emissions from industry s in all countries from which country j imports (averaged across origin countries, value-weighted); tons of **total** CO_2 emitted per dollar of imported goods

α = duties collected per ton of CO_2 emitted, representing the carbon tariff implicit in existing trade policy
$\Longrightarrow$ estimated [-120, -85], a carbon subsidy in trade policy of $85 to $120 per ton of CO_2.

(2SLS to address potential measurement error: instrument total emission rates by direct emission rates)

Econometrics: Political Economy Explanations

Testing: political economy variables are omitted from Equation (1); they determine trade policy and correlate with CO_2 intensity.

1. estimate a separate regression for each political economy variable F_{js} (+one controlling for all potential political economy explanations at once)

$$t_{js} = \beta E_{js} + \pi F_{js} + \mu_j + \varepsilon_{js} \tag{2}$$

   (using both linear regression and the least absolute shrinkage and selection operator – Lasso)

2. assess which of these variables most attenuates the estimated β

The environmental bias in trade policy (1)

TABLE I

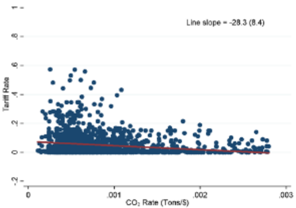
CLEANEST AND DIRTIEST MANUFACTURING INDUSTRIES IN THE GLOBAL DATA

	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

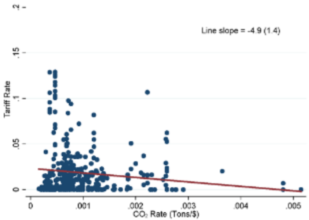
Notes. CO_2 rates are measured in metric tons of CO_2 per thousand dollars of output, calculated by inverting a global multiregion input-output table from Exiobase. Dollars are deflated to real 2016 values using the U.S.

The environmental bias in trade policy (2)

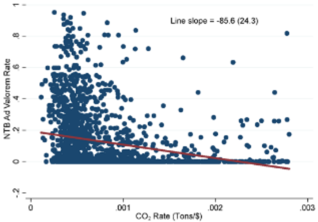
(C) Actual global tariffs



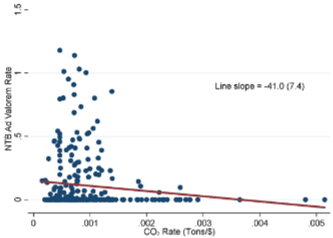
(D) Actual U.S. tariffs



(E) Actual global nontariff barriers



(F) Actual U.S. nontariff barriers



The environmental bias in trade policy (3)

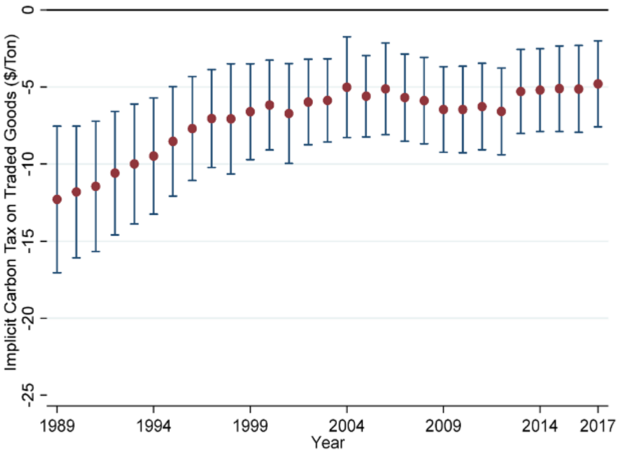


FIGURE III

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

The environmental bias in trade policy (4)

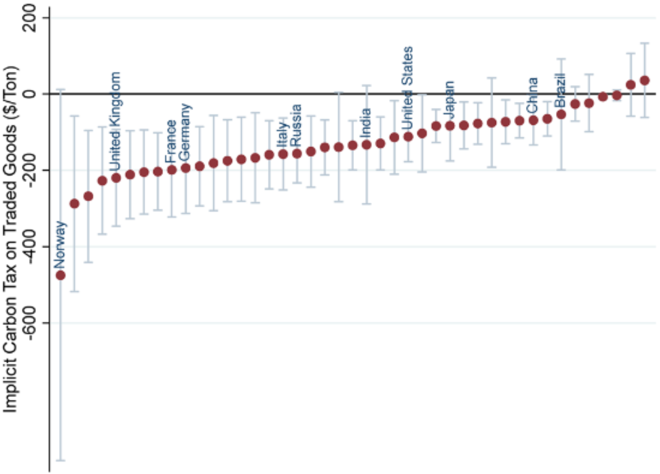


FIGURE IV

The environmental bias in trade policy (5)

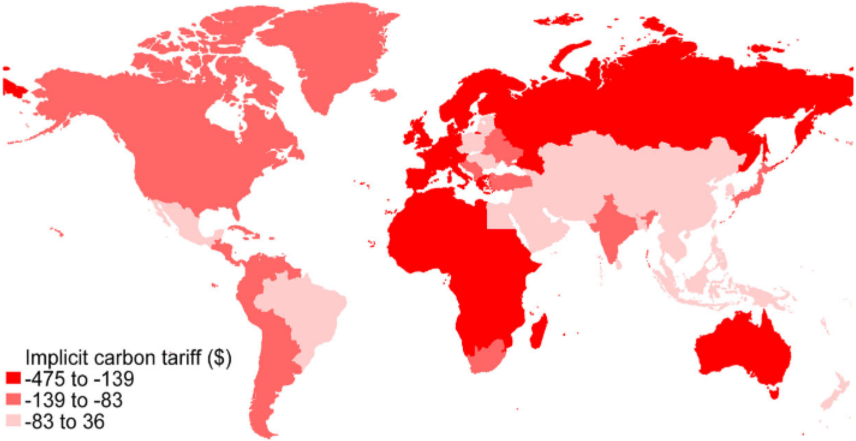


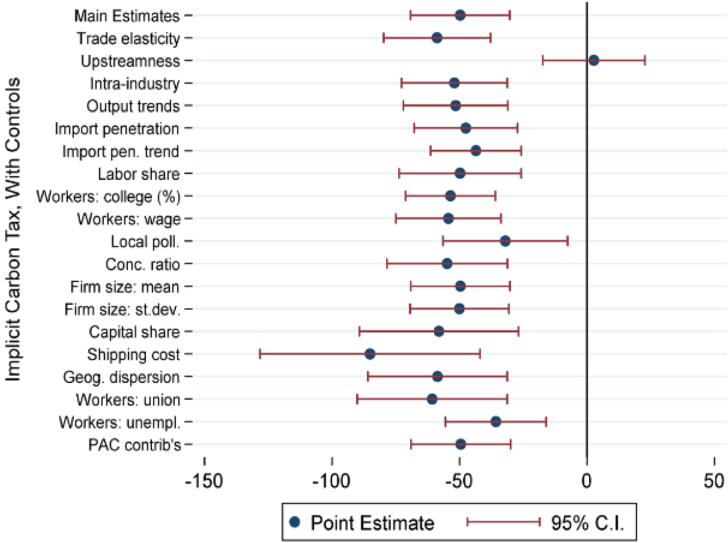
FIGURE V

Implicit Carbon Tax on Traded Goods, by Country

Explanations for the relationship — Why do countries impose higher tariffs and NTBs on clean goods than on dirty goods?

- Which are the most important omitted variables in regressions of trade policy on CO2 intensity?
  $\Rightarrow$ the association between emissions and **upstreamness** is stronger than the association between emissions and other political economy variables (intraindustry trade, import penetration ratio, labor share and mean wage) in U.S. and global data (p860, Table IV)

In US: the coefficient on total CO2 intensity (β)



Explanations for the relationship (cont.)

- Why is an industry's upstreamness strongly correlated with its CO_2 intensity?
  $\Rightarrow$ Upstream industries use a larger share of fossil fuels than downstream industries do. Relative to upstream industries, downstream industries spend relatively more on labor and intermediate goods.
- If downstream goods are just combinations of upstream goods, why would different import tariff rates on upstream versus downstream goods affect CO_2 emissions?
  $\Rightarrow$ Downstream industries use as inputs both upstream goods and relatively clean factors like labor. Hence, imposing high tariffs on downstream but not upstream goods can encourage consumers to substitute from demanding relatively clean factors like labor to demanding relatively dirty factors like energy.
- Local pollution does not statistically account for the association between CO_2 emissions and trade policy

Partial Equilibrium Approximation of tax revenue loss

$$\hat{\alpha} \sum_{j,s} E_{js} \sum_{i \neq j} X_{ijs}, \tag{4}$$

where $\sum_{i \neq j} X_{ijs}$ represents the value of international imports by country j in sector s. This represents the revenue that a carbon tariff would collect if it had the same pattern as trade policy's environmental bias (i.e., −\$85 to −\$120/ton). The parameter $\hat{\alpha}$ is the implicit carbon subsidy in trade policy from equation (1).

⇒ Using α from the chosen specifications, it calculated that global trade policy provided an implicit subsidy of \$550 to \$800 billion in 2007 (measured in 2016 dollars). (a similar magnitude to the global direct subsidies to fossil fuels, which were about \$530 billion in 2007 according to IMF 2013)

Analytical Model: two symmetric countries and two industries (1)

(s=1 dirty sector that emits, s=2 clean sector that does not)

- Preferences: representative agent in country j maximizes national utility U_j

$$U_j = \prod_s Q_{js}^{\beta_{js}} f(Z).$$

where $Q_{js} = (\sum_i q_{ijs}^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}}$, σ is the elasticity of substitution between goods from each country.
  - for sector $s = \{1,2\}$, $q_{ijs}, i \neq j$: international trade; $q_{ijs}, i = j$: intranational trade
  - Z = global pollution emissions (treated as a pure externality by the agent)
  - β_{js} = expenditure shares (Cobb-Douglas across sectors), taste for variety
- The associated price index $$P_{js} = \left[\sum_i (c_{is}\phi_{ijs})^{-\epsilon}\right]^{-\frac{1}{\epsilon}}$$ where
  - the elasticity of trade flows with respect to trade costs $\varepsilon = \sigma - 1$;
  - trade costs $\phi_{ijs} = \tau_{ijs}(1 + t_{ijs})(1 + n_{ijs}) \geq 1$ with iceberg trade costs $\tau_{ijs} \geq 1$ and tariffs(t_{ijs}) and NTBs (n_{ijs})≥ 0

Analytical Model: two symmetric countries and two industries (2)

- Technology: unit cost of production is cobb-douglas in labor and in intermediate goods from other sectors $$c_{is} = w_i^{1-\alpha_{is}} \prod_k P_{ik}^{\alpha_{iks}}$$ where
  - α_{is} is the labor share
  - α_{iks} is the cost share of industry k to produce output in country i and industry s

- Pollution emitted for country i to sell goods to destination j: $$Z_{ij1} = \frac{X_{ij1}}{c_{i1}(1+t_{ij,1})}$$ where
  - **pollution intensity in revenue terms is normalized to 1!**
  - c_{is} = unit production cost (factory-gate price)
  - X_{ijs} = total expenditure on goods produced in origin country i, shipped to destination j, in sector s
  - one country's pollution emissions $Z_i = \sum_j Z_{ij1}$, emissions from selling goods globally (global pollution emissions $Z = Z_1 + Z_2$)

Analytical Model: two symmetric countries and two industries (3)

- Trade flows

$$X_{ijs} = \left(\frac{c_{is}\phi_{ijs}}{P_{js}}\right)^{-\epsilon} X_{js} = \lambda_{ijs} X_{js},$$

where
- $\lambda_{ijs} = \frac{X_{ijs}}{X_{js}}$, the share of country j's expenditure on sector s varieties which is sourced from country i
- $X_{js} = \sum_i X_{ijs}$, total expenditure on sector s goods in country j

- Equilibrium: consumers maximize utility, firms maximize profits, and markets clear. Trade is balanced. Global GDP is the numeraire.
Total expenditure on goods in a country × sector equals the sum of expenditure on final and intermediate goods:

$$X_{js} = \beta_{js}(Y_j + T_j) + \sum_k \alpha_{jsk} R_{jk}$$

where Y_j is the factor payment, $T_j = \sum_{i,s} \frac{X_{ijs} t_{ijs}}{1+t_{ijs}}$ is the tariff revenue, $R_{is} = \sum_j \frac{X_{ijs}}{1+t_{ijs}}$ is the country X sector revenues.

Counterfactual Results and Interpretation (1)

Express each variable in changes from baseline levels (exact hat algebra):

- changes in expenditure shares due to a counterfactual trade policy $\hat{\lambda_{ijs}}$ $\hat{\lambda}_{ijs} = \left(\frac{\hat{c}_{is}\hat{\phi}_{ijs}}{\hat{P}_{js}}\right)^{-\epsilon}$
- changes in country X sector price index $\hat{P_{js}}$ $\hat{P}_{js} = \left[\sum_i \lambda_{ijs}(\hat{c}_{is}\hat{\phi}_{ijs})^{-\epsilon}\right]^{-\frac{1}{\epsilon}}$
- changes in pollution emissions $\hat{Z} = Z'/Z$ and do the substitutions

$$\hat{Z}_i = \frac{\hat{X}_{i1}}{\hat{c}_{i1}}\left[\frac{\hat{\lambda}_{ii1}Z_{ii1} + (\widehat{1 + t_{ij1}})^{-1}\hat{\lambda}_{ij1}Z_{ij1}}{Z_i}\right]$$

= product of two terms:

the change in real expenditure on dirty goods X the change in the pollution intensity of expenditure

Counterfactual Results and Interpretation (2)

$$\hat{Z}_i = \frac{\hat{X}_{i1}}{\hat{c}_{i1}} \left[\frac{\hat{\lambda}_{ii1} Z_{ii1} + (\widehat{1 + t_{ij1}})^{-1} \hat{\lambda}_{ij1} Z_{ij1}}{Z_i} \right]$$

Separate the changes in pollution intensity into two channels:

- (ii) the counterfactual emissions from domestic sales
- (ij) the counterfactual emissions from exports

Besides, the changes in real spending on dirty goods $\frac{\hat{X_{i1}}}{\hat{c_{i1}}}$ follow

$$\hat{c}_{11} = [\lambda_{111} + \lambda_{211}(\hat{\phi}_{211})^{-\epsilon}]^{-\frac{1}{\epsilon}\frac{\alpha_{121}\alpha_{112} + (1-\alpha_{122})\alpha_{111}}{(1-\alpha_{111})(1-\alpha_{122}) - \alpha_{112}\alpha_{121}}} \times [\lambda_{112} + \lambda_{212}(\hat{\phi}_{212})^{-\epsilon}]^{-\frac{1}{\epsilon}\frac{\alpha_{121}\alpha_{122} + (1-\alpha_{122})\alpha_{121}}{(1-\alpha_{111})(1-\alpha_{122}) - \alpha_{112}\alpha_{121}}},$$

and

$$\hat{X}_{js} = \frac{\beta_{js}(Y_j + T_j^{'}) + \sum_k \alpha_{jsk} R_{jk}^{'}}{\beta_{js}(Y_j + T_j) + \sum_k \alpha_{jsk} R_{jk}}$$

$\Rightarrow$ reflecting changes in spending on dirty final goods (**tariff revenue channel**), dirty intermediate goods (**input-output link channel**), and the production cost (**only change if trade policy affects dirty and clean sectors asymmetrically**).

Counterfactual Results and Interpretation — Social welfare (1)

The change in social welfare due to a counterfactual equals the product of the change in real income and pollution damages: $\hat{W}_j = \frac{\hat{X}_j}{\hat{P}_j} f(\hat{Z})$

$$\hat{W}_j = \frac{Y_j + T_j'}{Y_j + T_j} \prod_s \left[\sum_o \lambda_{ojs} (\hat{c}_{os} \hat{\phi}_{ojs})^{-\epsilon} \right]^{\frac{\beta_{js}}{\epsilon}} \widehat{f(Z)}.$$

Product of 3 terms: the increase in nominal expenditure from tariff revenues (higher tariff ⇒ higher T_j'), the (inverse of the) price index (higher tariff ⇒ lower inverse of price index), and the change in pollution damages.

theoretically ambiguous welfare effects of counterfactual policies that increase protection for dirty goods but decrease protection for clean goods

Quantitative Model

Quantify effects of these counterfactuals in a richer model (many asymmetric countries; many industries; input-output links; trade imbalances; multiple dirty (fossil fuel) industries; distinctions between iceberg trade costs, nontariff barriers, and tariffs; and others)

- aggregate the data to 10 regions and 21 industries
- assume intraregional tariffs are zero
- aggregate multiple estimates of sector-specific trade elasticities using inverse variance weighting, which minimizes variance

Choice of Counterfactuals

Main **changes each country's bilateral import tariffs to the country's weighted mean baseline bilateral tariff, and similarly for NTBs, with weights equal to baseline trade** ⇒ harmonizing trade policy between clean and dirty industries

- others:

  - single tariff per trading partner
  - only EU adopts this policy
  - changing tariffs/NTBs to equal either the baseline level of the cleanest third or dirtiest third of industries
  - every country adds a carbon tariff
  - countries completely eliminated tariffs and NTBs

Counterfactuals: Results for Main Counterfactual

EFFECTS OF SETTING TARIFFS AND NTBS TO MEAN, MODEL-BASED ESTIMATES

	Change in CO_2 emissions (%) (1)	Change in real income (%) (2)	Change in CO_2 intensity (%) = (1) – (2) (3)	Climate benefits (%) (4)	Social welfare (%) (5)
Panel A: Global total					
Global total	–3.59	0.65	–4.24	0.08	0.57
Panel B: By region					
Pacific Ocean	33.31	1.02	32.29	—	—
Western Europe	23.33	0.90	22.43	—	—
Eastern Europe	0.77	0.99	–0.22	—	—
Latin America	–3.36	0.74	–4.10	—	—
North America	–3.80	0.26	–4.06	—	—
China	0.03	0.22	–0.19	—	—
Southern Europe	54.67	0.64	54.03	—	—
Northern Europe	26.96	1.06	25.90	—	—
Indian Ocean	–5.15	0.31	–5.46	—	—
Rest of world	–14.96	0.93	–15.89	—	—
Panel C: Decomposition					
Scale	0.20	—	—	—	—
Composition	–1.29	—	—	—	—
Technique	–2.50	—	—	—	—
Panel D: By fossil fuel					
Coal	–2.63	—	—	—	—
Oil	–4.65	—	—	—	—
Natural gas	–3.97	—	—	—	—

Notes. Global change in real income refers to the weighted mean percentage change in countries' real incomes due to a counterfactual policy, where weights equal each country's baseline income. In all baseline and counterfactual scenarios, intranational tariffs and NTBs are assumed to equal zero.

- decrease global CO2 emissions by about 3.6 percentage points
- increase global real income by 0.7 percentage points
- decreases CO2 intensity by 4.2 percentage points
- increase in social welfare due to the decreased CO2 emissions is much smaller than the increase in social welfare due to the increased real income

Counterfactuals: Decomposition

(the main counterfactual requires each country to impose the same trade policies on different goods $\Rightarrow$ turns off differences in trade policy between clean and dirty goods)

- increases relative rates of protection for all energy-intensive goods
- directly decreases international trade in fossil fuels (domestic supply of fossil fuels does increase, but the domestic supply is not enough to offset the decrease in imported fuels)
- increases the price of fossil fuels (fossil fuel extraction uses other energy-intensive goods whose prices also increase)
- decreases in the share of fossil fuels purchased from international sources (same as above:the value of the fall in international purchasing exceeds the value of the rise in domestic production)
- decrease spending on fossil fuels as an intermediate good (decreased demand for fossil fuels from other energy-intensive goods sectors)
- net effect from the change in spending on fossil fuels as a final good is small

Conclusion

The question was how and why do tariffs and NTBs differ between clean and dirty industries.

- documenting the environmental bias in trade policy — The implicit subsidy to CO2 in trade policy totals $550 to $800 billion a year
- showing that trade policy has this subsidy because political economy variables that determine trade policy are correlated with CO2 emissions
- describing theory and evidence consistent with the idea that **firms lobby for high protection on their own outputs but low protection on their intermediate inputs**
- bringing the climate and environment into the argument against tariff escalation has important consequences

The end!