The Environmental Bias of Trade Policy

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Motivation

- **Need global policy, have regional policy**
  - 20% of global carbon emissions face carbon prices (EU, California, etc.)
  - Leakage a big concern
- **Carbon tariffs a possible solution**
  - Waxman-Markey (2009) Bill, California's AB32
  - France, Mexico, Canada recent threats
- **Do countries already have higher tariffs / non-tariff barriers on dirty industries?**
  - Plausible: dirty industries are politically influential
  - Implicitly, would resemble carbon tariffs

Overview

1. **One new fact, three ways to say it**
   - Countries have higher tariffs and non-tariff barriers on clean than dirty goods
     - ★ "Dirty" based on tons CO_2 emissions to produce \$1 output
   - Countries implicitly have carbon border adjustments, but they are subsidies
   - Trade policy implicitly subsidizes climate change
     - ★ Global implicit carbon subsidy in trade: \$85 to \$120/ton
2. **Political Economy Explanations**
3. **Consequences**

Overview

1. **One new fact, three ways to say it**
2. **Political Economy Explanations**
   - Little role for standard stories (unionization, optimal tariffs, etc.)
   - Main story: downstream industries have lower emissions, higher tariffs
   - Interpretation: upstream-downstream lobbying
3. **Consequences**

Overview

1. **One new fact, three ways to say it**
2. **Political Economy Explanations**

   American manufacturers, energy companies, and retailers reliant on cheap steel are quietly lobbying against President Donald Trump's desire to impose tariffs on steel imports ahead of possible decision by the U.S. Commerce Department next week. . . . U.S. manufacturers and energy companies who use steel want to keep their costs down and say tariffs could cost jobs in their industries . . .

   – Reuters 7/14/2017, "Behind the scenes, companies fight Trump on U.S. steel tariffs"

3. **Consequences**

Overview

1. **One new fact, three ways to say it**
2. **Political Economy Explanations**
3. **Consequences**
   - Global implicit subsidy to CO2 $>$ \$500 billion / year
   - Same trade policy for clean, dirty industries would decrease global CO2, increase GDP

Interpretation

- **Is this a subsidy?**
  - Relative subsidy: lower taxes in setting with mostly positive taxes
  - Quantitative model: this environmental bias increases global CO_2
- **Possible mechanisms to affect CO_2**
  - Traded goods dirtier due to transportation, outsourcing to India/China
  - Substitution between producing/consuming goods (e.g., aluminum/steel)
  - Broadly, sends wrong price signal
  - Agents respond in many ways, paper models some

What is New Here

- **Trade and the environment; Industrial ecology** (Copeland and Taylor 2003; Fowlie et al. 2016; Kortum and Weisbach 2016; Shapiro and Walker 2017)
  - New: compare trade policy to pollution embodied in goods

- **Political economy and environment** (Hillman and Ursprung 1994; Oates and Portney 2003; Schleich and Orden 2000; Burgess et al. 2012; Sallee 2017)
  - New: trade policy as setting for political economy and the environment

- **Trade policy** (Grossman and Helpman 1994; Goldberg and Maggi 1999; Copeland 2000; Gawande and Bandyopadhyay 2000; Ederington 2010; Gawande et al. 2012; Maggi 2016)
  - New: addressing tariff escalation slows climate change
  - NTB escalation, nonparametric tariff escalation

- **Quantitative General Equilibrium Models** (Krugman 1980; Grossman and Helpman 1994; Costinot and Rodríguez-Clare 2014; Ossa 2014; Caliendo, Parro, and Tsyvinski 2017; Caron and Fally 2018)

Overview

- **Data**
- Econometrics
- Trade Policy and Carbon Intensity
- Explanations for Tariff-Pollution Relationship
- Consequences of Tariff-Pollution Relationship

Data: Trade Policy

- **Global tariffs**
  - CEPII Macmap, 200 million observations
  - 192 countries, 5,000 products (6-digit Harmonized System codes)
  - Tariffs, trade agreements, customs unions, tariff-rate quotas, etc.

- **U.S. import tariffs**
  - Source: U.S. Census Imports of Merchandise series
  - 375 industries (6-digit NAICS for manufacturing)

Data: Trade Policy

- **Non-tariff barriers (NTBs)**
  - What are NTBs? Quotas, product standards, licenses, etc.
  - Source: Kee et al. (2009) Ad valorem equivalents Kee details
  - Widely used (Irwin 2010; Limao and Tovar 2011; Novy 2013; Handley 2014)
  - Bagwell and Staiger (2011): "the best [NTB] measures that are available"
  - 5,000 products (6-digit Harmonized System codes)
  - One year per country, in 2000-2003

Data: Pollution Emissions

- **Measuring CO_2 emissions, national data**

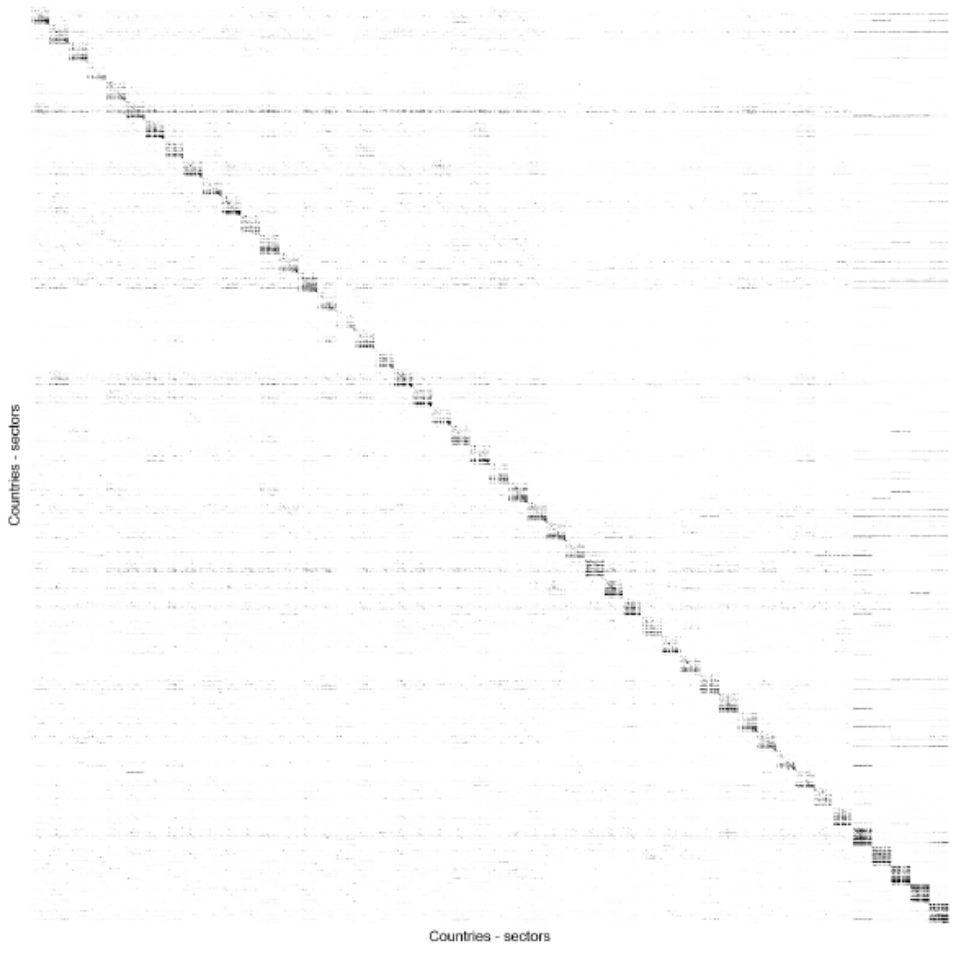
$$\begin{aligned} x &= Ax + d \\ (I - A)x &= d \\ x &= (I - A)^{-1} d \\ E &= e(I - A)^{-1} d \end{aligned}$$

- **Definitions:**

x	Gross output ($S \times 1$)
A	Input-output matrix ($S \times S$)
d	Final demand, including exports ($S \times 1$)
e	Tons CO_2 emitted per dollar of fuel input ($S \times S$, diagonal)
E	Tons CO_2 emitted per dollar of industry output ($S \times 1$)

Data: Global Pollution Emissions

- **Total emissions, global**
  - Exiobase, a multi-region input-output database
  - Year 2007, 61 million trade flows (48 countries, 163 industries)



Data: U.S. Pollution Emissions

- **Total emissions, U.S. 2007**
  - Input-output table from Bureau of Economic Analysis
  - Energy Information Agency: emissions per physical unit of coal/oil/gas
  - Combine Make, Use tables; exclude feedstock

- **Direct U.S. emissions**
  - Manufacturing Energy Consumption Survey (MECS) and Census of Manufactures (CM)
  - Physical consumption of coal, oil, gas by NAICS industry
  - Census of Manufactures (CM) : electricity consumption and cost of fuels

Data: Trade Policy and Pollution Emissions

Table 1—Cleanest and Dirtiest Manufacturing Industries in Global Data

	CO_2 Rate (Tons/$)×1000 (1)	Import Tariff Rate (2)	Non-Tariff 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 5 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 5 industries	*1.88*	*0.02*	*0.05*

Data: Tariffs and Pollution Emissions

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Data: Political Economy Variables

- **Optimal tariffs**: Inverse export supply elasticities. Bickerdike (1907); Broda, Limao, and Weinstein (2008)
- **Lobbying supply**: Four-firm concentration ratio; mean firm size; standard deviation of firm size; capital share; shipping cost; geographic dispersion; workers unionized; workers unemployed; PAC contributions
- **Demand for protection** Output trends; import penetration ratio; import penetration ratio trends; labor share; workers college share; workers mean wages
- **Demand for low protection from customers**: Intra-industry trade, upstreamness
- **Upstreamness**: Simple measure; Antras et al. (2012)

$$
\begin{aligned}
U_i^S &= \sum_{j=1}^{n} \Omega_{ij} y_j / y_i \\
U_i^D &= [I - \Omega_{ij} y_j / y_i]^{-1} \mathbf{1}
\end{aligned}
$$

Overview

- Data
- **Econometrics**
- Trade policy and carbon intensity
- Explanations for tariff-pollution relationship
- Consequences of tariff-pollution relationship

Econometrics: Implicit Carbon Subsidies

Basic Equation

$$t_{js} = \alpha E_{js} + \zeta_j + \varepsilon_{js}$$

Notes

- Averages over exporters (average excludes intra-national trade)
- α is carbon tax implicit in trade policy (\$ per ton CO_2)
- Carbon tax reflects industry emissions (not firm). May not reflect abatement.
- Importer chooses tariffs, exporter determines emissions.
- Heteroskedastic-robust standard errors (appendix: cluster by country)
- Main analysis: manufacturing only
- Data for year 2007
- U.S.: instrument E with E^{direct} to address measurement error:

$$E_{js} = \alpha E_{js}^{direct} + X_{js}'\beta + \varepsilon_{js}$$

Econometrics: Political Economy

Basic Equation

$$t_{js} = \alpha E_{js} + F'_{js}\pi + \mu_j + \varepsilon_{js}$$

Details:

- F political economy explanations
- Focus on U.S.–better political economy and other data
- Lasso (machine learning) and OLS

Overview

- Data
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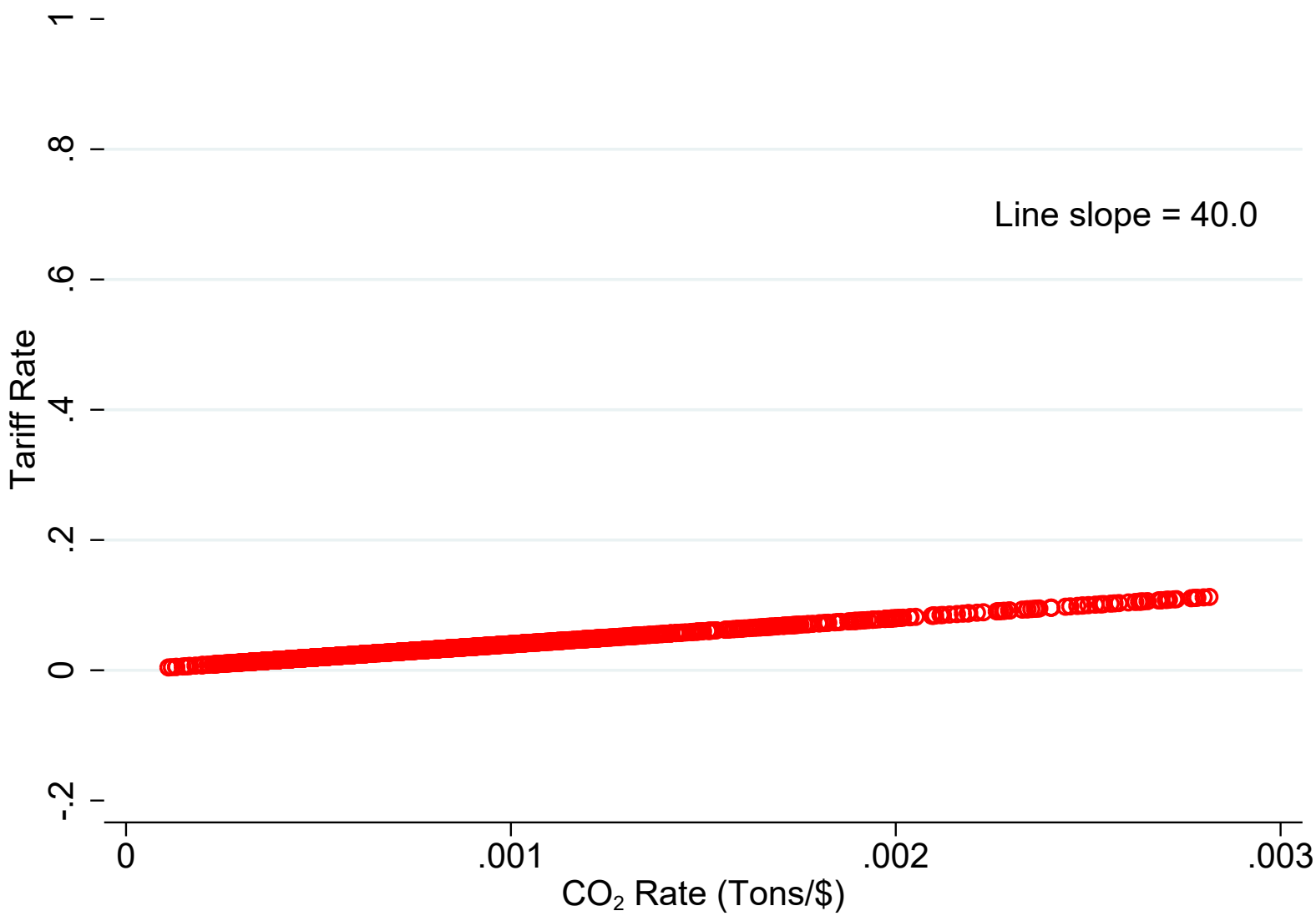
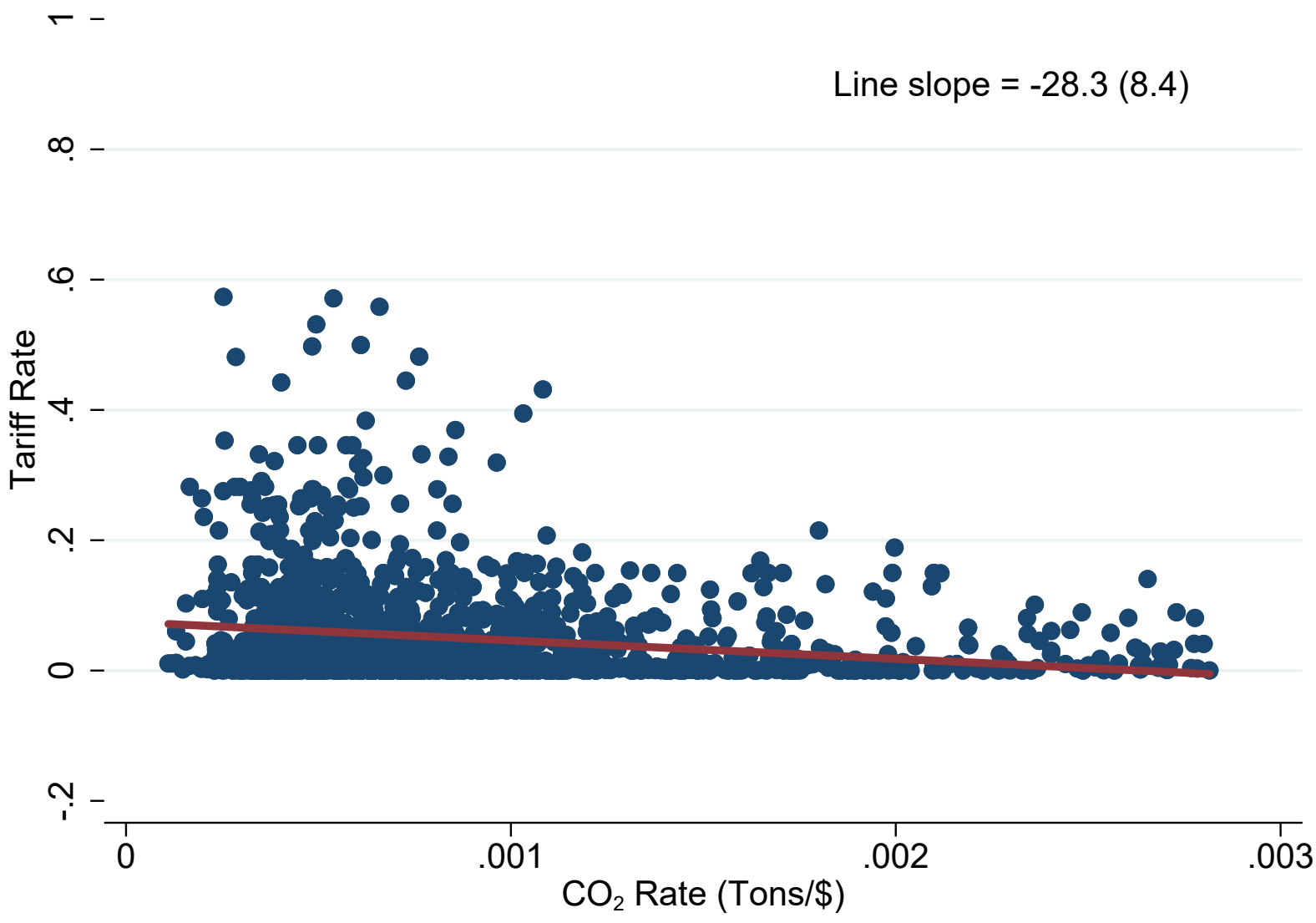
- **Trade Policy and Carbon Intensity**
  - **Tariffs**
  - Non-tariff barriers
  - Tariffs + non-tariff barriers
  - Extensions
- Explanations for Tariff-Pollution Relationship
- Consequences of Tariff-Pollution Relationship

Hypothetical Carbon Border Adjustment with $40/Ton Carbon Tax

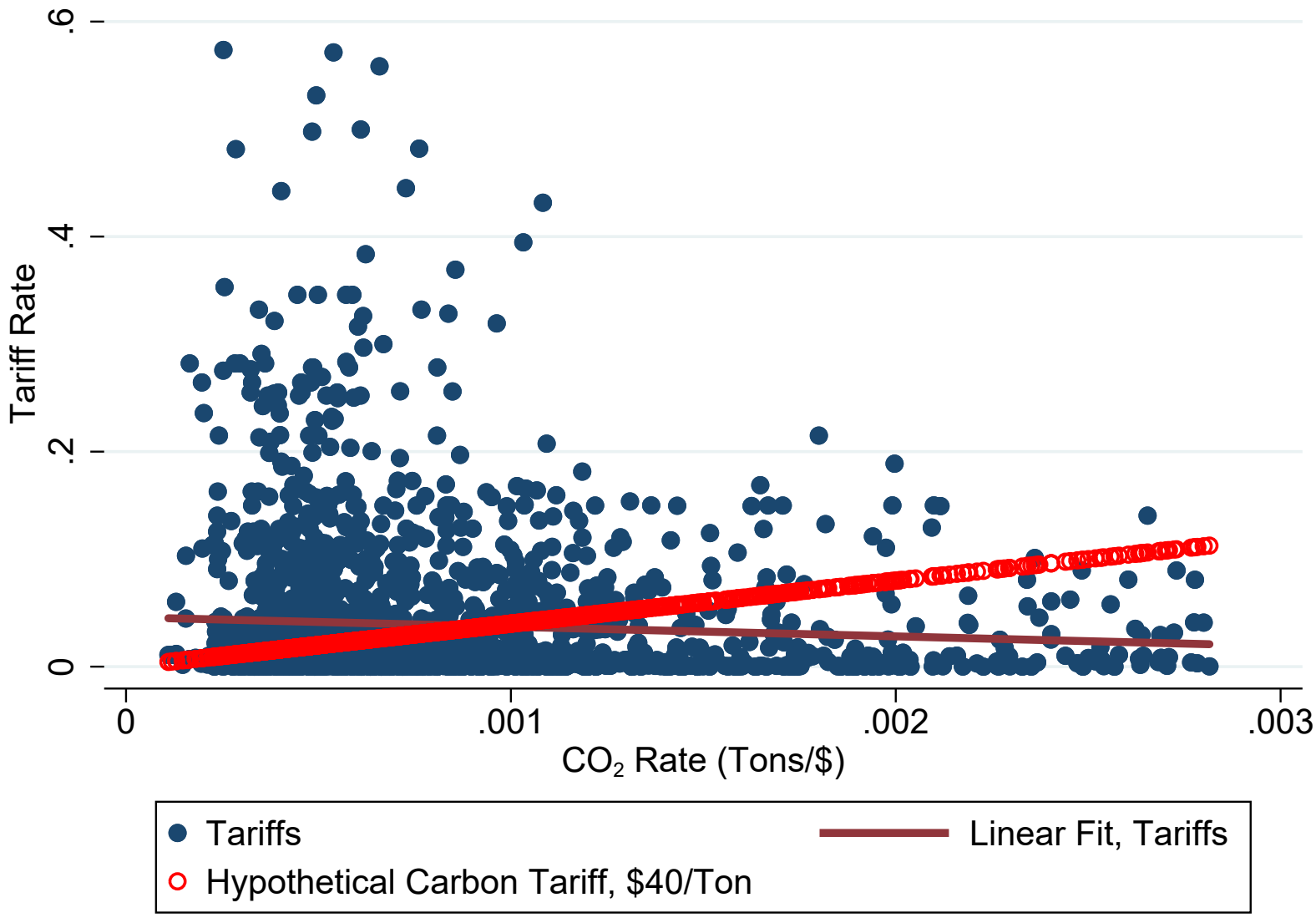


Results: Actual Global Tariffs Versus Carbon Intensity



Graph with weights

Results: Actual Global Tariffs Versus Carbon Intensity



Results: Carbon Taxes Implicit in Import Tariffs

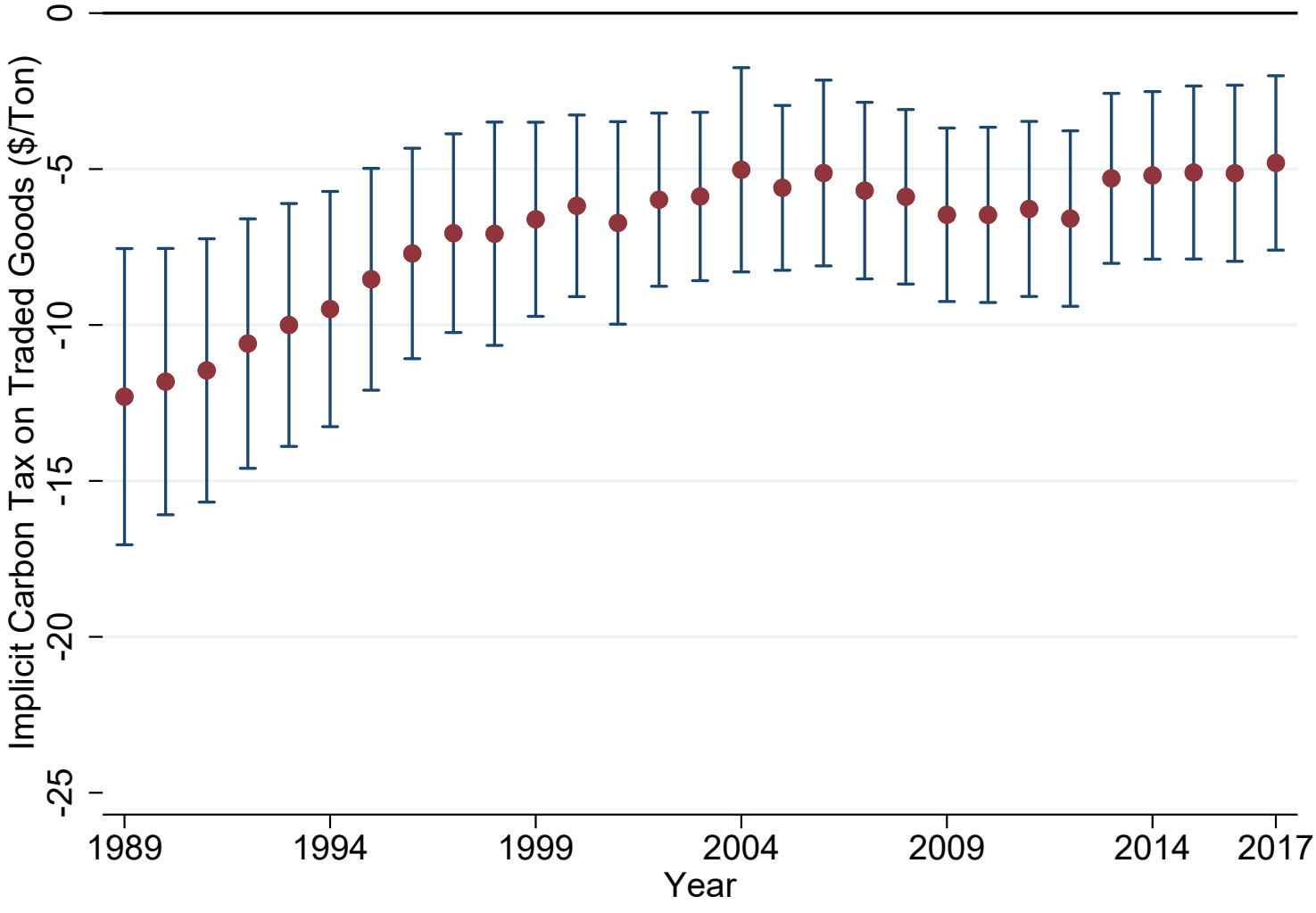
$$t_{js} = \alpha E_{js} + \zeta_j + \varepsilon_{js}$$

Table 2—Association of Import Tariffs and CO_2 Emissions Rates

	FS		RF		OLS		IV	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. All global trade (global input-output table)								
CO_2 rate	1.38***	1.54***	-44.53***	-17.19**	-28.28***	-4.48	-32.25***	-11.17**
	(0.09)	(0.08)	(13.13)	(8.15)	(8.42)	(6.17)	(8.37)	(5.40)
N	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021
Dependent Var. Mean	0.001	0.001	0.052	0.028	0.052	0.028	0.052	0.028
K-P F Statistic	—	—	—	—	—	—	232.65	352.34
Panel B: U.S. Imports (U.S. data)								
CO_2 rate	1.32***	1.58***	-7.52***	-10.35***	-4.89***	-3.23***	-5.69***	-6.55***
	(0.19)	(0.51)	(2.00)	(3.71)	(1.40)	(0.94)	(1.44)	(2.29)
N	379	379	379	379	379	379	379	379
Dependent Var. Mean	0.001	0.001	0.018	0.016	0.016	0.018	0.018	0.016
K-P F Statistic	—	—	—	—	—	—	50.33	9.77
Weighted		X		X		X		X

Results: Tariff Rates Versus Carbon Intensity, U.S. Import Tariffs 1989-2017

$$t_{js} = \alpha E_{js} + \zeta_j + \varepsilon_{js}$$



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  - **Non-tariff barriers**
  - Tariffs + non-tariff barriers
  - Extensions
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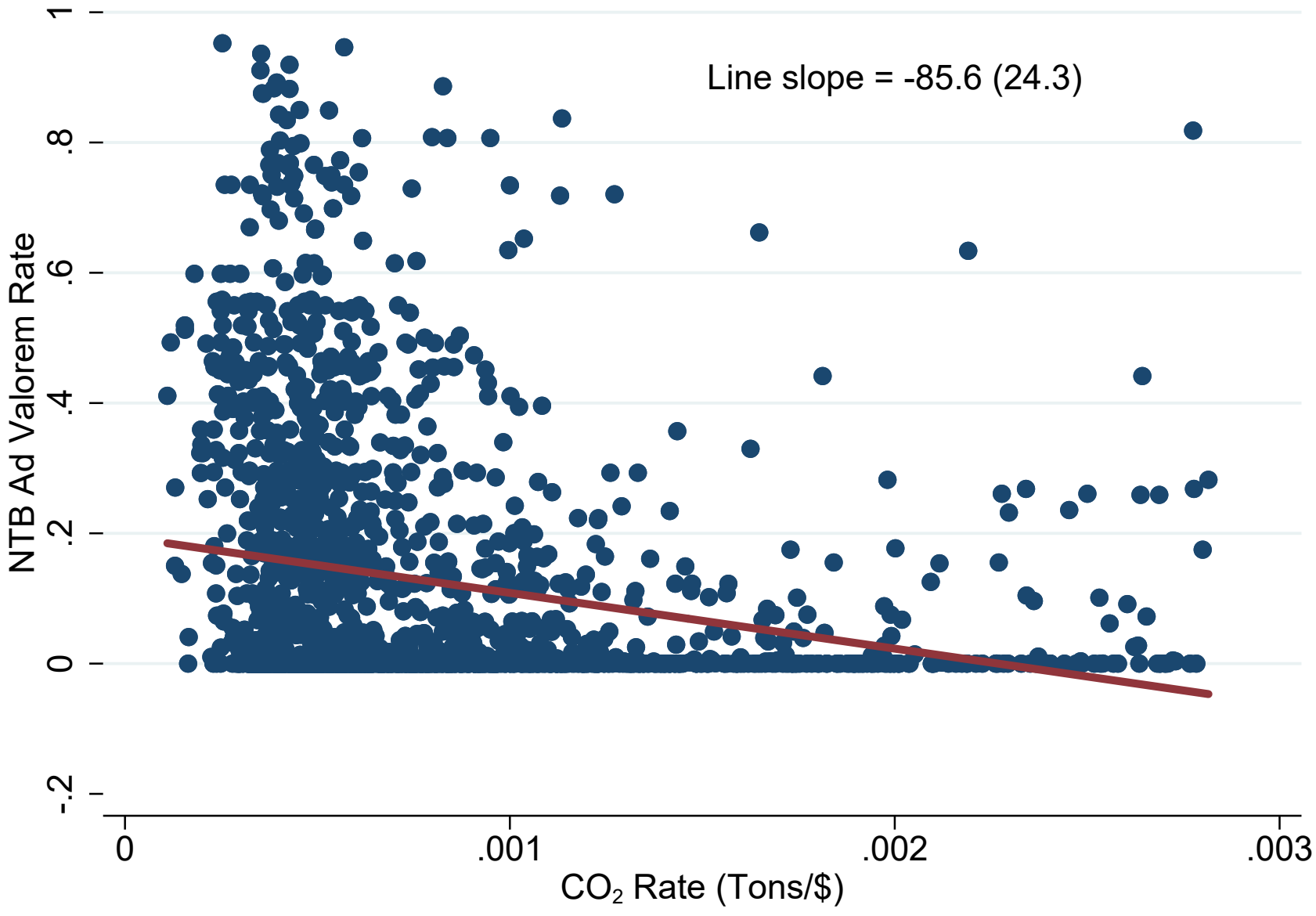
Results: Carbon Taxes Implicit in Global Non-Tariff Barriers



Results: Carbon Taxes Implicit in Non-Tariff Barriers

$$t_{js} = \alpha E_{js} + \zeta_j + \varepsilon_{js}$$

Table 3—Association of Non-Tariff Barriers and CO_2 Emissions Rates

	FS		RF		OLS		IV	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. All global trade (global input-output table)								
CO_2 rate	1.38***	1.54***	-124.01***	-116.47**	-85.58***	-73.22*	-89.82***	-75.67**
	(0.09)	(0.08)	(40.72)	(43.79)	(24.33)	(36.75)	(26.73)	(29.38)
N	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021
Dep. Var. Mean	0.001	0.001	0.126	0.088	0.126	0.088	0.126	0.088
K-P F Statistic	—	—	—	—	—	—	232.65	352.34
Panel B. U.S. imports (U.S. data)								
CO_2 rate	1.32***	1.58***	-63.34***	-59.13***	-41.04***	-17.98***	-47.96***	-37.41***
	(0.19)	(0.51)	(16.68)	(20.78)	(7.44)	(4.15)	(10.03)	(12.33)
N	379	379	379	379	379	379	379	379
Dep. Var. Mean	0.001	0.001	0.109	0.079	0.109	0.079	0.109	0.079
K-P F Statistic	—	—	—	—	—	—	50.33	9.77
Weighted		X		X		X		X

Overview

- Data
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  - **Tariffs+Non-tariff barriers**
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- Consequences of Tariff-Pollution Relationship

Results: Total Implicit Carbon Taxes, by Country

$t_s = \alpha_j E_s + \varepsilon_s$

Appendix Table 1—Carbon Taxes Implicit in Trade Policy, Sensitivity Analysis

	Global				US Imports			
	Tariffs		NTBs		Tariffs		NTBs	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1. Main estimates	-32.25***	-11.17**	-89.82***	-75.67**	-5.69***	-6.55***	-47.96***	-37.41***
	(8.56)	(5.52)	(27.32)	(30.02)	(1.44)	(2.30)	(10.06)	(12.36)
Other econometrics								
2. Tobit (no IV)	-35.63***	-5.29	-157.58***	-146.00**	-6.19***	-3.61***	-270.19***	-156.78***
	(11.52)	(6.09)	(40.74)	(59.37)	(1.96)	(1.30)	(60.86)	(56.43)
3. Tobit (IV)	-44.24***	-11.57**	-191.41***	-154.32**	-7.22***	-10.04***	-480.32***	-369.11**
	(15.51)	(5.74)	(56.45)	(70.20)	(2.29)	(3.59)	(132.43)	(158.31)
4. Standard errors	-32.25***	-11.17***	-89.82***	-75.67***	—	—	—	—
clustered by importer	(7.70)	(3.30)	(11.69)	(12.84)	—	—	—	—
Nonlinearity								
5. Logs	-0.66	-0.91**	-0.09***	-0.02	-0.64*	-0.22	-0.07***	-0.04*
	(0.45)	(0.43)	(0.03)	(0.05)	(0.36)	(0.59)	(0.02)	(0.02)
Weighted		X		X		X		X

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$t_s = \alpha_j E_s + \varepsilon_s$

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	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
6. Quadratic in emissions								
no IV. CO_2 rate	-58.33***	3.58	-194.52***	-152.31	-10.15**	-1.29	-45.45*	8.17
	(20.32)	(14.81)	(55.98)	(113.86)	(4.65)	(5.63)	(25.49)	(27.49)
CO_2 rate^2	9,539.88**	-3,508.35	34,582.94**	34,420.37	1,260.10	-355.19	1,055.59	-4,798.88
	(4,668.97)	(4,695.02)	(14,405.20)	(34,372.49)	(807.49)	(882.31)	(5,166.68)	(4,704.39)
fitted slope, 10th pct.	-51.56	1.09	-169.99	-127.89	-9.22	-9.22	4.62	4.62
fitted slope, 50th pct.	-46.70	-0.70	-152.35	-110.34	-8.22	-8.22	0.82	0.82
fitted slope, 90th pct.	-30.26	-6.74	-92.77	-51.04	-4.86	-4.86	-11.99	-11.99
7. Nonparametric marginal effect (no IV)	-18.56	—	-81.48	—	-4.89	-4.89	-41.04	-41.04
Other data cleaning and aggregation								
8. Winsorize dependent, independent variables	-25.45***	-10.66*	-90.40***	-75.69**	-5.75***	-6.42***	-51.40***	-38.01***
	(6.57)	(5.39)	(27.72)	(29.95)	(1.62)	(2.29)	(10.45)	(12.69)
9. Include non-manuf. industries	-32.32***	-9.9	-84.18***	-72.75**	—	—	—	—
	(8.60)	(8.95)	(24.00)	(33.10)	—	—	—	—
Weighted		X		X		X		X

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10. Multiple partners	-37.21**	-11.24*	-82.46**	-75.70**	-6.95***	-6.55***	-55.10***	-37.41***
(i×j×s level data)	(16.43)	(5.84)	(32.10)	(29.64)	(2.10)	(2.29)	(12.34)	(12.34)
11. i×j×s level data	-38.23**	-16.35**	-84.30**	-93.60**	-6.54***	-2.61*	-54.23***	-38.40***
exporter fixed effects	(17.05)	(6.88)	(33.07)	(37.44)	(1.95)	(1.41)	(11.87)	(14.13)
12. Industry-level data	-21.80**	-12.77**	-124.16**	-78.08*	—	—	—	—
(no IV)	(10.38)	(5.14)	(52.71)	(45.14)	—	—	—	—
13. Add intra-national	-5.80***	-11.75***	-60.42**	-80.99***	—	—	—	—
trade	(1.39)	(3.83)	(23.29)	(20.72)	—	—	—	—
Other measures of emissions								
14. Direct emissions	-27.48***	-11.53	-78.33***	-104.70***	-3.86***	-3.40***	-36.32***	-19.93***
	(7.91)	(8.10)	(22.30)	(34.86)	(1.17)	(0.64)	(7.69)	(3.81)
15. Direct emissions	49.89*	-21.03	183.49**	6.37	4.88	-0.98	32.70**	-13.82
	(28.79)	(24.12)	(78.40)	(135.57)	(3.07)	(2.98)	(14.45)	(16.18)
Total emissions	-62.72**	6.55	-212.24***	-76.56	-7.83***	-2.54	-61.79***	-6.42
	(26.28)	(16.00)	(70.42)	(100.21)	(2.96)	(3.65)	(14.68)	(17.43)
16. Include all	-16.87***	-6.55**	-46.72***	-41.65**	—	—	—	—
greenhouse gases	(4.48)	(2.56)	(14.34)	(16.96)	—	—	—	—

Results: Total Implicit Carbon Taxes, by Country

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	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Consumption emissions from energy-consuming durable goods								
17. Exclude energy-consuming durables	-35.23***	-16.50**	-98.52***	-113.23**	-9.60***	-17.40***	-60.92***	-66.09***
	(9.34)	(7.89)	(29.78)	(47.39)	(2.10)	(6.50)	(14.00)	(23.26)
18. Adjust CO_2 rates: 50% goods, 50% energy	-32.85***	-12.33**	-91.08***	-83.46**	-6.04***	-8.34**	-50.89***	-47.66***
	(8.69)	(6.03)	(27.85)	(33.52)	(1.55)	(3.32)	(11.11)	(16.07)
19. Adjust CO_2 rates: 5% goods, 95% energy	-32.65***	-12.02**	-90.55***	-81.34**	-6.39***	-11.07*	-53.86***	-63.25**
	(8.66)	(5.90)	(27.67)	(32.39)	(1.67)	(6.29)	(12.31)	(30.48)
Additional sensitivity analyses								
20. Reverse regression (no IV)	-0.0004***	-0.0002	-0.0006***	-0.0003**	-0.0040***	-0.0040***	-0.0009	-0.0009
	(0.0001)	(0.0004)	(0.0001)	(0.0001)	(0.0011)	(0.0011)	(0.0006)	(0.0006)
21. Lifecycle tariffs	-7.81**	-5.05	-89.72***	-51.38**	—	—	—	—
	(3.55)	(9.30)	(26.98)	(25.25)	—	—	—	—
Weighted		X		X		X		X

Results: Total Implicit Carbon Taxes, by Country

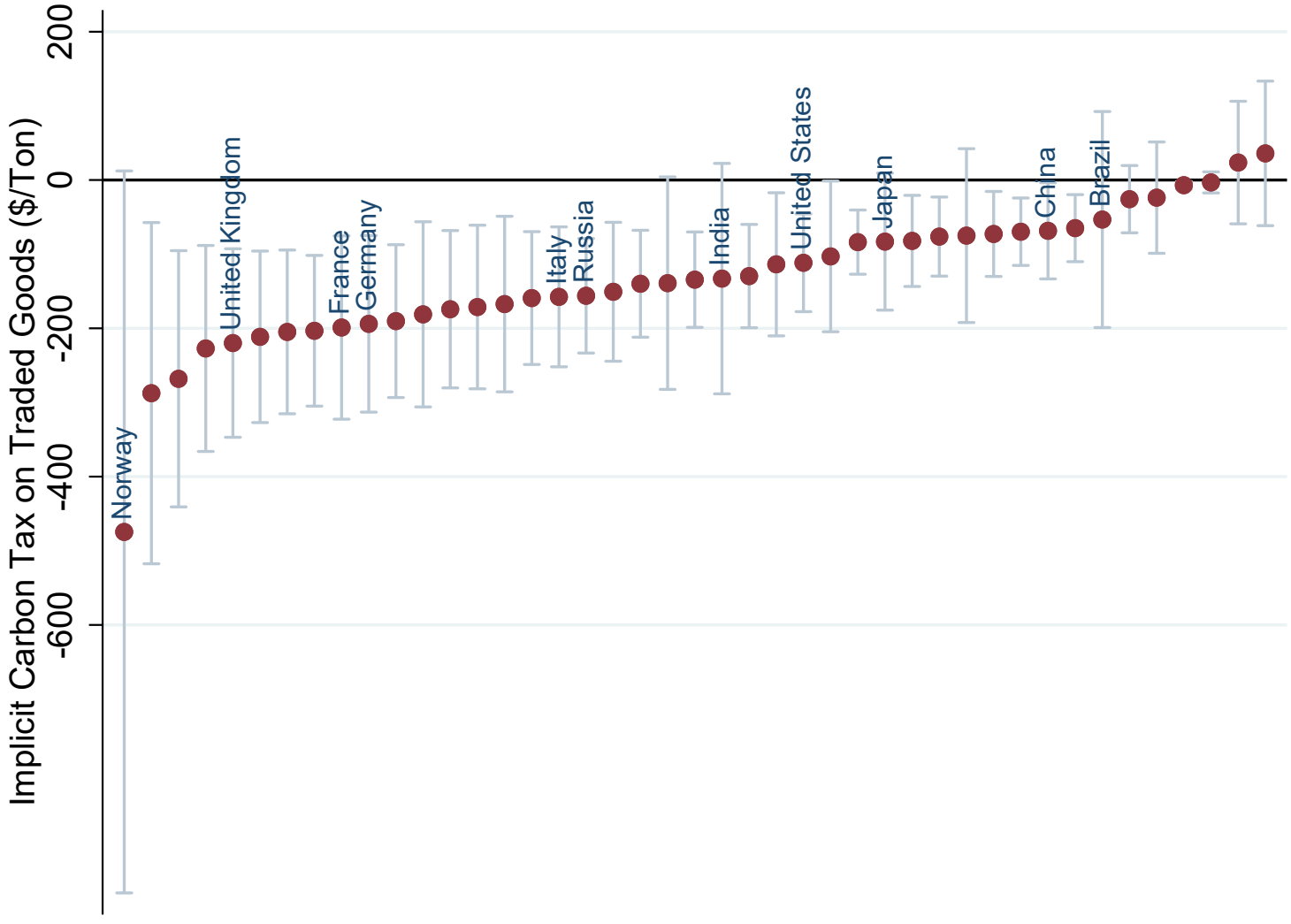
$t_s = \alpha_j E_s + \varepsilon_s$

Appendix Table 1—Carbon Taxes Implicit in Trade Policy, Sensitivity Analysis

	Global				US Imports			
	Tariffs		NTBs		Tariffs		NTBs	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
22. No importer fixed	-32.11***	-13.53*	-97.58	-83.64***	—	—	—	—
effects	(8.43)	(7.18)	(55.30)	(30.54)	—	—	—	—
23. WIOD, not Exiobase	-13.43	-19.88	-9.24	-121.44	—	—	—	—
(no IV)	(12.87)	(16.83)	(38.12)	(84.18)	—	—	—	—
24. Add industry fixed	11.73	-2.12	-16.07	38.81	—	—	—	—
effects	(13.89)	(10.49)	(13.39)	(28.76)	—	—	—	—
25. Exclude manuf.	-5.29	-5.87	-75.67**	-40.78**	-5.70***	-6.68***	-36.55***	-37.67***
food, ag. goods	(6.09)	(4.52)	(30.02)	(17.35)	(1.47)	(2.33)	(8.87)	(12.22)
Trade war in 2018								
26. U.S. tariffs in 2017	—	—	—	—	-4.80***	-4.14**	—	—
	—	—	—	—	(1.68)	(1.45)	—	—
27. U.S. tariffs including	—	—	—	—	-3.97***	-4.29**	—	—
2018 protectionism	—	—	—	—	(1.43)	(1.75)	—	—
Weighted		X		X		X		X

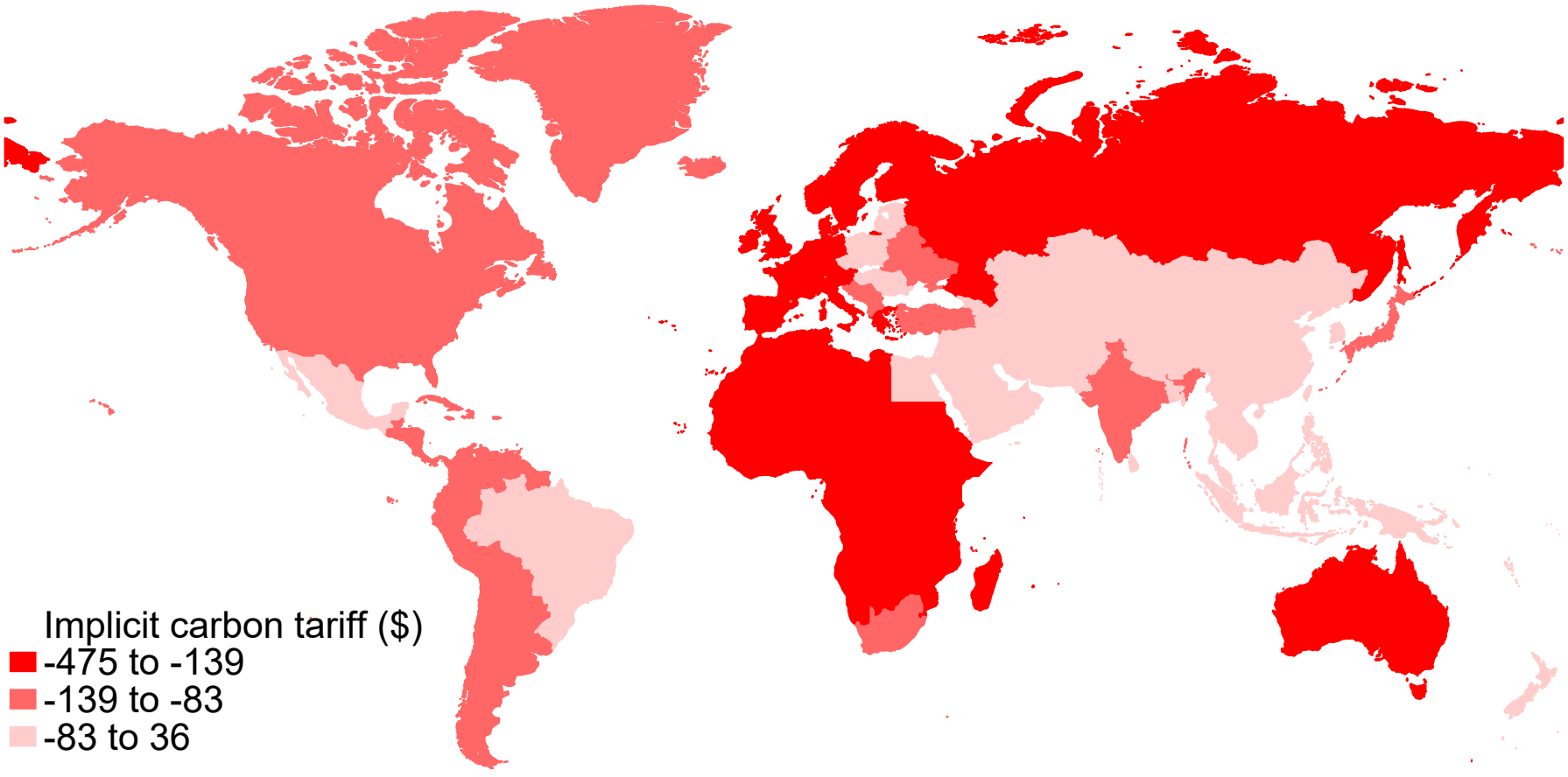
Results: Total Implicit Carbon Taxes, by Country

$t_s = \alpha_j E_s + \varepsilon_s$



Results: Total Implicit Carbon Taxes, by Country

$t_s = \alpha_j E_s + \varepsilon_s$



Overview

- Data
- Econometrics
- **Trade Policy and Carbon Intensity**
  - Tariffs
  - Non-tariff barriers
  - Tariffs+Non-tariff barriers
  - **Extensions**
- Explanations for Tariff-Pollution Relationship
- Consequences of Tariff-Pollution Relationship

Cooperative Versus Noncooperative Tariffs

Appendix Table 3—Carbon Taxes Implicit in Cooperative Versus Non-Cooperative Tariffs

	Cooperative		Non-Cooperative	
	(1)	(2)	(3)	(4)
Panel A. U.S. import tariffs				
CO_2 rate	-8.20***	-6.25**	-75.59***	-62.07**
	(2.37)	(2.63)	(15.05)	(28.61)
N	382	382	382	382
Dep. Var. Mean	0.030	0.020	0.322	0.289
Panel B. Japanese import tariffs				
CO_2 rate	-58.93***	-49.13*	-66.29***	-41.91
	(17.92)	(28.12)	(19.25)	(25.68)
N	47	47	47	47
Dep. Var. Mean	0.084	0.044	0.09	0.046
Panel C: Chinese import tariffs				
CO_2 rate	8.37	23.67	-161.29**	-143.42*
	(13.53)	(17.61)	(63.32)	(83.86)
N	47	47	47	47
Dep. Var. Mean	0.100	0.068	0.601	0.491
Weighted		X		X

Overview

- Data
- Econometrics
- Trade Policy and Carbon Intensity
- **Explanations for Tariff-Pollution Relationship**
- Consequences of Tariff-Pollution Relationship

Political Economy Explanations

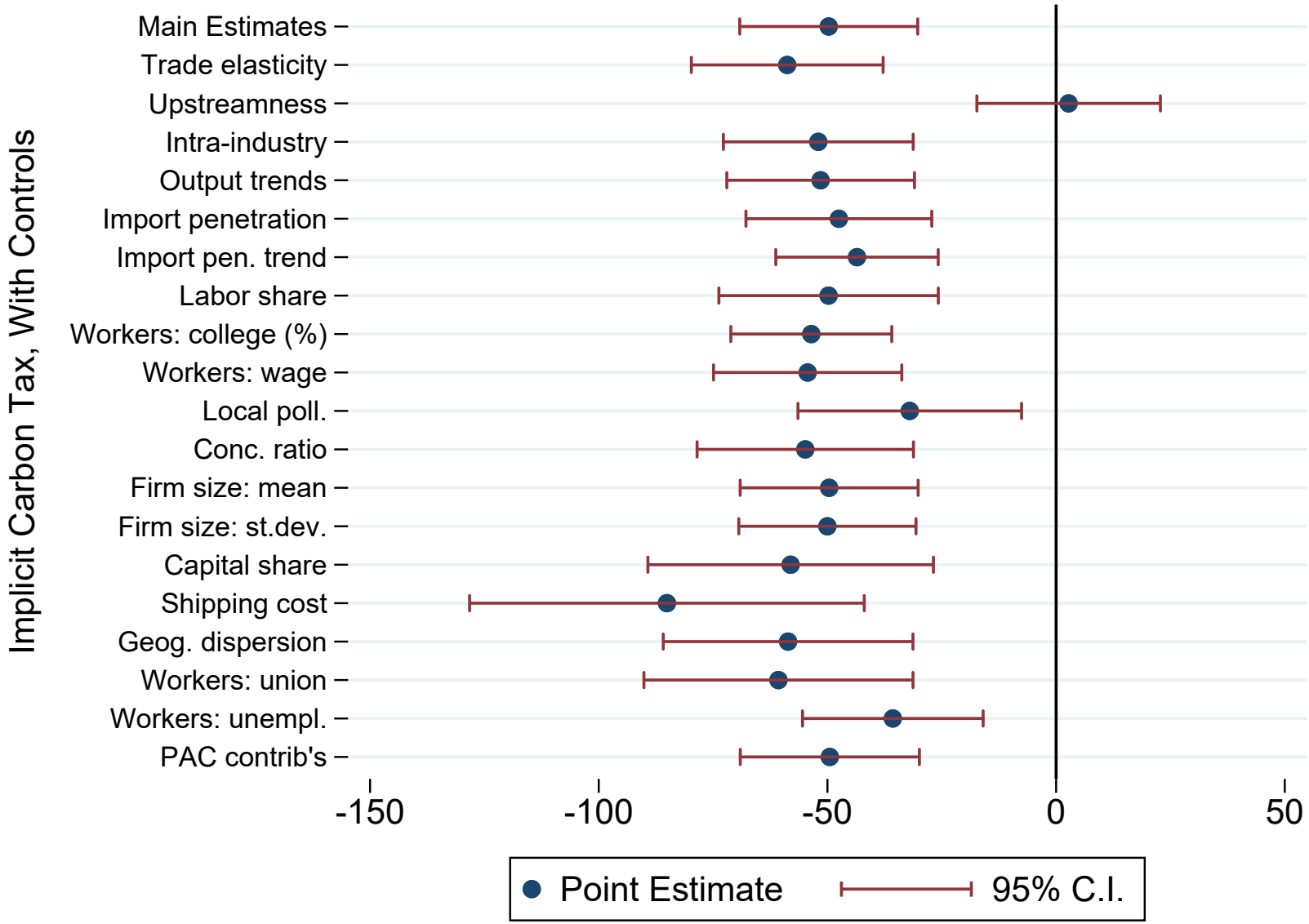
$$t_{js} = \alpha E_{js} + F'_{js}\gamma + \zeta_j + \varepsilon_{js}$$

Table 4—Political Economy Explanations for Implicit Carbon Taxes

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. All global trade						
CO_2 rate	-120.53***	-32.86	-120.74***	-121.45***	-120.90***	-120.41***
	(33.69)	(25.61)	(33.13)	(35.48)	(34.08)	(33.58)
N	1,990	1,990	1,990	1,990	1,990	1,990
Panel B. All global trade, instrument for political economy						
CO_2 rate	-120.53***	34.03	-111.90***	-125.82***	-102.61**	-119.35***
	(33.69)	(38.64)	(39.44)	(47.27)	(43.26)	(33.86)
K-P F Statistic	—	45.09	31.09	42.03	10.94	22.71
N	1,990	1,990	1,990	1,990	1,990	1,990
Panel C. U.S. imports						
CO_2 rate	-49.72***	2.74	-51.99***	-47.50***	-49.75***	-54.32***
	(9.90)	(10.19)	(10.54)	(10.32)	(12.19)	(10.45)
N	358	358	358	358	358	358
Upstreamness		X				
Intra-industry			X			
Import pen. ratio				X		
Labor share					X	
Mean wage						X

Political Economy Explanations

$$t_{js} = \alpha E_{js} + F'_{is}\gamma + \zeta_j + \varepsilon_{js}$$



Global values

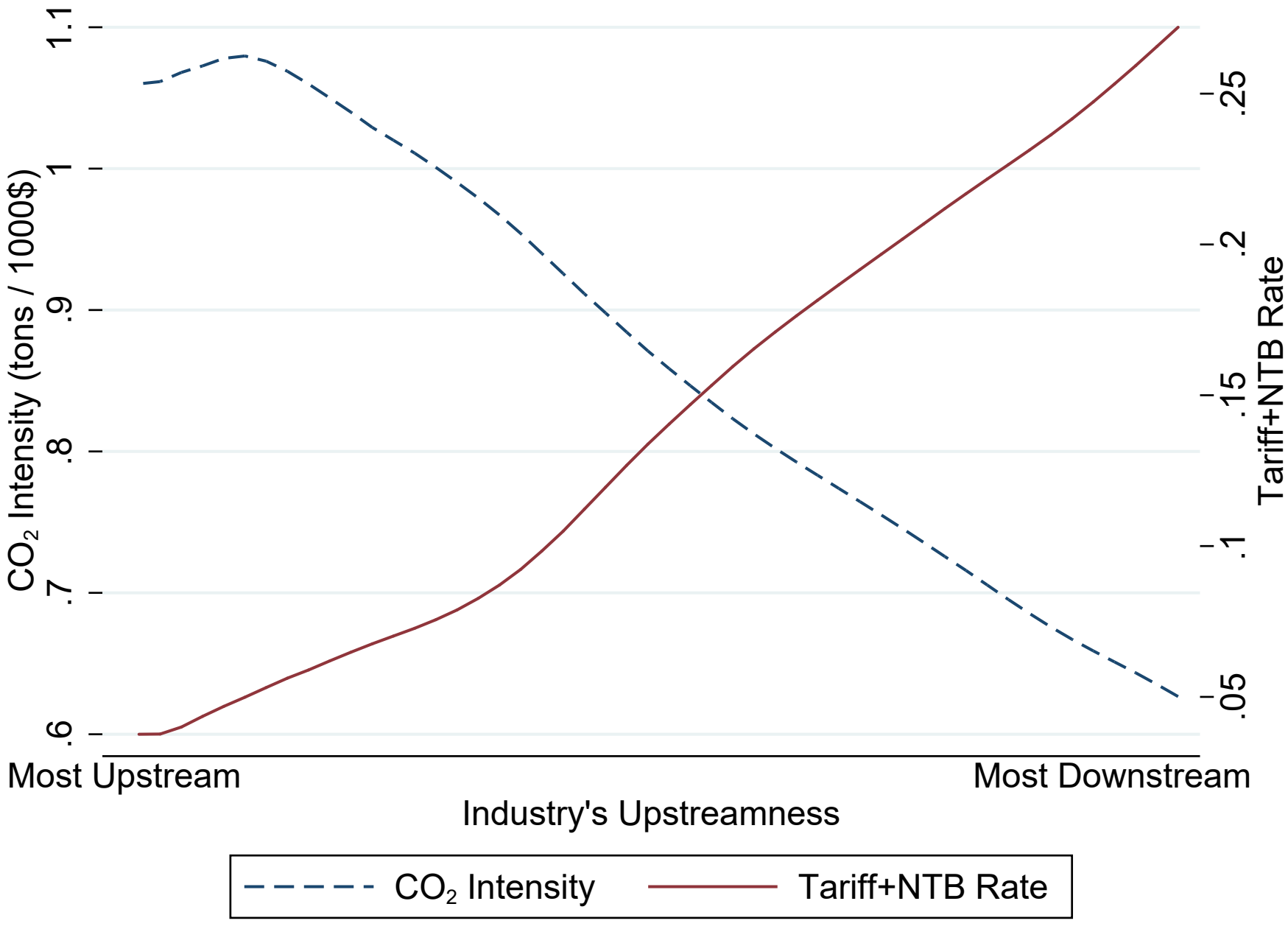
Political Economy Explanations

$$t_{js} = \alpha E_{js} + F'_{js}\gamma + \zeta_j + \varepsilon_{js}$$

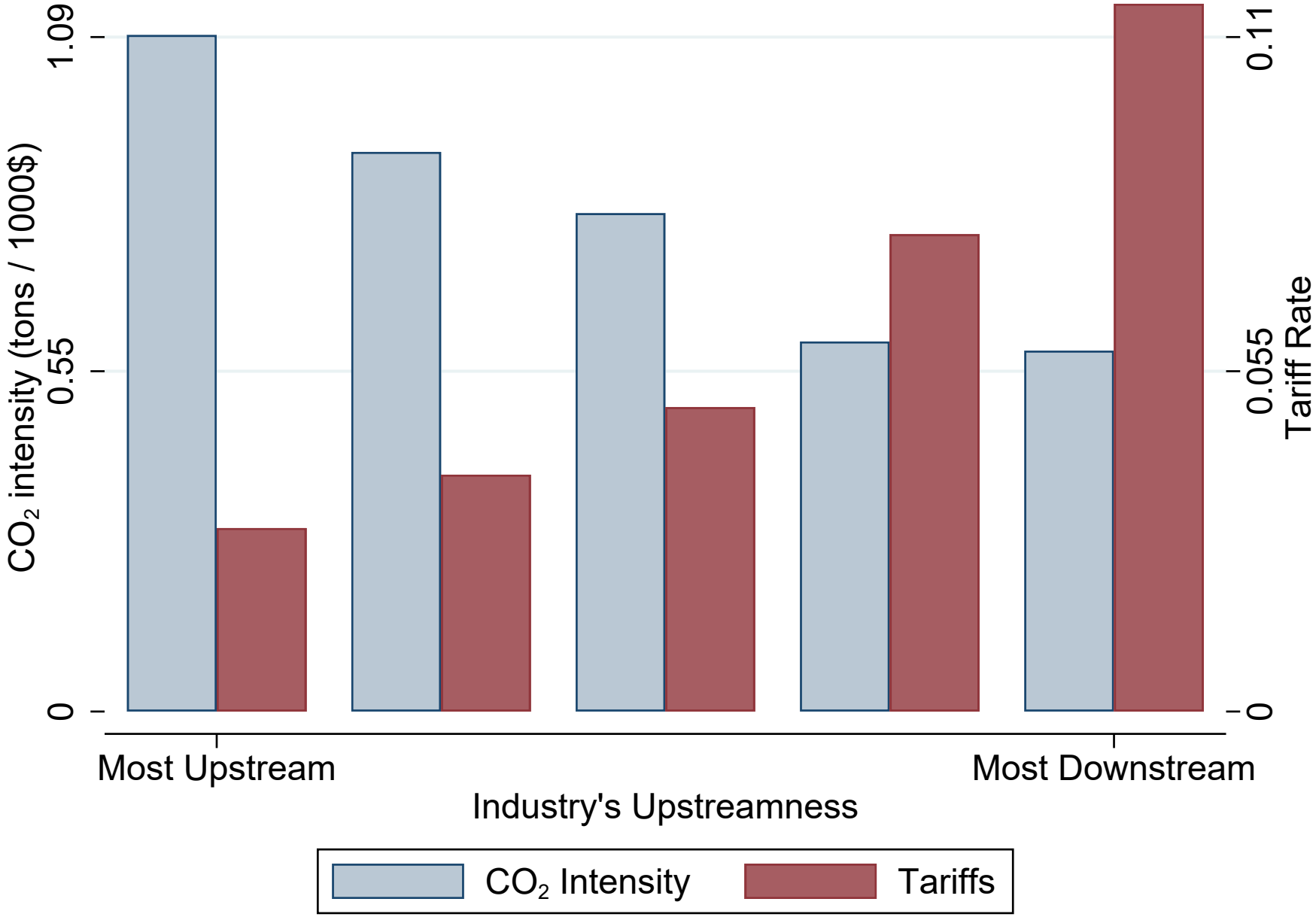
Appendix Table 5—Political Economy Explanations: All Controls Together

	All global trade			U.S. imports	
	IV	IV	Lasso	IV	Lasso
	(1)	(2)	(3)	(4)	(5)
CO_2 rate	-29.237	-28.083	-24.780	-112.754*	-44.065
	(19.444)	(29.538)	(18.726)	(64.063)	(41.779)
Upstreamness	-0.105***	-0.179***	-0.106***	-0.044***	-0.069***
	(0.017)	(0.029)	(0.017)	(0.016)	(0.015)
Intra-industry trade	-0.004	-0.052	0	-0.007	0
	(0.010)	(0.050)	0	(0.015)	0
Import penetration ratio	-0.027**	-0.227***	0	-0.016	0
	(0.012)	(0.069)	0	(0.017)	0
Labor share	-0.012*	-0.336**	0	-0.042	0
	(0.006)	(0.144)	0	(0.026)	0
Workers: mean wage	0.003	0.114	0	-0.034*	0
	(0.019)	(0.072)	0	(0.020)	0
Inverse export supply elast.	—	—	—	-0.023**	0
				(0.011)	0
Output trends 1972-2002	—	—	—	0.007	0
				(0.011)	0
Trend in import pen. ratio	—	—	—	0.026	0
				(0.016)	0
Workers: share w/ college	—	—	—	-0.034	0
				(0.028)	0
Four-firm conc. ratio	—	—	—	-0.059	0
				(0.038)	0
Mean firm size	—	—	—	0.109*	0
				(0.061)	0
Standard dev. of firm size	—	—	—	-0.120*	0
				(0.062)	0
Capital share	—	—	—	0.032	0
				(0.025)	0
Shipping cost per dollar*km	—	—	—	0.034	0.034
				(0.033)	(0.029)
Geographic dispersion	—	—	—	0.083	0
				(0.053)	0
Workers: unemployed	—	—	—	0.001	0
				(0.028)	0
Workers: unionized (%)	—	—	—	0.025	0
				(0.017)	0
Local pollution				0.008	0
				(0.015)	0
PAC contributions	—	—	—	0.028	0
				(0.021)	0
Instrument political economy		X			

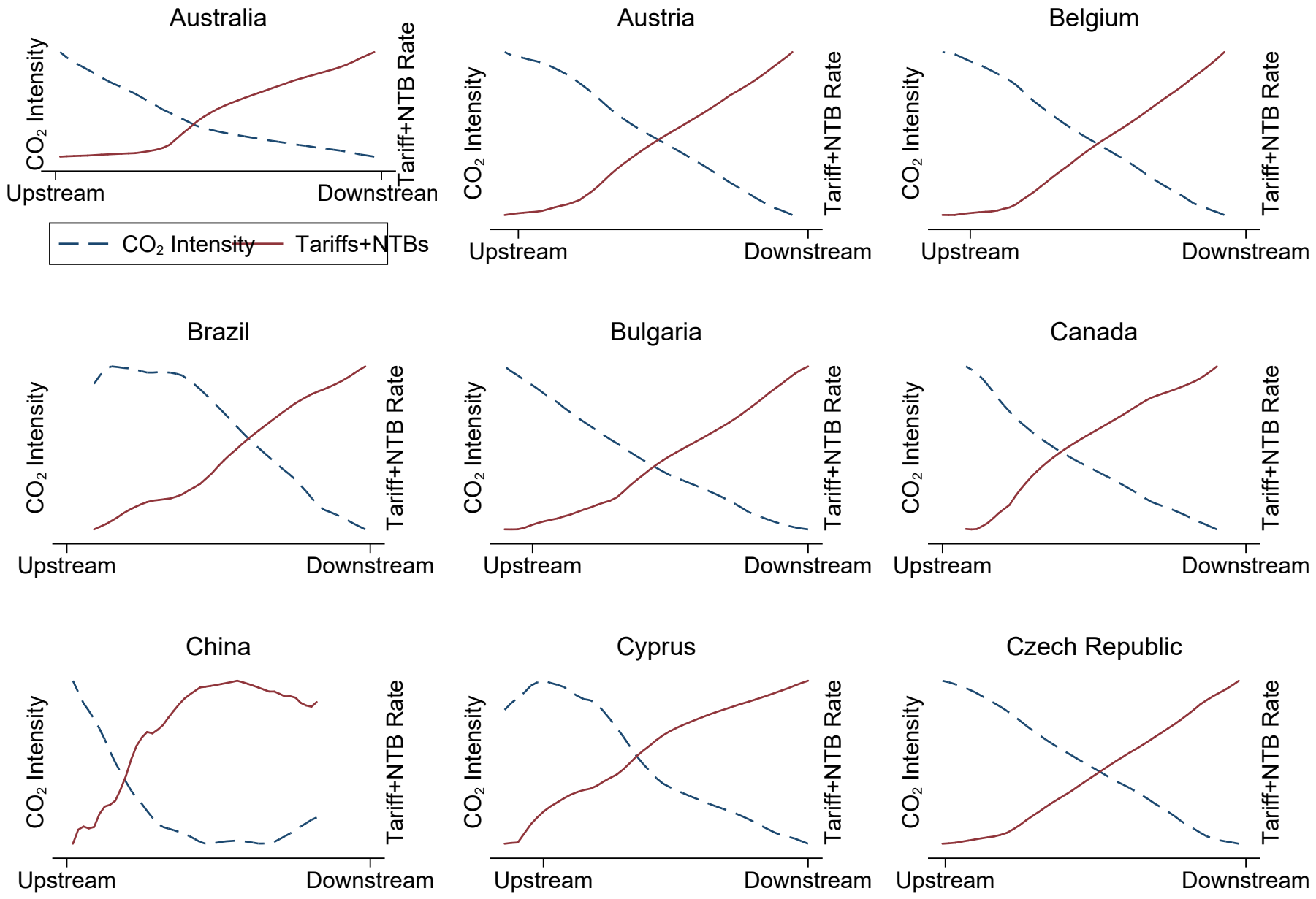
Political Economy Explanations



Political Economy Explanations

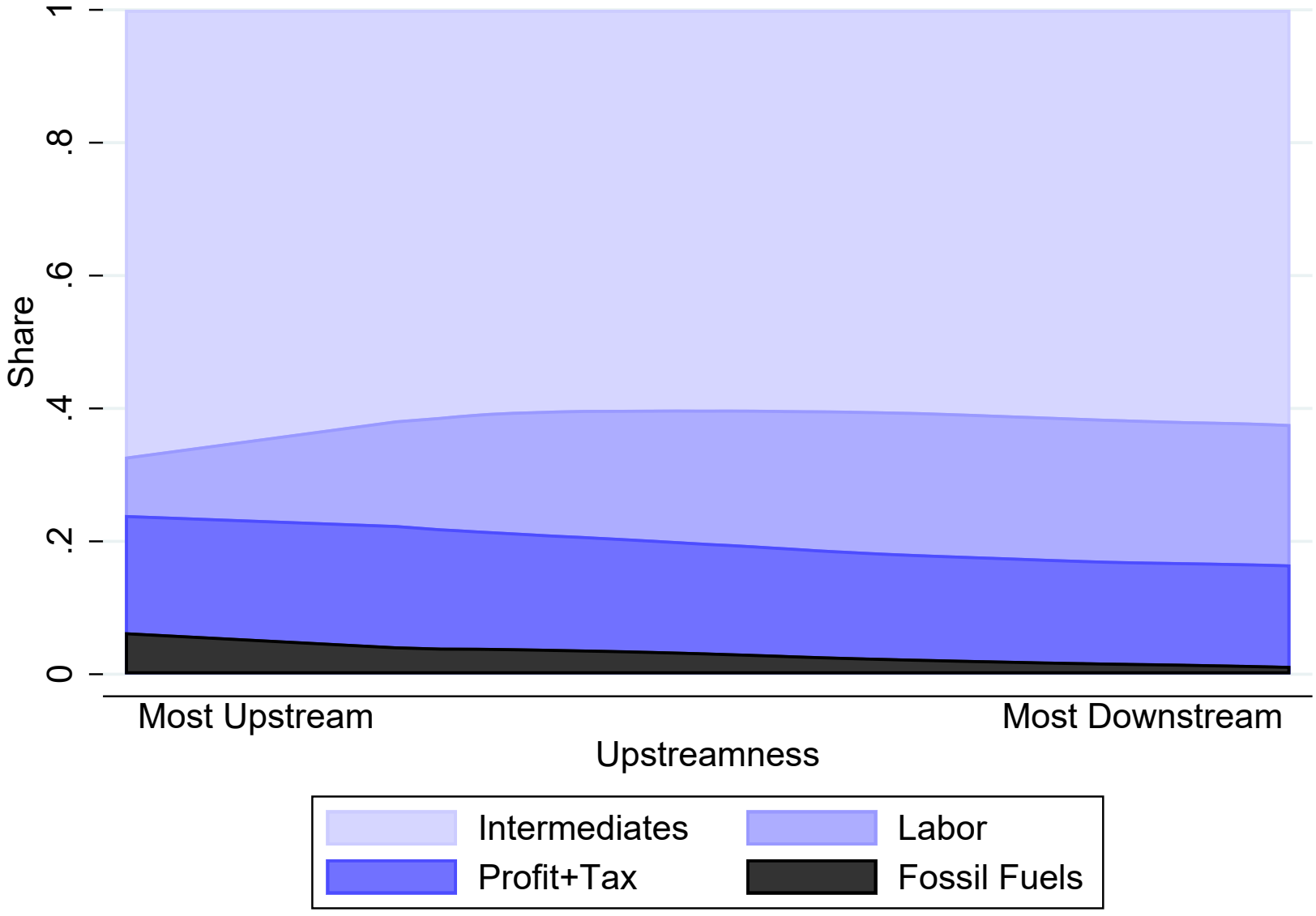


Political Economy Explanations



Explanations: Why are upstream industries dirtier?

Cost shares versus upstreamness, by U.S. industry



Explanations: Broad View of Theory

- **Non-cooperative theory**
  - Protection for sale (Grossman and Helpman 1994)
  - Political economy motive and terms-of-trade motive
- **Cooperative theory**
  - Trade wars and trade talks (Grossman and Helpman 1995)
  - Commitment (Maggi and Rodriguez-Clare 1998, 2007)
  - Political economy motive remains, terms-of-trade motive diminished
- **Production efficiency (Diamond-Mirrlees 1971)**
  - Can't explain escalation in NTBs
  - Tariff escalation isn't optimal tax

Overview

- Data
- Econometrics
- Trade Policy and Carbon Intensity
- Explanations for Tariff-Pollution Relationship
- **Consequences of Tariff-Pollution Relationship**
  - **Partial equilibrium approximation**
  - Analytical model
  - Quantitative model

Consequences: Partial Equilibrium

Calculation:

$$\sum_{i,s} \hat{\alpha}_j X_{js} E_{js}$$

- Recall, α_j implicit subsidy, X_{js} trade flows, E_{js} emissions rate

Result:

- Year 2007: \$550 to \$800 billion subsidy per year
- For reference, total direct subsidies to fossil fuels: \$530 billion/year (IMF 2013)

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  - **Quantitative model**

Consequences: Quantitative Model

A1: Consumer Preferences

$$U_j = \prod_s \left(\sum_i q_{ijs}^{\frac{\sigma_s - 1}{\sigma_s}} \right)^{\frac{\sigma_s}{\sigma_s - 1} \beta_{js}} [1 + \delta(Z - Z_0)]^{-1}$$

Details:

- Representative agent
- CES across varieties, Cobb-Douglas across sectors
- Climate damages δ calibrated to \$40/ton

Consequences: Quantitative Model

A2: Firms, Production Technology

$$a_{jt} = (L_{jt})^{1-\eta_{is}} \prod_s \left(\sum_o (q^I_{ojst})^{\frac{\sigma_s - 1}{\sigma_s}} \right)^{\frac{\sigma_s}{\sigma_s - 1}\eta_{jst}}$$

Details:

- Aggregate input A: factors and composite intermediates
- Composite intermediates: CES across varieties, Cobb-Douglas input-output

Trade costs: $\phi_{ijt} = \tau_{ijt}(1 + t_{ijt})(1 + n_{ijt})$

Consequences: Quantitative Model

A3: Pollution

$$Z_{is} = \gamma_{is} \frac{R_{is}}{P_{is}}$$

A4: Market Clearing

$$\begin{aligned} L_i &= \sum_s L_{is} \\ \sum_{j,s} X_{ijs} &= \sum_{j,s} X_{jis} - D_i \end{aligned}$$

Consequences: Quantitative Model

Unit costs:

$$c_{is} = w_i^{1-\eta_{is}} \prod_k P_{ik}^{\eta_{iks}}$$

Price index:

$$P_{js} = \left(\sum_i (\phi_{ijs} c_{is})^{\epsilon_s} \right)^{\frac{1}{\epsilon_s}}$$

Expenditure shares:

$$\lambda_{ijs} = \frac{(\phi_{ijs} c_{is})^{\epsilon_s}}{\sum_o (\phi_{ojs} c_{os})^{\epsilon_s}}$$

Expenditure, country-sector

$$X_{js} = \frac{\beta_{js} \left(Y_j + D_j + \sum_{i,l} \frac{t_{ijl}}{1+t_{ijl}} \lambda_{ijl} \sum_k \alpha_{jlk} R_{jk} \right)}{1 - \sum_{i,l} \frac{t_{ijl}}{1+t_{ijl}} \lambda_{ijl} \beta_{jl}} + \sum_k \alpha_{jlk} R_{jk}$$

Consequences: Quantitative Model

Revenue, country-sector

$$R_{is} = \sum_j \frac{\lambda_{ijs}}{1 + t_{ijs}} X_{js}$$

National income

$$Y_i = \sum_s (1 - \alpha_{is}) R_{is}$$

Consequences: Quantitative Model

Counterfactual Methodology:

- Exact hat algebra (Dekle, Eaton, and Kortum 2008)

$$x_i' = \hat{x}_i x_i$$

Consequences: Quantitative Model

Equilibrium in changes

Unit costs:

$$\hat{c}_{is} = \hat{w}_i^{1-\eta_{is}} \prod_k \hat{P}_{ik}^{\eta_{iks}}$$

Trade shares:

$$\hat{\lambda}_{ijs} = \frac{(\hat{\phi}_{ijs}\hat{c}_{is})^{\epsilon_s}}{\sum_o \lambda_{ojs}(\hat{\phi}_{ojs}\hat{c}_{os})^{\epsilon_s}}$$

Expenditure, country-sector:

$$\hat{X}_{js}X_{js} = \frac{\beta_{js}\left(\hat{w}_j Y_j + D_j + \sum_{i,l} \frac{t'_{ijl}}{1+t'_{ijl}} \hat{\lambda}_{ijl}\lambda_{ijl} \sum_k \alpha_{jlk}\hat{R}_{jk}R_{jk}\right)}{1 - \sum_{i,s} \frac{t'_{ijs}}{1+t'_{ijs}} \hat{\lambda}_{ijs}\lambda_{ijs}\beta_{js}} + \sum_k \alpha_{jsk}\hat{R}_{jk}R_{jk}$$

Consequences: Quantitative Model

Equilibrium in changes

Revenue, country-sector:

$$\hat{R}_{is} R_{is} = \sum_j \frac{\hat{\lambda}_{ijs} \lambda_{ijs}}{1 + t'_{ijs}} \hat{X}_{js} X_{js}$$

Gross output:

$$\hat{Y}_i Y_i = \sum_s (1 - \eta_{is}) \hat{R}_{is} R_{is}$$

Consequences: Quantitative Model

Counterfactuals

$$
\begin{aligned}
\hat{V}_j &= \frac{\widehat{Y_j + D_j + T_j}}{\hat{P}_j} \\
\hat{Z}_i &= \frac{\sum_s \gamma_{is} \hat{R}_{is} R_{is} / \hat{P}_{is} P_{is}}{\sum_s \gamma_{is} R_{is} / P_{is}} \\
\hat{W}_j &= \frac{\hat{V}_j}{1 + \delta(Z' - Z_0)}
\end{aligned}
$$

Consequences: Quantitative Model

Counterfactuals:

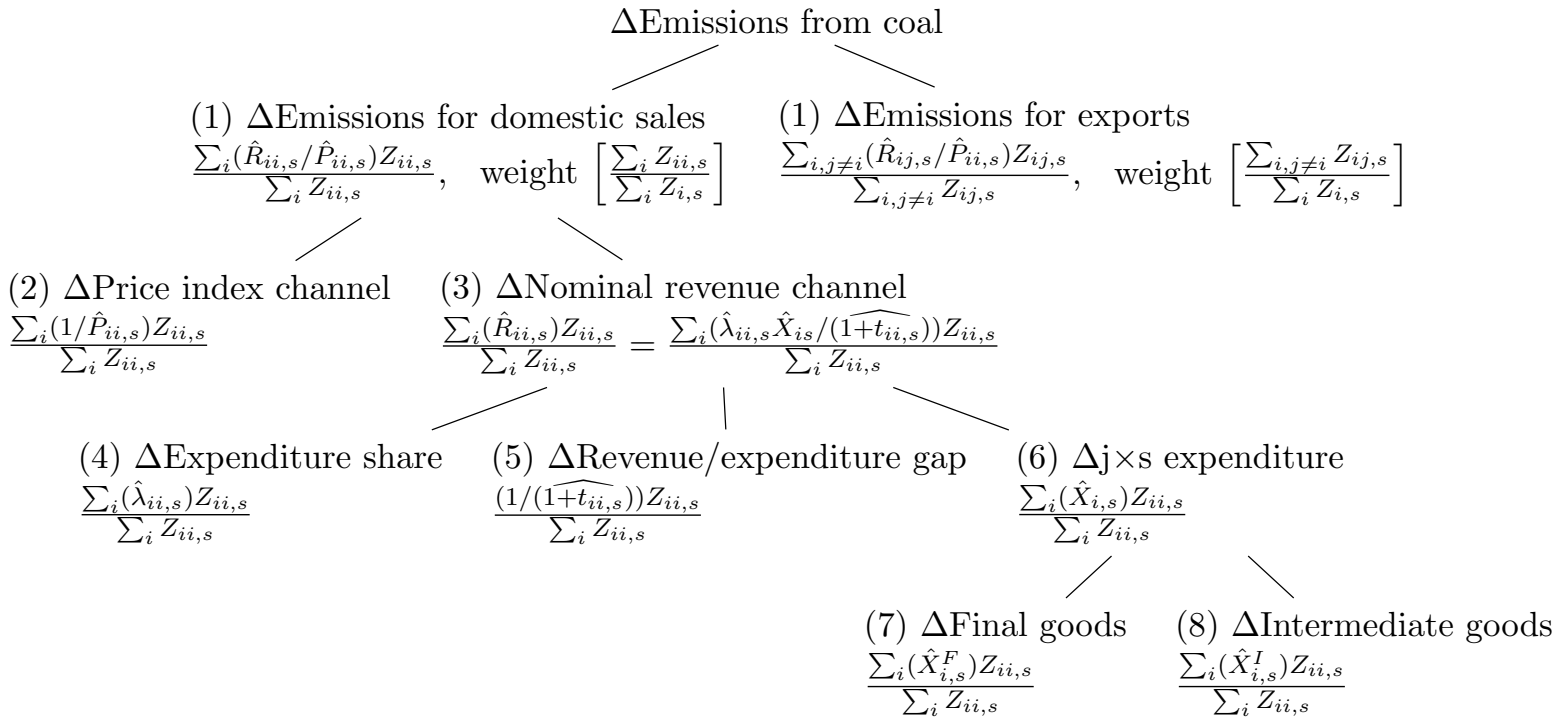
1. Average tariff and NTB on all industries, each country
2. Average tariff and NTB on all industries, EU only
3. Carbon tariffs
4. Remove all tariffs and NTBs

Model-Based Estimates

Table 5—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%	—	—

Model-Based Estimates



Model-Based Estimates

Appendix Table 9--Components of Changes in Fossil Fuel Consumption Due to Counterfactual Tariffs

	Total	Prices	Nominal Revenue						Baseline Emissions	Counterfactual Emissions
						Country×Sector Expenditure				
			Total	Expenditure Share	Revenue / Expenditure	Total	Final Goods	Intermediates		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: Oil										
Domestic Sales	-1.2%	-0.3%	-1.0%	1.3%	0.0%	-0.7%	0.6%	-0.7%	5.7	5.7
Exports	-8.2%	-0.6%	-6.4%	-7.5%	-1.5%	-0.8%	-0.7%	-0.7%	5.7	5.2
Panel B: Natural Gas										
Domestic Sales	-0.9%	-0.5%	-0.5%	0.0%	0.0%	-0.5%	0.6%	-0.6%	4.4	4.3
Exports	-12.8%	-0.5%	-11.0%	-11.6%	-1.5%	0.7%	-0.6%	0.8%	1.5	1.3
Panel C: Coal										
Domestic Sales	-4.7%	0.5%	-5.2%	-3.2%	0.0%	-2.1%	-0.5%	-2.1%	12.6	12.0
Exports	9.1%	0.3%	8.0%	8.0%	-1.1%	1.0%	-0.5%	1.1%	1.2	1.4

Model-Based Estimates

Appendix Table 8—Effects of Counterfactual Tariffs and NTBs on CO_2 Emissions and Welfare, Sensitivity Analysis

	CO_2 Emissions (1)	Real Income (2)	CO_2 Intensity = (1) - (2) (3)	Climate benefits (4)	Social welfare (5)
Panel A: Sensitivity Analysis for Main Counterfactual					
1. Baseline estimates	-3.59%	0.65%	-4.24%	0.08%	0.57%
2. Trade elasticities: Caliendo-Parro	-5.66%	0.55%	-6.21%	0.13%	0.42%
3. Larger energy elasticity	-2.53%	0.47%	-3.00%	0.06%	0.41%
3. Harmonize tariffs only	-1.75%	0.13%	-1.88%	0.04%	0.09%
4. Harmonize NTBs only	-2.26%	0.47%	-2.73%	0.05%	0.42%
5. Algorithm: trust-region	-3.59%	0.65%	-4.24%	0.08%	0.57%
6. Algorithm: Levenberg-Marquardt	-3.59%	0.65%	-4.24%	0.08%	0.57%
Panel B: Counterfactual sets EU tariffs and NTBs to mean					
Global total	-1.84%	0.25%	-2.10%	—	—
Panel C: Counterfactual sets tariffs and NTBs to mean of cleanest third of goods					
Global total	-5.09%	0.06%	-5.15%	0.11%	-0.05%
Panel D: Counterfactual sets tariffs and NTBs to mean of dirtiest third of goods					
Global total	-4.20%	1.13%	-5.33%	0.09%	1.04%
Panel E: All countries add a carbon tariff					
Global total	-2.52%	0.45%	-2.97%	0.06%	0.39%
Panel F: All Countries set tariffs and NTBs to zero					
Global total	1.31%	2.65%	-1.34%	-0.03%	2.68%

Conclusions

- Existing trade policy implicitly subsidizes CO_2 emissions
  - EU: trade policy is encouraging leakage, not preventing it
  - Aggregate subsidy to climate change $>$ \$500 billion/year
  - Policy reforms could decrease global CO_2, increase global GDP
- Main explanation: downstream industries have higher tariffs, lower CO_2 intensity
- Consequences
  - Trade policy negotiations consider climate change consequences of tariff escalation?

Additional Slides

Non-tariff barriers ad valorem equivalent: methodology (Kee et al. 2009)

1. Estimate impact of NTBs on imports by nonlinear least squares:

$$lnm_{n,c} - \varepsilon_{n,c} ln(1+t_{n,c}) = \alpha_n + \sum_k \alpha_{n,k} C_c^k + (-e^{\beta_{n,c}^{Core} + \sum_k \beta_{n,k}^{Core} C_c^k}) Core_{n,c}$$
$$+ (-e^{\beta_n^{DS} + \sum_k \beta_{n,k}^{DS} C_c^k}) lnDS_{n,c} + \kappa_{n,c}$$

   Good n; country c; imports m; import demand elasticity ε (Kee et al. 2008); tariff t; country characteristics C , core NTB dummy $Core$; agricultural domestic support DS; error $\mu_{n,c}$

2. Recover NTB ad valorem equivalents from

$$ave_{n,c}^{Core} = \frac{1}{\varepsilon_{n,c}} \frac{\partial lnm_{n,c}}{\partial Core_{n,c}} = \frac{e^{\beta_{n,c}^{Core}} - 1}{\varepsilon_{n,c}}$$

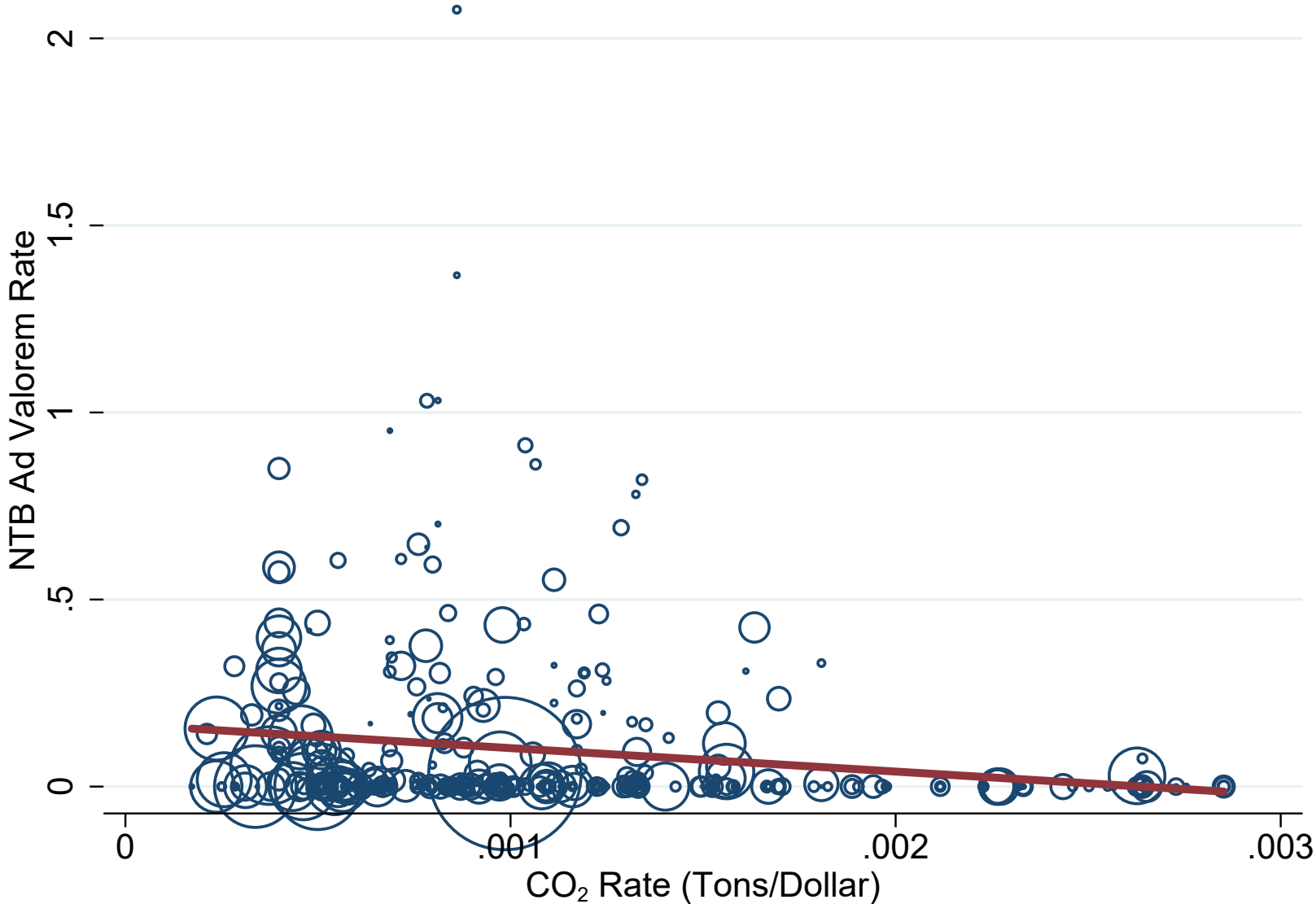
$$ave_{n,c}^{DS} = \frac{1}{\varepsilon_{n,c}} \frac{\partial lnm_{n,c}}{\partial lnDS_{n,c}} = \frac{\beta_{n,c}^{DS}}{\varepsilon_{n,c}}$$

Back to Main Slides

Data: U.S. Air Pollution Emissions

- **Criteria Air Pollution**
  - Carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter ($PM_{2.5}$, PM_{10}), sulfur dioxide (SO_2), volatile organic compounds (VOCs)
  - U.S. National Emissions Inventory 2002
  - Again invert input-output matrix.

Results: Actual Tariff Rates Versus Carbon Intensity, U.S. Imports (weighted)



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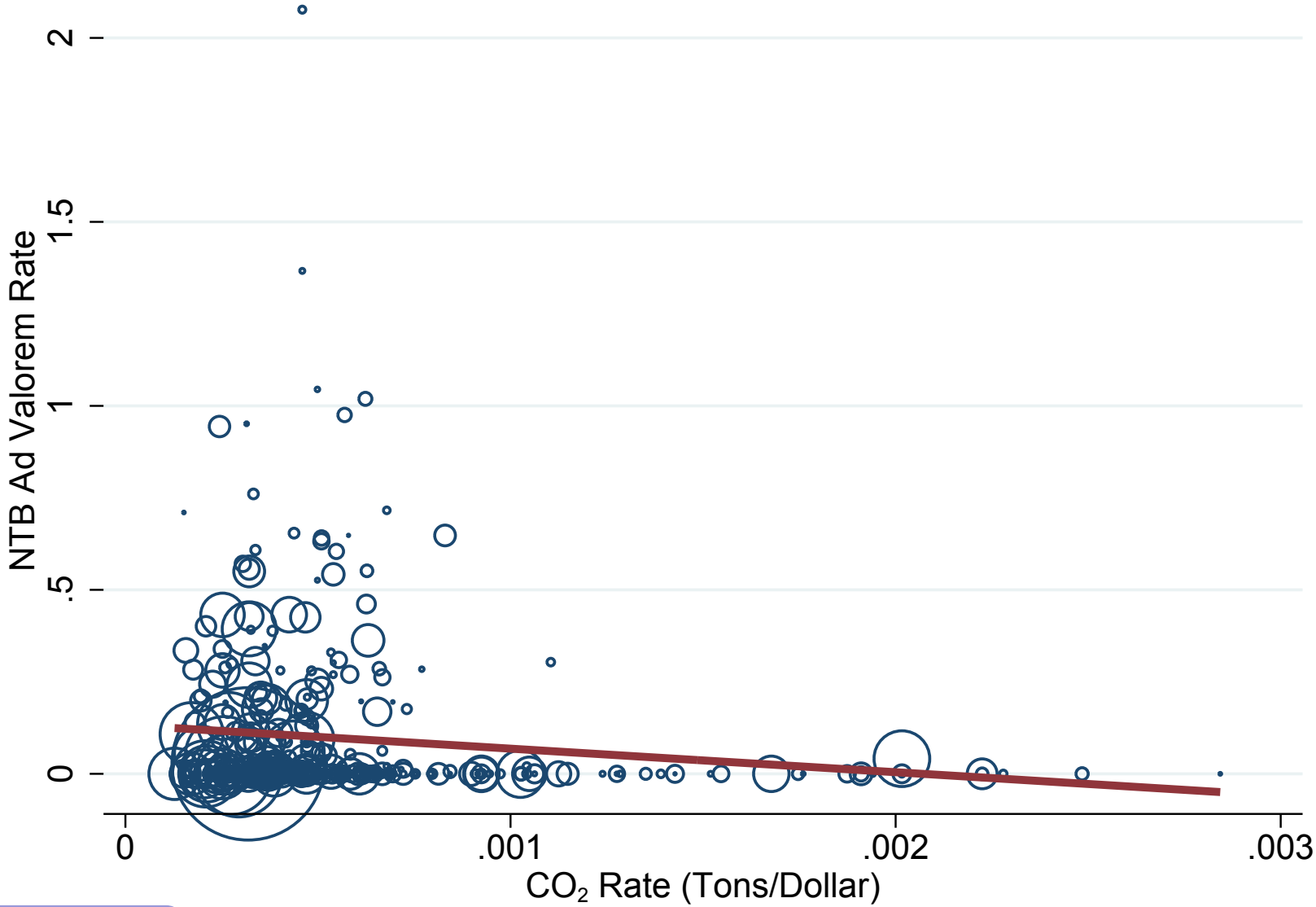
Results: Carbon Taxes Implicit in U.S. Non-Tariff Barriers (weighted)



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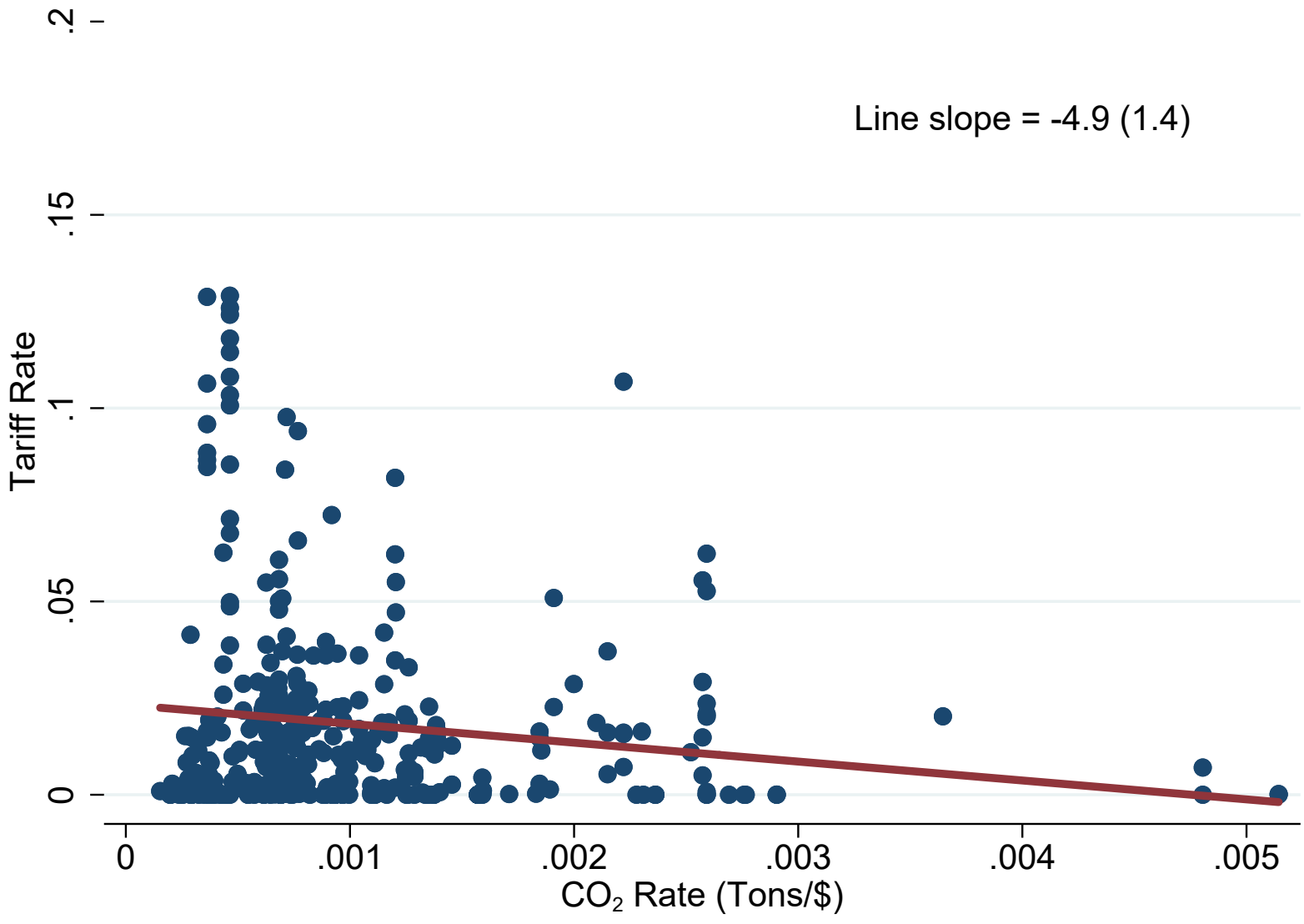
Results: Carbon Taxes Implicit in Global Tariffs



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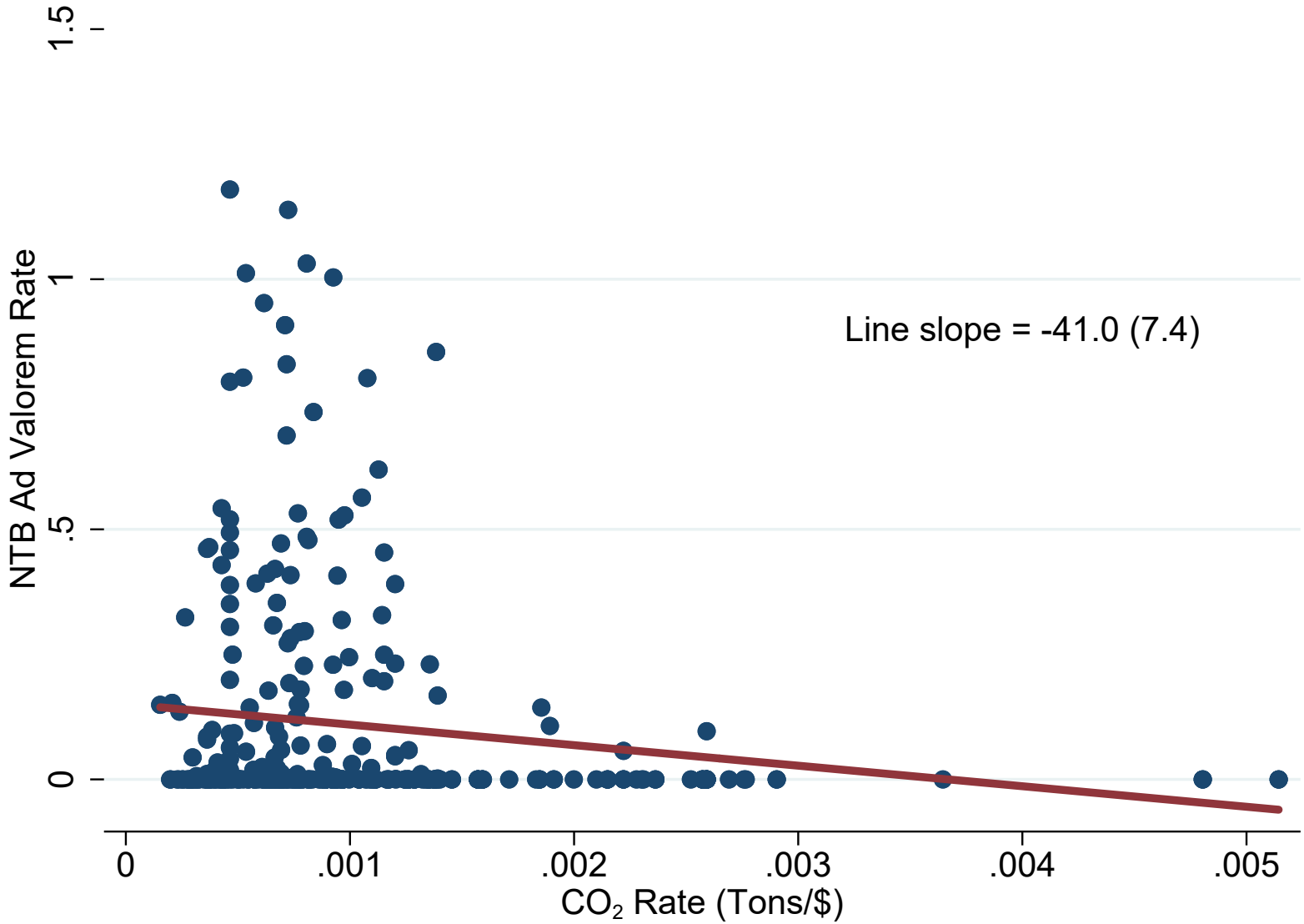
Results: Carbon Taxes Implicit in Global Non-Tariff Barriers



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Data: Pollution Emissions

- **Measuring CO_2 emissions**, $L \equiv (I - A)^{-1}$

$$L \circ e = \begin{array}{c} \\ coal \\ oil \\ gas \\ toys \\ pots \end{array} \begin{array}{c} \begin{array}{ccccc} coal & oil & gas & toys & pots \end{array} \\ \begin{bmatrix} L_{11} & L_{12} & L_{13} & L_{14} & L_{1N} \\ L_{21} & L_{22} & L_{23} & L_{24} & L_{2N} \\ L_{31} & L_{32} & L_{33} & L_{34} & L_{3N} \\ L_{41} & L_{42} & L_{43} & L_{44} & L_{4N} \\ L_{N1} & L_{N2} & L_{N3} & L_{N4} & L_{NN} \end{bmatrix} \end{array} \circ \begin{bmatrix} e_{coal} & e_{coal} & e_{coal} & e_{coal} & e_{coal} \\ e_{oil} & e_{oil} & e_{oil} & e_{oil} & e_{oil} \\ e_{gas} & e_{gas} & e_{gas} & e_{gas} & e_{gas} \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$= \begin{bmatrix} L_{11}e_{coal} & L_{12}e_{coal} & L_{13}e_{coal} & L_{14}e_{coal} & L_{1N}e_{coal} \\ L_{21}e_{oil} & L_{22}e_{oil} & L_{23}e_{oil} & L_{24}e_{oil} & L_{2N}e_{oil} \\ L_{31}e_{gas} & L_{32}e_{gas} & L_{33}e_{gas} & L_{34}e_{gas} & L_{3N}e_{gas} \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$(L \circ e)'\mathbf{1} = \begin{array}{c} \\ coal \\ oil \\ gas \\ toys \\ pots \end{array} \begin{bmatrix} L_{11}e_{coal} + L_{21}e_{oil} + L_{31}e_{gas} \\ L_{12}e_{coal} + L_{22}e_{oil} + L_{32}e_{gas} \\ L_{13}e_{coal} + L_{23}e_{oil} + L_{33}e_{gas} \\ L_{14}e_{coal} + L_{24}e_{oil} + L_{34}e_{gas} \\ L_{15}e_{coal} + L_{25}e_{oil} + L_{35}e_{gas} \end{bmatrix}$$

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Theory: Broad View

- **Non-cooperative theory**
  - Protection for sale (Grossman and Helpman 1994)
  - Political economy motive and terms-of-trade motive
- **Cooperative theory**
  - Trade wars and trade talks (Grossman and Helpman 1995)
  - Commitment (Maggi and Rodriguez-Clare 1998, 2007)
  - Political economy motive remains, terms-of-trade motive diminished
- **Production efficiency (Diamond-Mirrlees 1971)**
  - Can't explain escalation in NTBs
  - Tariff escalation isn't optimal tax

Theory

- Consumers maximize:

$$U = c_0 + \sum_i u_i(c_i)$$

- Firms maximize:

$$\pi_i = p_i y_i - l_i - \sum_h p_h x_{hi}$$

- Non-numeraire industries Leontief in $f(k_i, l_i), x_{0i}, \ldots, x_{ni}$
- Imports:

$$m_i = c_i + \sum_j x_{ij} - y_i$$

Theory

- Who is organized? Assume all industries, no consumers.
- Government preferences:

$$G(p) = \sum_i C_i(p) + aW(p)$$

- (Noncooperative) policy maximizes firm + government surplus:

$$G(p) + \sum_i \big(v_i(p) - C_i(p)\big) = \sum_i \pi_i(p) + aW(p)$$

- Tariffs satisfy FOC:

$$\sum_i \frac{\partial \pi_i}{\partial p_i} + a\frac{\partial W}{\partial p_i} = 0 \qquad \forall i$$

Theory

- Rewriting,

$$\frac{t_i}{1+t_i}\frac{m_i}{y_i}\cdot|e_i| = \frac{1}{a}\left(1-\frac{\sum_j \Omega_{ij}y_j}{y_i}\right)$$

- Stochastic version:

$$\frac{t_i}{1+t_i}\frac{m_i}{y_i}\cdot|e_i| = \beta_1+\beta_2 U_i+\eta_i$$

- Notes:
  - $\beta_1 > 0$ inverse welfare weight for upstream industries, $\beta_2 < 0$ downstream
  - $U_i \equiv \sum_{j=1}^{n}\Omega_{ji}y_j/y_i$ share of output used as intermediates
  - Assess model fit with U_i versus E_i
  - Noncooperative $\rightarrow$ more relevant to non-tariff barriers than tariffs

Up-Downstream Example

Political Economy Explanations: Model-Based Estimate

$$\frac{t_s}{1+t_s}\frac{m_s}{y_s}|e_s| = \beta_1 + \beta_2 U_s + \beta_3 E_s + \eta_s$$

Table 5—Model of Lobbying Competition and Protection for Sale

	(1)	(2)	(3)	(4)	(5)
Panel B: Non-tariff barriers (ad valorem equivalent)					
Upstream Location	-0.25**	-0.11***	—	-0.26**	-0.14**
	(0.10)	(0.04)	—	(0.11)	(0.05)
CO_2 rate	—	—	-78.30***	8.63	46.66
	—	—	(29.16)	(15.67)	(31.84)
Constant	0.23***	0.32***	0.16***	0.23***	0.33***
	(0.08)	(0.11)	(0.05)	(0.08)	(0.12)
Welfare Weight	17.52	—	—	—	—
	(4.65)	—	—	—	—
First Stage F (K-P)	—	—	7.4	7.1	5.8
AIC	330.0	333.5	367.1	332.7	344.7
Relative Likelihood	—	0.17	0.00	0.26	0.00
Upstreamness: Basic	X			X	
Upstreamness: Full		X			X