Navigating international taxation: The effects of a carbon levy on shipping

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Motivation

- International taxation of maritime transport is a longstanding issue,
- International Maritime Organization 2023 revised strategy: pricing mechanism for GHG emissions,
- COP28 in Dubai: launch of a task force on international taxation (member countries: Antigua and Barbuda, Barbados, France, Kenya, Spain),
- Confluence of climate and development agendas; proceeds of a tax could feed the loss and damage fund created after COP27,
- Many developing countries, including SIDS, advocate for a carbon tax on maritime transport.

Research questions

- What countries would be impacted the most by a carbon tax on international shipping?
- What would be the effects on carbon emissions of such a tax?
- What would be the proceeds? and the economic cost?

Research question

- We consider that the carbon tax is implemented worldwide but only on maritime transport (i.e. not on aviation),
- We do not scrutinize what could be financed by the proceeds,
- The tax is calibrated at 40$ per ton of CO_2 corresponding to approx. 120$ per ton of maritime fuel.

Analytical framework

- Analysis based on trade data covering 185 countries over the period 2012-2018, disaggregated at the HS2 level,
- Structural gravity model with multiple sectors; marine fuel costs being a component of iceberg trade costs,
- Counterfactual analysis: what effects of a carbon levy if it were implemented in 2018? (120$ tax per ton of fuel represents 29% of baseline price)

Main results

- The proceeds from the tax are estimated in the range 20 M$ to 60 M$ for a total economic cost of 166 M$.
- Richer countries would be relatively less impacted by the tax than poorer countries. For instance, OECD countries would bear an average 0.37 % purchasing power loss on tradables, while Least Developed countries would bear a 1.11 % purchasing power loss,
- Maritime sector emissions would be reduced by 1.75%; however, trade flows would be redirected towards more carbon intensive transport modes and global transport emissions would vary in a range -0.7% - +0.1%

Our contributions

- Carbon tax: structural analysis of a carbon tax on international maritime transport,
- Multisector gravity models: counterfactual analysis in multisector gravity models; application to a dataset covering 185 countries at the HS2 level of disaggregation,
- Analysis conducted with publicly available data only.

Related literature

- Transportation costs: Hummels (2007), Hummels and Schaur (2013), Feyrer (2019), value of time as an important factor in the choice of transport mode,
- Oil price shocks and maritime bulk transport costs: Brancaccio et al. (2020, 2023), average fuel cost elasticity of 0.35, similar to what we find.
- Carbon tax on maritime trade: Mundaca et al. (2021), Cariou et al. (2023), focus on partial equilibrium elasticities, find much larger impact of the tax,
- Structural gravity and carbon pricing: Shapiro (2016), elasticities estimated on US and Australia data, focus on price index and welfare, counterfactuals built with air, or air and sea, transport taxes.

Related literature

- Multisector structural gravity: Anderson and van Wincoop (2003), Larch and Yotov (2016), Armington-type fixed endowment demand side model,
- Counterfactual general equilibrium computations: GEPPML, Anderson et al. (2018); *ge_gravity*, Baier et al. (2019); *gegravity*, Herman (2021); all those packages are designed for one sector models,
- Remoteness indices: UNDESA, Brun et al. (2005), we go beyond such indices by looking at welfare effects, distinguishing sectors, and taking into account multilateral resistances.

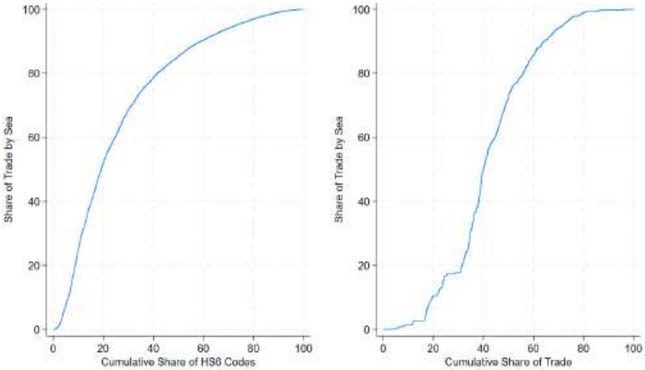
Data sources

- BACI database for bilateral trade flows at the HS6 level (CEPII, 2010), in value and in volume,
- Gravity dataset (CEPII, 2022) for control variables,
- CERDI-Seadistance dataset (2016), for maritime distance,
- Trade and production dataset (CEPII, Mayer et al., 2023) for intranational trade flows,
- Sector-level trade elasticities from Fontagné et al. (2022),
- World Development Indicators (World Bank), for GDP per capita,
- Carbon intensities from an official report from French Ministry of Ecological Transition (2018).

Preliminary analysis

- US maritime trade, exports + imports, at the HS6 level (US Census Bureau),

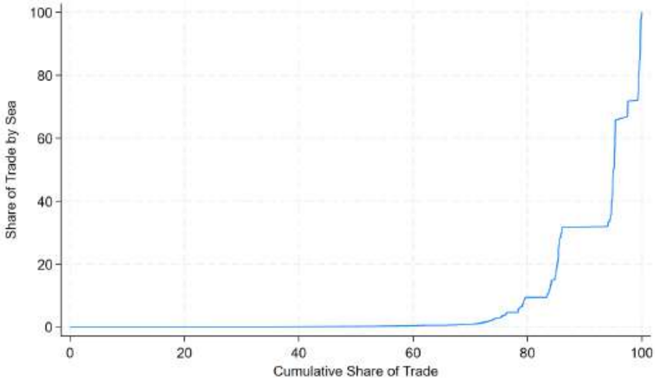
Figure: Shares of U.S. seaborne trade excl. Canada and Mexico



Preliminary analysis

- US maritime trade, exports + imports with neighbors,

Figure: Shares of U.S. seaborne trade with Canada and Mexico



Isolating maritime flows

- Baseline: HS6 codes for which US share of seaborne trade is less than 60% are spotted as "non-maritime", HS6 codes for which US share of seaborne trade is more than 60% are spotted as "maritime",
- "maritime" flows are aggregated as the HS2 level, "non-maritime" flows are aggregated in a single "non-maritime" sector,
- Robustness checks with 50%, 70% thresholds and with the Hummels and Schaur's procedure (spotting keywords in HS6 description of goods).

Final dataset

- In the BACI database, 69% of bilateral flows in value are spotted as "maritime" and aggregated at the HS2 level,
- Seadistance is set to 0 for countries sharing a terrestrial border (no impact of the tax on transport costs for those bilateral flows),
- Intranational flows are calculated at the HS2 level from the Trade and Production dataset: each HS2 code is associated to an industry for which the Trade and Production dataset gives the ratio of intra- to inter-national flows in value. This ratio is applied to each country HS2 flows. Trade Prod and HS2

Specification

- Sector by sector gravity equation for "maritime" flows:

$$Y_{ijkt} = \exp\left[\beta_k C_{ijt} + \gamma_k . X_{ijt} + F_{ikt} + G_{jkt}\right] \epsilon_{ijkt} \qquad (1)$$

- Y_{ijkt} is the value of flows from country i to country j in year t for HS2 category k,
- C_{ijt} is a maritime transport cost variable,
- X_{ijt} is a vector of control variables defined at the dyadic (importer-exporter) and year (t) level,
- F_{ikt} and G_{jkt} are respectively exporter.product.year and importer.product.year fixed effects that capture the multilateral resistances to trade. Model

Specification

- The maritime transport cost variable is defined as:

$$C_{ijt} = \ln(1 + SeaDist_{ij} \, . \, p_t) \quad (2)$$

  where $SeaDist_{ij}$ is the maritime distance between country i and country j and p_t is the average price of heavy fuel oil in year t. Transport costs

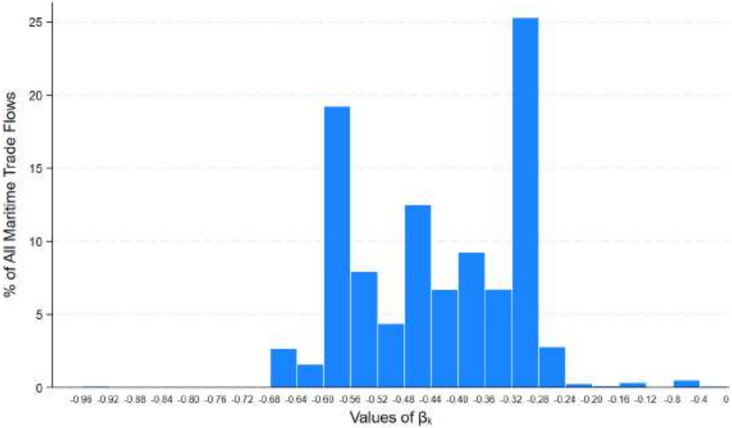
- The vector of control variables X_{ijt} is standard, it contains: $Border_{i,j}$, $Language_{i,j}$, $Colonization_{i,j}$, $Custom_{i,j,t}$, $FTA_{i,j,t}$, $EU_{i,j,t}$, $WTO_{i,j,t}$, $Home_{i,j}$.

Elasticities

- The system of gravity equations (1) is estimated with Poisson Pseudo Maximum Likelihood (PPML),
- We focus on the β_k coefficients, i.e. the sector specific partial equilibrium elasticities of trade with respect to the maritime transport cost variable C_{ijt},
- Those elasticities are estimated in the range $[-0,93; -0,02]$, hence are all negative as expected, for 8 sectors the elasticity is non significantly different from 0 at 5%.

Elasticities

Figure: Distribution of partial elasticities (% of maritime flows in value)



Structural gravity

- Counterfactual analysis: we assume a 40$ tax (T) per ton of CO_2 implemented in 2018, with full pass-through, hence a 29% of increase in the price of fuel p_t that becomes $p_t + T$;
- The counterfactual transport cost variable is

$$C^c_{ijt} = \log(1 + SeaDist_{ij}(p_t + T)). \tag{3}$$

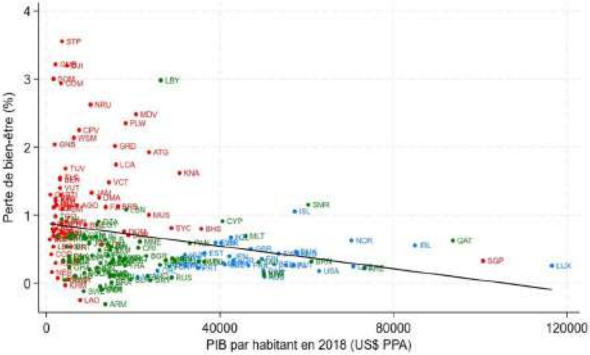
- The tax impacts trade costs and hence multilateral resistances to trade: we cannot assume that the fixed effects F_{ikt} and G_{jkt} remain constant, i.e. looking at partial equilibrium elasticities is not sufficient,
- Our structural model is suited for a rigorous comparative statics exercise, a so-called general equilibrium analysis.

Structural gravity

- Following Dekle, Eaton and Kortum (2007, 2008) we adopt the *exact hat algebra* approach,
- The equilibrium in the counterfactual scenario can be derived from the baseline bilateral flows and the ratio of trade costs (counterfactual over baseline) which are obtained from our estimated elasticities β_k.
- We obtain the counterfactual trade flows, and variation in consumer welfare (purchasing power). exact hat algebra

Welfare

Figure: Impact of a carbon tax on welfare by countries



Welfare

- A simple descriptive linear regression gives

$$\textit{Welfare Loss} = 0.8802154 - 8.32e^{-06}\ \textit{GDPpc}$$

▸ world map

- The average loss is 0.37% for OECD countries while it reaches 1.11% for Least Developped Countries,
- The aggregate equivalent variation in income (estimated at baseline prices) is 166 M$.

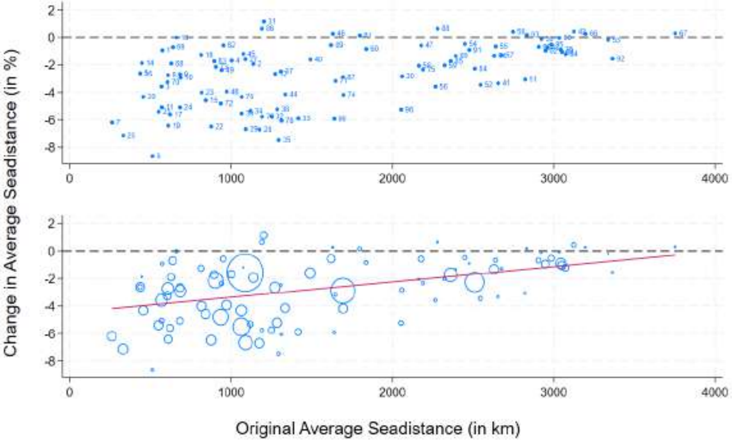
Geography of trade

Trade flows are redirected towards closer neighbors:

- The tax reduces the average distance traveled at sea by 1$ of good by 2.59%,
- The modification of distance is different from one HS2 sector to the other.

Geography of trade

Figure: Change in average seadistance traveled by sector (% change)



Maritime sector emissions

To translate the reduction in distance into a reduction in emissions, we first translate values of flows into volumes (tons) of flows. Then use carbon intensity data to compute emissions.

Table: List of vessels, sectors, and carbon intensities

Vessel	HS2 sectors	Min. CI	Max. CI
Bulk Carrier	02; 03; 07; 08; 10; 11; 12; 13; 14; 15; 22; 23; 25; 26; 31; 44	3.65	11.10
Container Ship	01; 04; 05; 06; 09; 16; 17; 18; 19; 20; 21; 24; 30; 37; 39; 40; 41; 42; 43; 45-85; 89; 90; 91; 92; 93; 94; 95; 96	10.02	21.90
Oil Tanker	27	3.36	18.70
Chemical Tanker	28; 29; 32; 33; 34; 35; 36; 38	14.70	54.70
Ro-Ro Ship	01; 86; 87; 88; 89	103	
Plane	99	1065	
Truck	All Products if $Border = 1$	85	
Train	All Products if $Border = 1$	13.5	

Note: Carbon Intensity (CI) is expressed in $gCO2.ton^{-1}.km^{-1}$.

Source: Ministère de la Transition écologique et solidaire (2018) and authors.

International trade emissions

- With the tax, flows are redirected towards closer trade partners, notably neighbors, for which transport mode may be more carbon intensive,
- Consumers may also redirect consumption choices towards goods which price is less affected by the tax (e.g. goods in the "non-maritime" sector).

International trade emissions

Table: Revenue collection and change in CO_2 emissions

	Scenario 1: Lowest CI of Vessels and land transport by road	Scenario 2: Highest CI of Vessels and land transport by rail
Pre-tax CO_2 Emissions (billion tons)	0.499	1.513
Post-tax CO_2 Emissions (billion tons)	0.491	1.487
Change in Maritime Transport Emissions	-1.76%	-1.74%
Revenues Collected ($ billion)	19.624	59.476
Change in Total Transport Emissions	+0.12%	-0.72%

Note: These figures are consistent with the IMO estimate of 1.056 billion tons of CO_2 emissions in 2018.

Conclusion

- A \$40 per ton of CO_2 tax on marine fuel would disproportionately impact poor countries.
- It would induce a 1.75% reduction in maritime sector emissions but a more modest impact on trade emissions due to redirection of trade flows towards more carbon intensive transport modes if it is adopted independently from a more global carbon tax.
- The ratio economic cost/proceeds is estimated in the range [2.78; 8.47], much higher than usual marginal costs of public funds.

Shipping sector pushes to keep emissions-tax cash for itself

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The industry and governments' maritime ministries want a proposed levy on emissions spent on cleaning up shipping, not used for wider climate goals like loss and damage

The opening of the International Maritime Organisation's 81st Marine Environment Protection Committee (March 18/ IMO)

By Joe Lo

Shipping negotiators for governments at UN talks this week want a proposed tax on the sector's emissions to be spent mostly on cleaning up the industry – which could thwart international plans to use some of the money to address broader damage from climate change.

Trade and production database

Table: List of industries and equivalences HS2-digit products (rev.12) - Industry classification from Trade Prod database

Trade Prod Classification	HS2-digit Classification (rev. 12)
Food and Animal Products (ISIC 15; 16)	1 to 24
Textiles (ISIC 17; 18; 19)	41 to 43; 50 to 65
Wood and Paper (ISIC 20; 21; 22)	44 to 49
Chemicals (ISIC 23; 24; 25)	27 to 35; 37 to 40
Minerals (ISIC 26)	25; 68 to 70
Metals (ISIC 27; 28)	26; 71 to 76; 78 to 83
Machines (ISIC 29; 30; 31; 32; 33)	84; 85; 90; 91; 93
Vehicles (ISIC 34; 35)	86 to 89
Other (ISIC 36)	36; 66; 67; 92; 94 to 97

Note: There is no category 77 in the HS2-digit revision 12 Classification.

back

Model

- Representative consumer preferences in country i

$$U_j = \Pi_{k=1}^{K} \left\{ \sum_{i=1}^{N} \beta_{ik}^{\frac{1-\sigma_k}{\sigma_k}} c_{ij}^{\frac{\sigma_k - 1}{\sigma_k}} \right\}^{\alpha_{jk}}$$

  where K is the total number of sectors, N is the number of countries, and the parameters α_{jk} can be country specific.
- Fixed endowment Y_{ik} for sector k good in country i,
- Expenditures E_{ik} and possible trade imbalances characterized by ϕ_i with $E_{ik} = \alpha_{ik}\phi_i Y_i$ where $Y_i = \sum_{k=1}^{K} Y_{ik}$.
- Price in country j for good ik is $p_{ijk} = p_{ik} t_{ijk}$ where t_{ijk} are the iceberg trade costs.

Model

- Structural gravity system

$$Y_{ijk} = \left(\frac{t_{ijk}}{P_{jk}\Pi_{ik}}\right)^{1-\sigma_k} Y_{ik}E_{jk} \tag{4}$$

$$P_{jk}^{1-\sigma_k} = \sum_i \left(\frac{t_{ijk}}{\Pi_{ik}}\right)^{1-\sigma_k} Y_{ik} \tag{5}$$

$$\Pi_{ik}^{1-\sigma_k} = \sum_j \left(\frac{t_{ijk}}{P_{jk}}\right)^{1-\sigma_k} E_{jk} \tag{6}$$

$$E_{ik} = \alpha_{ik}\phi_i Y_i \tag{7}$$

A normalization is required. We assume that nominal resources are held constant so that

$$\sum_{i=1}^{N} Y_i = Y = \bar{Y} \tag{8}$$

back

Transportation costs

- Iceberg trade costs are defined as

$$t_{ijkt}^{1-\sigma_k} = \exp[\beta_k C_{ijt} + \gamma_k . X_{ijt}]$$

where X_{ijt} is a vector of control variables, and where

$$C_{ijt} = \ln(1 + SeaDist_{ij} . p_t) \quad (9)$$

is the component of trade costs related to maritime transport variable costs which are proportional to the maritime distance between country i and country j (measured by $SeaDist_{ij}$).

- Replacing in the first equation of the structural gravity system gives

$$Y_{ijkt} = \exp\left[\beta_k \ln(1 + SeaDist_{ij} . p_t) + \gamma_k . X_{ijt} + F_{ikt} + G_{jkt}\right] \epsilon_{ijkt} \quad (10)$$

back

Exact hat algebra

- Hat variables are the ratios of counterfactual over baseline values, e.g. $\hat{t}_{ijk} = t^c_{ijk}/t_{ijk}$, we also denote for each sector k, $\lambda_{ijk} = Y_{ijk}/E_{jk}$ the share of country j expenditures on goods from country i,
- The counterfactual equilibrium is derived from the system

$$\hat{Y}_{ik} = \left[\frac{1}{Y_{ik}} \sum_{j=1}^{N} \frac{\lambda_{ijk} \left(\hat{t}_{ijk}\right)^{1-\sigma_k}}{\hat{P}_{jk}^{1-\sigma_k}} E^c_{jk}\right]^{\frac{1}{\sigma_k}} \tag{11}$$

$$\hat{Y}_{ik} = \hat{Y}_{ik} \frac{Y}{\sum_{j=1}^{N} \sum_{l=1}^{K} \hat{Y}_{jl} Y_{jl}} \tag{12}$$

$$\hat{P}_{jk} = \left[\sum_{l=1}^{N} \lambda_{ljk} \left(\hat{Y}_{lk} \hat{t}_{ljk}\right)^{1-\sigma_k}\right]^{\frac{1}{1-\sigma_k}} \tag{13}$$

$$E^c_{jk} = \alpha_{jk} \phi_j \hat{Y}_j Y_j \tag{14}$$

Exact hat algebra

- The parameters ϕ_i and α_{ik} are computed from baseline trade flows,
- The system can be solved via a fixed point algorithm that generalizes to multiple sectors the *ge_gravity* package developed by T. Zylkin (2019),
- From baseline trade flows and ratios of trade costs we recover counterfactual trade flows, and two important statistics: purchasing power and consumer price index. back

Map

Figure: World map of countries by welfare loss / gain