Do domestic climate policies stimulate the export of polluting technologies? Evidence from trade data

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Abstract

This study estimates the impact of carbon pricing on international trade in equipment used in the combustion of fossil fuels during the period 1995–2021. Using detailed data on bilateral trade combined with data on domestic carbon prices, we find that carbon pricing policies are associated with greater exports of this equipment. Our results provide new evidence for this unexplored form of leakage due to more stringent climate policies.

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1 Introduction

Fossil fuel combustion holds the dubious distinction as principal source of global greenhouse gas emissions. In industrial processes, combustion is typically done using specialized technologies. The production and sales of these technologies hence facilitate greenhouse gas emissions and, in so doing, fuel global warming. This paper studies how climate policy affects international trade in combustion equipment.

By increasing the effective cost of emissions, climate policy creates incentives to substitute away from fossil fuels toward less emissions-intensive sources of energy.[1] Facing a fallout in domestic demand, a producer of combustion technologies may be inclined to export its output in response. We build a simple theory model of international trade in polluting technologies to illustrate this mechanism. Our theoretical analysis shows that this effect is unambiguous; in theory at least, domestic climate policy tends to facilitate the export of emissions-intensive technologies abroad. Of course, validity of this prediction is fundamentally an empirical question. We therefore take our hypothesis to the data. To our knowledge, this paper is the first to study the effect of climate policy on the trade in emissions-facilitating technologies.

We document strong evidence that domestic climate policies stimulate the export of fossil fuel combustion technologies. Our preferred specification focuses on *burners*, a kind of technology used in the combustion of fossil fuels, especially coal. We consider three measures of climate policy stringency: (i) a binary carbon pricing indicator; (ii) a binary emissions trading system (ETS) indicator, which is a subset of (i); and (iii) a continuous measure of carbon prices that includes both taxes and ETS prices. According to all three measures, more stringent climate policy stimulates exports of burners. We document this effect both at the extensive and at the intensive margin.

At the extensive margin, we find that the probability of a country exporting burners is increasing in the stringency of the exporter country's climate policy. In our baseline specification, the presence of a carbon pricing policy within a country's borders increases the probability that said country exports burners by around nine percentage points. A one dollar increase in the carbon price in a country with an ETS raises the probability that it exports burners by 0.56 percentage points. At the intensive margin, our baseline specification suggests that the presence of a domestic carbon price or ETS increases the total value of burner exports by up to 15 percent, depending on the specification. Overall, our extensive margin results are more consistently significant across specifications.

[1] These incentives work: Bayer and Aklin (2020) and Dechezleprêtre et al. (2023) document a clear decrease in European carbon emissions due to its emissions trading system (the EU ETS). In addition, climate policy stimulates domestic low-carbon innovation patenting (Calel and Dechezleprêtre, 2016), arguably facilitating emissions reductions in the future.

The result that domestic climate policy stimulates exports of polluting technologies is related to carbon leakage or the pollution haven hypothesis. The latter states that environmental regulations will move polluting activities for tradeable products to countries where policy is less strict (Eskeland and Harrison, 2003). The similarity is clear: all else equal, stricter domestic climate policies tend to stimulate exports of polluting technologies and therefore facilitate emissions abroad. The empirical evidence on carbon leakage points in different directions. Aichele and Felbermayr (2015) find evidence that participation in the Kyoto protocol led to an increase in embodied carbon imports from noncommitted countries. Fell and Maniloff (2018) show that the Regional Greenhouse Gas Initiative (RGGI) reduced coal-fired electricity generation in participating U.S. States yet increased dirty electricity generation in surrounding states that do not participate RGGI. On the other side of the Atlantic, however, Naegele and Zaklan (2019) and Dechezleprêtre et al. (2022) do not find evidence that the EU ETS caused carbon leakage.

Despite the similarities, our findings are importantly different from carbon leakage. First, carbon leakage means that national climate policies shift the production of emissions-intensive goods abroad yet cause a less-than-proportionate reduction in consumption-based emissions due to changes in a country's imports and exports. In contrast, combustion technologies can be used for the production of both traded and non-traded commodities. If the technology is used to produce goods that are not traded internationally, then domestic climate policies should be expected to decrease national production- and consumption-based emissions at a roughly equal rate.

Second, our results raise novel policy questions. While domestic climate regulations may reduce national emissions (even at the level of consumption), the induced export of combustion technologies facilitates emissions abroad. This creates new policy challenges compared to traditional carbon leakage: while a carbon border adjustment mechanism may be able attenuate emissions leakage (Fischer and Fox, 2012), it does not prevent the export of combustion technologies in response to environmental regulation. Taking as given the climate policies of the importing country, there are only two obvious ways to avoid the kind of technology leakage identified here: a direct ban on exports of polluting technologies, or a price on potential emissions embedded in exports. Neither would seem a perfect solution to the problem, if a solution at all.

Although the scope for diffusion of clean technology across international borders is often discussed (Copeland et al., 2022), there is a dearth of studies on trade in dirty technologies that facilitate emissions abroad. Beyond the context of climate change, a related paper is Ferguson (2022), who shows that an increase in the stringency of regional animal welfare regulation stimulates the exports of regionally banned poultry-keeping equipment.

An important industry to which our results apply is the energy sector, which relies on combustion technologies to generate electricity from fossil fuels. This sector matters. According to the United States Environmental Protection Agency, electric power generation alone was responsible for 25% of U.S. greenhouse gas emissions in 2020 (EPA, 2022). To mitigate global warming it is hence critical to decarbonize the energy sector, not just in an individual country but also globally. Our results suggest that existing climate policies may fail to do so and thus contribute less to global emissions reduction than aimed and hoped for.

The paper proceeds as follows. Section 2 develops a simple model of trade in combustion technologies that formalizes our main hypothesis. Section 3 discusses our empirical methodology and identification strategy. Section 4 describes our data. Section 5 presents our main results. Section 7 discusses and concludes. A suite of robustness checks is presented in the Appendix.

2 Theory

This section develops a very simple model to describe the impact of domestic climate policy stringency on international trade in polluting technologies. Our model consists of two markets. One market describes the domestic demand for burners, which we will use as an umbrella term for all sorts of polluting-facilitating equipment. Utilities choose whether to generate electricity using either fossil fuels or renewables. Burners are needed only for the combustion of fossil fuels, which leads to emissions. More stringent climate policy increases the cost of using fossil fuels for electricity generation relative to the cost of (emissions-free) renewables. Ceteris paribus, an increase in climate policy stringency is hence associated with a decrease in the demand for burners.

The other market describes the international market for burners. Burner manufacturers can sell their product either domestically or abroad. When confronted with an increase in the stringency of domestic climate policy, the manufacturer faces a fallout of domestic demand. Domestic policies do not affect the foreign demand for burners, however. For any given market price of burners, an increase in domestic climate policy stringency thus increases foreign relative to domestic demand. This, then, is our main hypothesis: all else equal, domestic climate policies tend to stimulate exports of burners.

2.1 The Demand for Burners

In some country, there is a continuum of utilities $i \in [0, 1]$ who can generate electricity using either of two technologies. One technology, "burners" generates electricity through combustion of fossil fuels which causes pollution. The other technology, “renewables”, generates electricity in some other way and is associated with (substantially) less emissions. Each utility chooses which technology to operate. We write T for the stringency of domestic climate policy.

Let P denote the market price of a burner (e.g. per unit of electricity generated over the course of the burner's lifetime). Let $q_i \in \{0, 1\}$ denote the choice of technology by utility i, where $q_i = 1$ means that i chooses the burner technology. Each utility i has its own profit potential from using either technology, which we summarize by the parameter θ_i. We assume that θ_i is distributed according to a continuously differentiable distribution on a nonempty interval of positive real numbers.[2] Given its parameter θ_i, the price of burners P, and a climate policy of stringency T, the payoff U_i to utility i is given by:

$$U_i(q_i \mid P, T, \theta_i) = \begin{cases} 0 & \text{if} \quad q_i = 0, \\ \theta_i - P - T & \text{if} \quad q_i = 1, \end{cases} \tag{1}$$

where we normalize the payoff to using the renewable technology to 0. Let $q_i^*(P, T)$ denote the choice of technology that maximizes $U_i(q_i \mid P, T, \theta_i)$ for utility i. Given P and T, we define

$$D_D(P, T) = \int_0^1 q_i^*(P, T)\, di. \tag{2}$$

That is, $D_D(P, T)$ is the domestic market demand for burners given a price P and an emissions policy with stringency T. Inspection of (1) immediately reveals that

$$\frac{\partial D_D(P, T)}{\partial P} < 0, \quad \frac{\partial D_D(P, T)}{\partial T} < 0. \tag{3}$$

In other words, the demand for burners is decreasing both in the price of burners and the stringency of climate policy. We will use these properties when describing the international market for burners and, more precisely, a burner manufacturer's decision to sell its product domestically or abroad.

2.2 The Market for Burners

Consider a manufacturer of burners. For simplicity, we will refer to a single manufacturer although one could equally interpret our analysis in terms of a single *representative* manufacturer in some given country. Given a price P, the demand for burners is $D_D(P)$ in the domestic market and $Q^F(P)$ abroad. Net revenues from selling S_D burners domestically,

[2] Continuous differentiability of the distribution function is not necessary, but convenient: it implies that $D_D(P, T)$ is differentiable in P and T, which allows us to state our main hypotheses concisely in terms of derivatives.

given the market price P, are $P \cdot S_D$; revenues from selling S_X units in the foreign market are $(P - \tau) \cdot S_X$, where $\tau \geq 0$ describes additional costs associated with exporting such as shipping fees. The cost of producing a total of $S_D + S_X$ burners for the domestic and foreign market, respectively, is $C(S_D + S_X)$, which is an increasing convex function. Combining these elements, profits to the manufacturer are given by:

$$\Pi(S_D, S_X) = P \cdot S_D + (P - \tau) \cdot S_X - C(S_D + S_X). \tag{4}$$

We consider the case in which the manufacturer is small relative to world demand for burners and takes the world price $\bar{P}$ as given. Conditional on the climate policy T and the going world price, the problem of the manufacturer is to choose the domestic and foreign supply of production of burners, S_D and S_X, that maximizes profits. Formally, the manufacturer solves

$$\begin{aligned} \max_{S_D, S_X} \quad & \bar{P} \cdot S_D + (\bar{P} - \tau) < cdot S_X - C(S_D + S_X) \\ \text{s.t.} \quad & D_D(\bar{P}, T) \geq S_D \\ & S_D, S_X \geq 0 \end{aligned} \tag{5}$$

where the constraint $D_D(\bar{P}, T) \geq S_D$ says that the manufacturer cannot sell more burners domestically than are demanded at the going market price. Given a world price of burners $\bar{P}$ we let $S_D(\bar{P}, T)$ and $S_X(\bar{P}, T)$ denote the solutions to this problem. The first order conditions to this problem are $\bar{P} \geq C'(S_D(\bar{P}, T) + S_X(\bar{P}, T))$, with a strict inequality if the constraint $D_D(\bar{P}, T) \geq S$ is binding, and $\bar{P} - \tau \leq C'(D_D(\bar{P}, T) + S_X(\bar{P}, T))$, with equality if $S_X(\bar{P}, T) > 0$. We observe that a profit-maximizing manufacturer supplies all domestic demand for burners before exporting any excess supply to the global market should that be profitable. This makes sense: shipping costs reduce the revenues from a burner exported relative to one sold domestically so the manufacturer saturates all domestic demand before it starts exporting. To avoid corner solutions and simplify notation, we henceforth assume that $S_D(\bar{P}, T) + S_X(\bar{P}, T) > D_D(\bar{P}, T)$. We obtain the following implicit solution for $S_X(\bar{P}, T)$:

$$\bar{P} - \tau = C'(D_D(\bar{P}, T) + S_X(\bar{P}, T)). \tag{6}$$

Given $\bar{P}$ and convexity of C, exports $S_X(\bar{P}, T)$ are decreasing in domestic (equilibrium) demand $D_D(\bar{P}, T)$. Because domestic demand is decreasing in T, see (3), we have

$$\frac{\partial S_X(\bar{P}, T)}{\partial T} > 0, \tag{7}$$

that is, exports of burners are increasing in the stringency of domestic climate policy. Positivity of the derivative in (7) is the main hypothesis tested in this paper. The equilibrium effects are graphically illustrated in Figure 1. Note that Figure 1 plots the intensive margin effect of climate policy on exports. The figure rules out a clear extensive margin effect as exports are positive both before and after the introduction of a domestic climate policy. If instead one had $S_X(\bar{P}) < 0$ while $S_X(\bar{P}, T) > 0$, i.e. the solid black curve in the right-hand panel would intersect the world price curve $\bar{P}$ to the left of the vertical axis, a policy of stringency T also has an extensive margin effect.

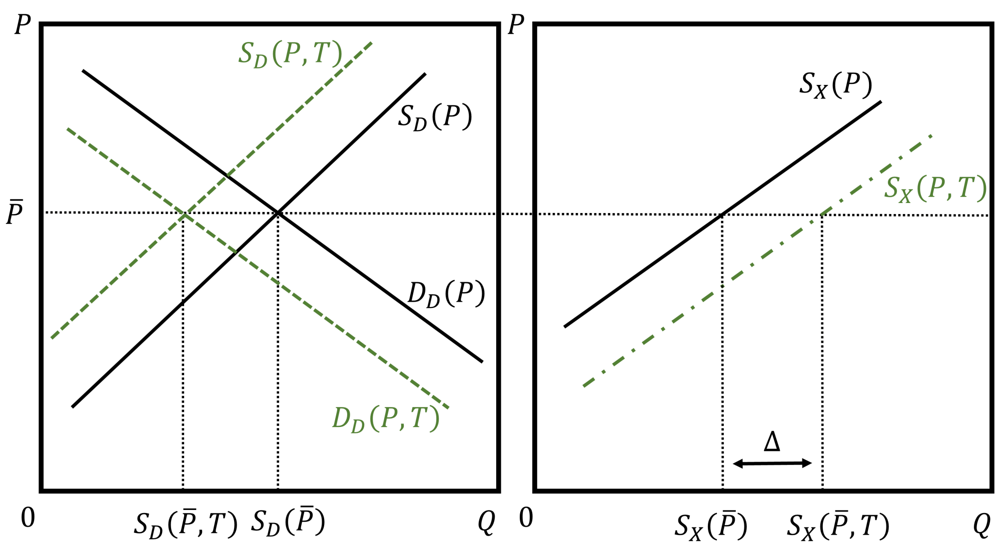

Figure 1: Equilibrium effects due to a change in domestic climate policy stringency on exports. The left panel describes the domestic market for burners, the right panel the international market. Our base case assumes the absence of domestic climate policies. The associated equilibrium is given by the intersection of the (solid black) domestic supply and demand curves; given the world price $\bar{P}$, exports are $S_X(\bar{P})$. When the country introduces a domestic climate policy, the domestic demand for burners shifts down to the dashed green curve $D_D(P, T)$, while domestic supply shifts up to $S_D(P, T)$. Meanwhile, supply on the international market shifts down to the green dashed-dotted curve $S_X(P, T)$. The increase in equilibrium exports is given by Δ.

The analysis assumed that burner manufacturers take the world price of burners as given. While customarily maintained in the context of global trade, one could imagine this assumption being violated if the exporting country is a large economy such as the U.S. or China. An explicit analysis of the large-country case, with downward-sloping international demand for burners, is beyond the scope of this paper. A graphical illustration is provided in Figure 2. The key takeaway is that in the large-country case, too, domestic climate policies stimulate the exports of burners. The same note on extensive margin effects discussed for

Figure 1 applies.

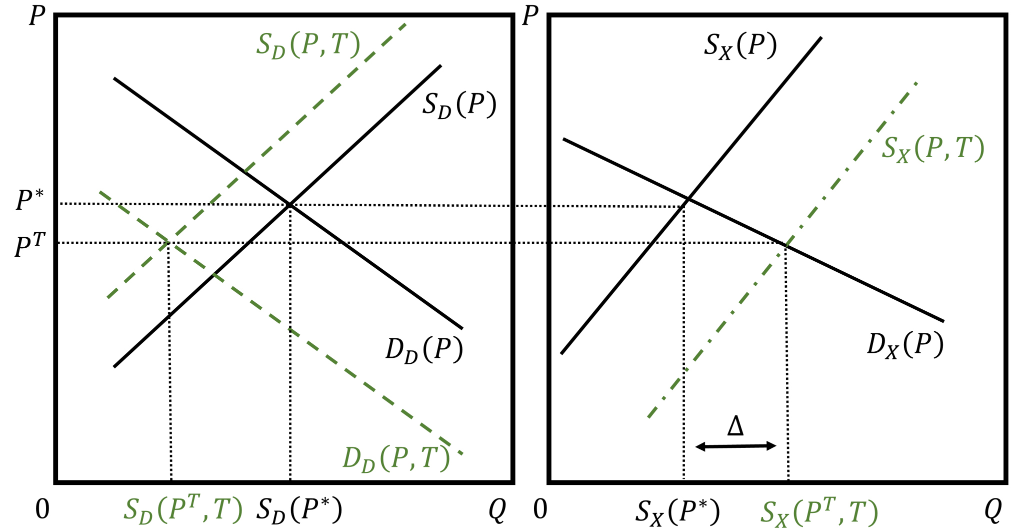

Figure 2: Graphical illustration of the equilibrium effects of domestic climate policy on burner exports when the world demand for burners is downward-sloping. Upon the introduction of a domestic climate policy, exports increase by Δ.

Our empirical analysis takes the main prediction of this theory model – that domestic climate policy stimulates the export of burners – to the date. In the next section, we explain our methodology.

3 Empirical Methodology

The analysis employs an OLS panel regression model with multiple levels of fixed effects (Correia, 2014). Using data on bilateral trade flows at the product-origin-destination-year level, we first estimate the relationship between a carbon price and the intensive margin of trade of products embodying polluting technologies. Our estimation of the intensive margin of trade follows an approach similar to Naegele and Zaklan (2019):

$$\ln(Y_{odkt}) \quad = \quad \alpha^i\theta_{okt} + \alpha^j\theta_{dkt} + \beta X_{okt} + \gamma X_{dkt} + \delta_{odk} + \delta_{odt} + \delta_{kt} + \tau_{odkt}, \tag{8}$$

where Y_{odkt} is the value of trade from origin country o to destination country d of product k in year t. Two products are included in each estimation, burners and a control product. θ_{okt} and θ_{dkt} are the carbon price dummy variables in the origin and destination countries respectively, while X_{okt} and X_{dkt} are vectors of country-product-year covariates, such as tariffs. δ_{odk} denote panel fixed effects, while δ_{odt} and δ_{kt} are origin-destination-year and product-year fixed effects.

The coefficients of most interest are α^o and α^d, which capture the effect on the intensive margin of trade, in percent associated with having an ETS or carbon tax. Our theoretical analysis predicts that a price on carbon in a country will increase its exports of products that embody dirty technologies ($\alpha^o > 0$) and will decrease its imports of such goods ($\alpha^d < 0$).

Equation (8) is our preferred specification, where the fixed effects are saturated. Panel fixed effects control for all time-constant factors that explain trade patterns. Origin-destination-year fixed effects control for changes in trade over time for each country-pair that affect trade in the polluting good and the control good in the same way. This specification controls for country-year price indices that are typically included in gravity models of trade, as well as GDP and GDP per capita. Any changes in a country's trade policies that affect both goods symmetrically will also be captured by the origin-destination-year fixed effects. Finally, the product-year fixed effects control for any changes in trade over time that are specific to a particular good, but not specific to a particular origin or destination country.

Our analysis of the extensive margin of trade also uses an OLS model, which permits the full set of fixed effects used in equation (8). We estimate the following linear probability model:

$$\Pr\left(Y_{odkt} > 0\,|\ldots\right) \;=\; \alpha^i\theta_{okt} + \alpha^j\theta_{dkt} + \beta X_{okt} + \gamma X_{dkt} + \delta_{odk} + \delta_{odt} + \delta_{kt} + \tau_{odkt}, \tag{9}$$

This is for Shon :).

4 Data and Descriptives

4.1 Measures of Carbon Prices

We use data from the World Carbon Pricing Database (WCPD), compiled by Dolphin (2022), as our measure of carbon prices. These data cover the period 1990–2021, include both national and subnational policies, and include both carbon taxes and cap-and-trade schemes. We convert the price data at the national and subnational levels from the local currency units to USD. We also construct an indicator variable equal to one each year that a country had a national price on carbon, and zero otherwise. We also construct an indicator variable if a country had a subnational carbon price. The evolution of ETS permit prices are illustrated in Figure 3. Carbon tax levels in EU and non-EU countries are illustrated in Figures 4 and 5, respectively.

As a rule cap-and-trade schemes are more common than carbon taxes, regulating a total of 18% and 6% of global greenhouse gas emissions, respectively (World Bank, 2023). A number of countries nevertheless had carbon taxes prior to entering an ETS, most notably several

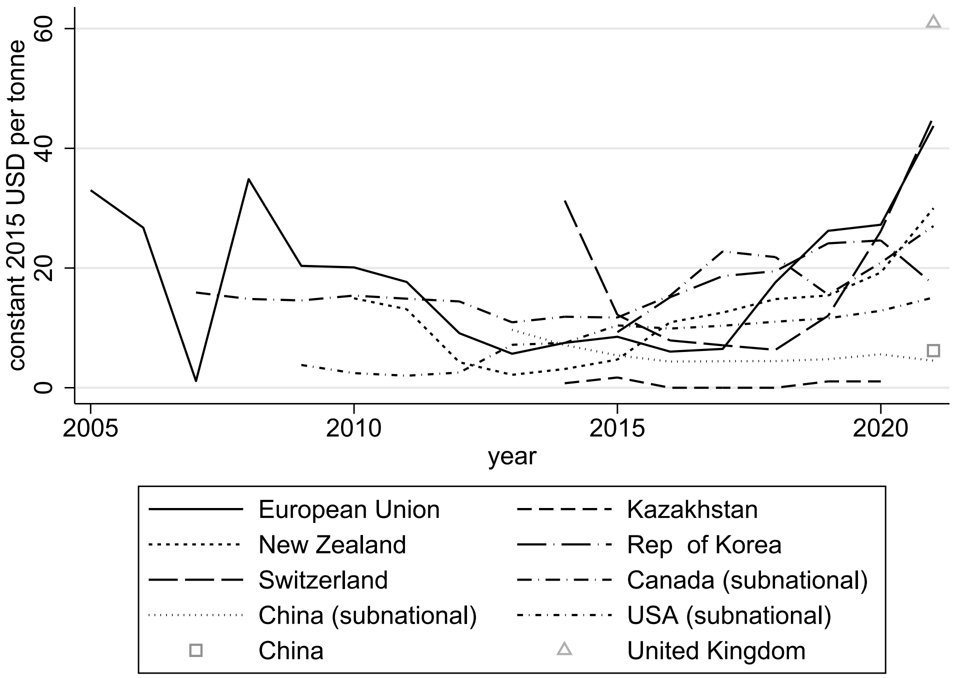

Figure 3: ETS permit prices by jurisdiction in the World Carbon Pricing Database, 1995–2021

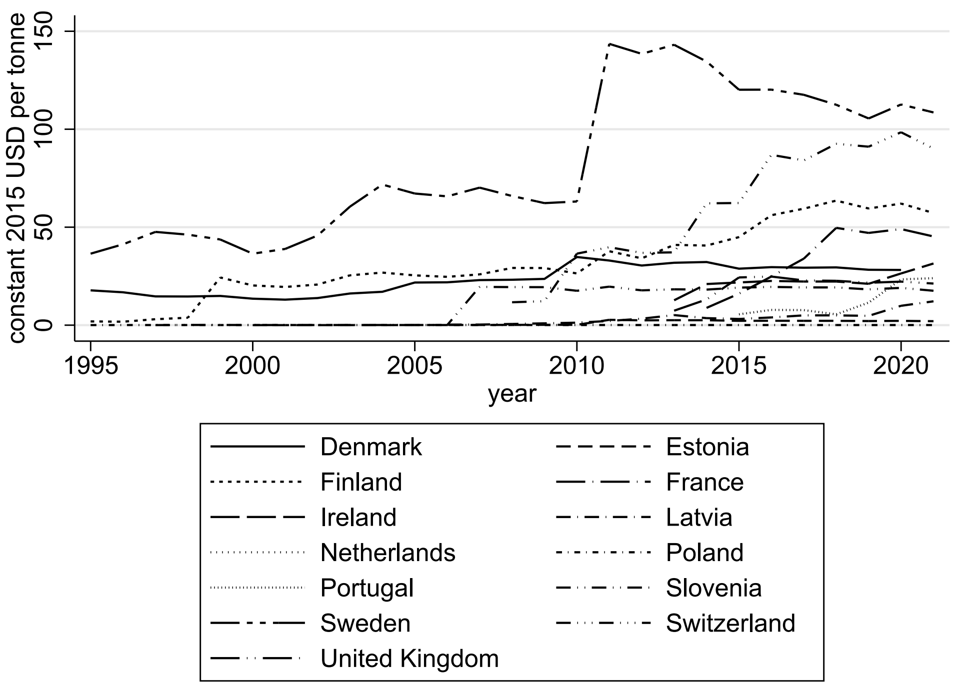

Figure 4: Carbon taxes in EU ETS countries according to the World Carbon Pricing Database, 1995–2021.

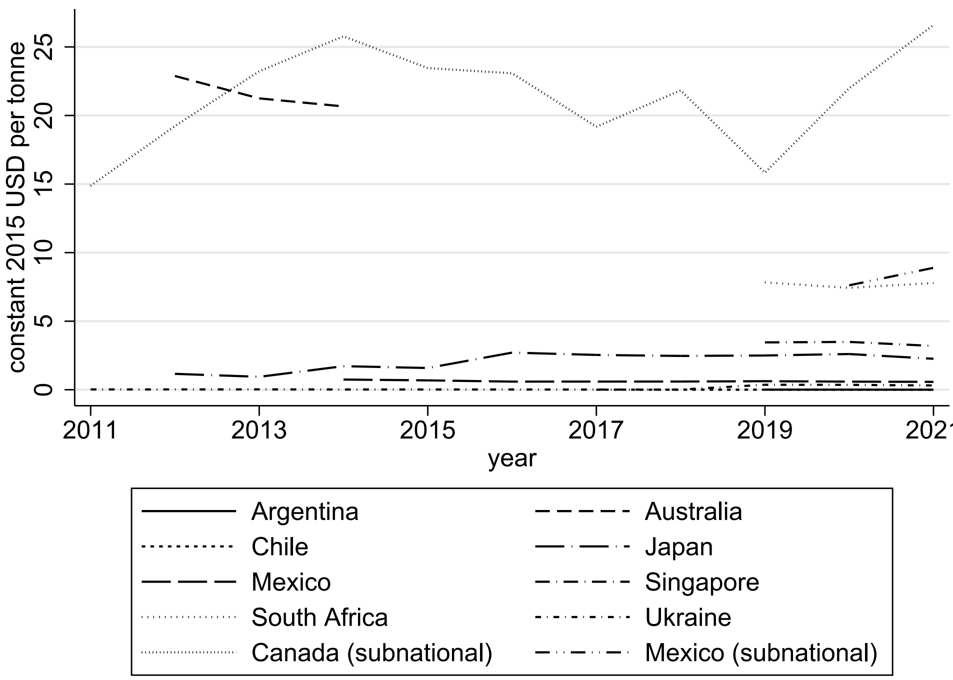

Figure 5: Carbon taxes in non-EU countries according to the World Carbon Pricing Database, other countries, 2011–2021 (no cuntry had a carbon tax prior to 2011).

European countries prior to the onset of the EU ETS or joining the EU. In addition, several countries have implemented carbon taxes but have not implemented an ETS. That said, the vast majority of countries with a carbon tax but not emissions trading have relatively low carbon taxes.

4.2 Bilateral Trade Flow Data

The analysis uses bilateral trade flow data at the 6-digit Harmonized System (HS) level. The source of the international trade data is CEPII's BACI database (Gaulier and Zignago, 2010). The trade data is available for the period 1995–2021. Belgium and Luxembourg are treated as a single country in the analysis. We include all trade zeros in the data.

Our main product of interest is "Furnace burners for liquid fuel, for pulverised solid fuel or for gas; mechanical grates, mechanical ash dischargers and similar appliances". These products are captured in the trade data by HS heading 8416. We refer to this group of products as "burners" for the rest of the analysis. In some specifications we use a more narrow product category, namely "Furnace accessories; mechanical stokers, mechanical grates, mechanical ash dischargers and similar appliances" (6-digit HS subheading 8416.30).

We use two different product groups as the control group in our analysis. The main control product is other products included in HS chapter 84 unrelated to combustion or the energy sector, which includes headings 8407–8409, 8412–8415, plus 8418 and higher. We argue that these other products included in Chapter 84 are the most similar in nature to our treatment product. We use this as our main control group in the analysis. The alternative control group is trade in the entire HS chapter 85 (Electrical machinery and equipment and parts). This group of products is clearly not as similar as the Chapter 84 alternative, but have the beneficial characteristic of not being deemed sensitive to carbon leakage Do we have a reference for this perhaps?.

An illustration of the top nine exporting and importing countries of burners is given in Figures 6 and 7, respectively. Several EU member states feature prominently among the largest exporters of burners, and and a sharp increase in exports from EU members states can be seen during the 2000's. China is historically the largest importer of burners.

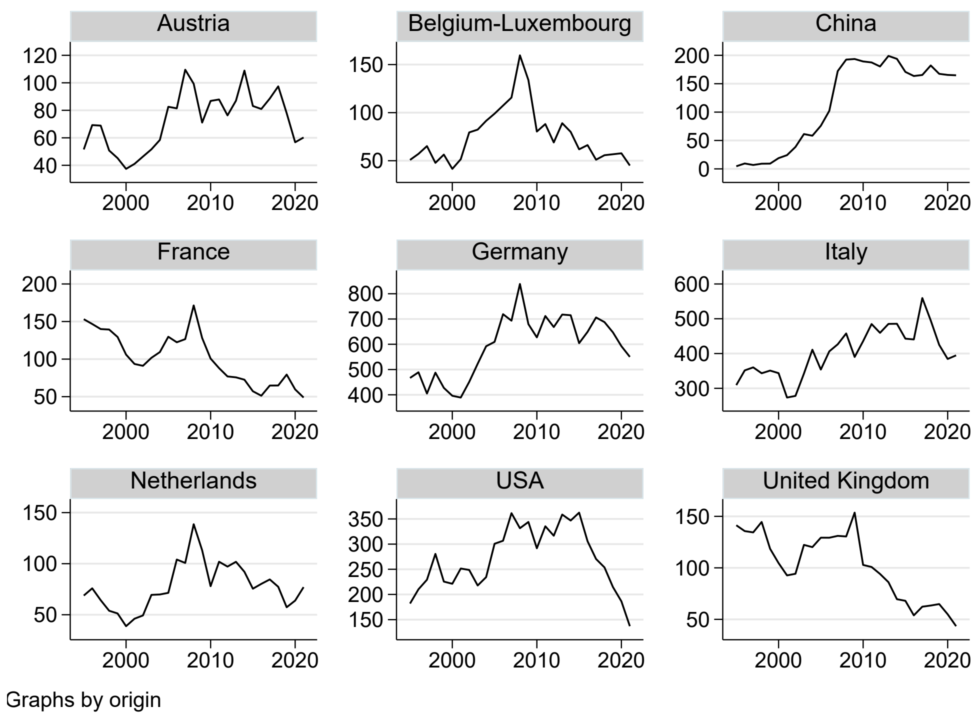

Figure 6: Exports of burners by top nine origins, 1995–2021

4.3 Other Data

In some specifications we include data on whether or not the country pair have a free trade agreement (FTA), as well as the origin and destination country GDP per capita. These data are derived from CEPII's Gravity database (Conte et al., 2022).

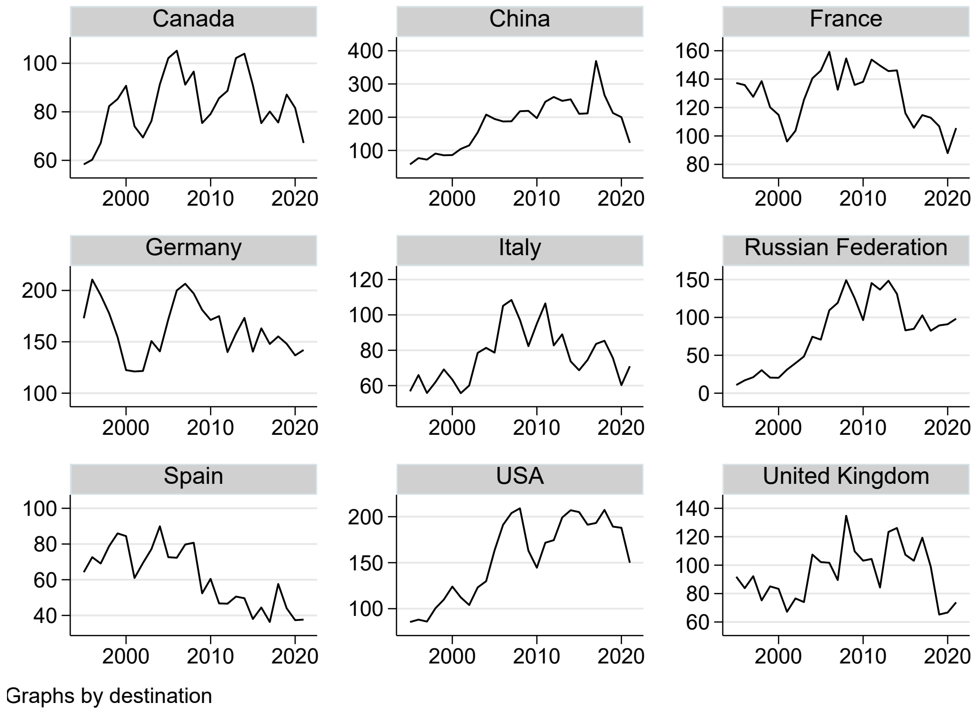

Figure 7: Imports of burners by top nine destinations, 1995–2021

In some specifications we include an indicator for if a destination belongs to the United Nations Committee for Development Policy's list of Least Developed Countries (LDCs).[3] We include all 46 current LDCs, plus the 6 countries that have graduated from the LDC list, for a total of 52 countries.

All prices and trade values are reported in USD, and we deflate to constant 2015 USD using the OECD's Domestic Producer Prices Index for Manufacturing for the United States. Descriptive statistics for the data, restricted to observations for trade in burners, is given in table 1.

5 Main Results

The main results are presented in Table 2. Estimation results for the intensive and extensive margins of trade are reported in columns (1)–(3) and (4)–(6), respectively. Panel, origin-destination-year and product-year fixed effects are included in all specifications. Standard errors are clustered at the origin country and destination country level.

We first discuss the results for the intensive margin of trade. The independent variables

[3]The complete list of least developed countries and graduated countries is available at https://www.un.org/development/desa/dpad/least-developed-country-category/ldcs-at-a-glance.html

Table 1: Descriptive statistics, product=burners

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
trade (million USD)	1410000	0.046	0.91	0	295
tradedum	1410000	0.061	0.24	0	1
ETSprice	1410000	1.35	5.99	0	60.9
tax	1410000	0.93	7.60	0	144
CO2pricedum	1410000	0.096	0.29	0	1
FTA	1350000	0.087	0.28	0	1

in column (1) are dummy variables to indicate the presence of an ETS in the origin or destination country. The point estimate for $ETSprice_o$ in column (1) suggests that a 1 USD/tonne increase in the carbon tax in the origin country is associated with a 0.39 percent increase in exports of burners relative to the control product. In contrast, the point estimate for $ETSprice_d$ in column (1) suggest that there is no statistically significant effect of an ETS in the destination country on its imports of burners compared to the control product.

In column (2) of Table 2 we include both ETS prices and carbon taxes, also in USD/tonne, in the origin and destination countries. The point estimate for $ETSprice_o$ suggests that a 1 USD/tonne increase in the ETS price in the origin country is associated with a 0.41 percent increase in exports of burners relative to the control product. In column (2) the point estimate for tax_o does not indicate a statistically significant relationship between ETS permit prices in the destination country and imports of burners.

In column (3) of Table 2 the independent variables are indicators for carbon pricing through either an ETS or carbon tax in the origin or destination countries, at either the national or sub-national level. The point estimate for $CO2pricedum_o$ suggests that carbon pricing in the origin country is positively associated with exports of burners, with 15 percent higher exports when carbon pricing is in place. The results for $CO2pricedum_d$ suggest that carbon pricing in the destination country is not associated with a change in imports of burners.

Turning to the results for the extensive margin of trade, the point estimates from the linear probability model reported in column (4) of Table 2 suggest that a 1 USD higher ETS permit price in the origin country raises the probability of trade by 0.10 percent. Adding carbon taxes in column (5) changes the results with respect to ETS prices to 0.08 percent, while the point estimate for tax_o suggests tat a 1 USD higher carbon tax in the origin country leads to a 0.13 percent increase in the probability of exporting. Finally, the results in column

Table 2: Regression of bilateral trade in burners on carbon pricing

VARIABLES	(1) OLS	(2) OLS	(3) OLS	(4) linearprob	(5) linearprob	(6) linearprob
ets_price_nat_o	0.0039**	0.0041**		0.0010**	0.00077*	
	(0.0017)	(0.0018)		(0.00044)	(0.00042)	
ets_price_nat_d	-0.0018	-0.0014		-0.000070	-0.000078	
	(0.0023)	(0.0023)		(0.00041)	(0.00040)	
tax_nat_o		-0.0011			0.0013***	
		(0.0016)			(0.00033)	
tax_nat_d		-0.0027			0.000041	
		(0.0019)			(0.00030)	
CO2pricedum_all_o			0.15**			0.052***
			(0.059)			(0.018)
CO2pricedum_all_d			0.073			0.023
			(0.068)			(0.015)
Constant	0.089***	0.094***	0.057***	0.20***	0.20***	0.20***
	(0.0064)	(0.0076)	(0.013)	(0.00036)	(0.00042)	(0.00097)
Observations	168,288	168,288	168,288	2,819,448	2,819,448	2,819,448
R-squared	0.966	0.966	0.966	0.859	0.859	0.859

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

(6) suggest that the presence of carbon pricing in the origin country raises the probability of trade by 5.2 percent.

6 Further Robustness

As a robustness check we use an alternative control group, trade in products included in HS Chapter 85 (Electrical machinery and equipment and parts). The result for the intensive and extensive margins of trade are reported in Table 3. The results suggest that carbon pricing policies in the origin country are associated with a higher value of export and a higher probability of export relative to trade in the alternative control product. The results using this alternative control group support the main results in Table 2 suggesting that carbon pricing in the origin country have a positive significant impact on the intensive and extensive margins of trade in burners.

As another robustness check we study whether the intensive and extensive margins of trade are are more sensitive to carbon pricing policies for country pairs with a free trade

Table 3: Regression of bilateral trade in burners on carbon pricing

VARIABLES	(1) OLS	(2) OLS	(3) OLS	(4) linearprob	(5) linearprob	(6) linearprob
ets_price_nat_o	0.0043**	0.0038*		0.00083*	0.00062	
	(0.0021)	(0.0020)		(0.00046)	(0.00044)	
ets_price_nat_d	-0.0033	-0.0031		-0.00011	-0.00013	
	(0.0026)	(0.0026)		(0.00043)	(0.00042)	
tax_nat_o		0.0024			0.0011***	
		(0.0028)			(0.00028)	
tax_nat_d		-0.0012			0.00011	
		(0.0022)			(0.00044)	
CO2pricedum_all_o			0.086			0.047**
			(0.084)			(0.019)
CO2pricedum_all_d			0.025			0.019
			(0.081)			(0.015)
Constant	-0.10***	-0.11***	-0.12***	0.20***	0.20***	0.20***
	(0.0069)	(0.010)	(0.019)	(0.00038)	(0.00044)	(0.0010)
Observations	168,196	168,196	168,196	2,819,448	2,819,448	2,819,448
R-squared	0.962	0.962	0.962	0.858	0.858	0.858

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

agreement (FTA). We include this as an interaction of the carbon pricing policy in the origin country with the FTA indicator variable. The uninteracted effect of an FTA on trade are subsumed by the origin-destination-year fixed effects. The results in Table 4 suggest that interaction term has a negative effect on the intensive margin of trade, and a positive effect on the extensive margin of trade. Furthermore, adding the interaction with FTA status does not overturn the main results of carbon pricing policies in the origin country. In fact, $ETSprice_o$ and $CO2pricedum_o$ are estimated with higher precision when the FTA control is included.

During the seminar at SLU someone suggested to use another HS category that should not be affected by climate policy as a placebo test. But don't we control for this already through the control HS category?

7 Conclusion

In this study, we evaluate the impact of carbon pricing on international trade in equipment used in the combustion of fossil fuels. Using detailed data on bilateral trade, we find that

Table 4: Regression of bilateral trade in burners on carbon pricing

VARIABLES	(1) OLS	(2) OLS	(3) OLS	(4) linearprob	(5) linearprob	(6) linearprob
ets_price_nat_o	0.0060***	0.0057**		0.00060	0.00035	
	(0.0021)	(0.0022)		(0.00049)	(0.00047)	
ets_o_fta_int	-0.0040**	-0.0030		0.0016***	0.0015***	
	(0.0020)	(0.0019)		(0.00045)	(0.00046)	
ets_price_nat_d	-0.00072	-0.00035		-0.00013	-0.00014	
	(0.0024)	(0.0024)		(0.00041)	(0.00040)	
tax_nat_o		0.00077			0.0015***	
		(0.0021)			(0.00034)	
tax_o_fta_int		-0.0032*			-0.000016	
		(0.0019)			(0.00028)	
tax_nat_d		-0.0026			0.000059	
		(0.0019)			(0.00030)	
CO2pricedum_all_o			0.17***			0.047**
			(0.061)			(0.019)
CO2pricedum_o_fta_int			-0.060			0.047***
			(0.073)			(0.017)
CO2pricedum_all_d			0.080			0.024
			(0.065)			(0.014)
Constant	0.087***	0.091***	0.058***	0.21***	0.21***	0.21***
	(0.0066)	(0.0076)	(0.013)	(0.00037)	(0.00043)	(0.0010)
Observations	168,266	168,266	168,266	2,693,016	2,693,016	2,693,016
R-squared	0.966	0.966	0.966	0.861	0.861	0.861

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

carbon pricing policies are associated with greater exports of this equipment. Our work is conceptually distinct from the carbon leakage literature, and suggest that the diffusion of technology can occur in dirty production methods. Our results provide new evidence for this unexplored form of leakage due to more stringent climate policies.

The facilitation of emissions abroad is a difficult policy issue for which there are no simple solutions. A ban on polluting technologies would be difficult to enforce and easy to circumvent by importing equipment from less regulated countries. We hope that our work has brought this issue to the forfront and encourages further work in this area.

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