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GREENING RICARDO: ENVIRONMENTAL COMPARATIVE ADVANTAGE AND THE ENVIRONMENTAL GAINS FROM TRADE

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Greening Ricardo: Environmental Comparative Advantage and the Environmental Gains From Trade *

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Abstract

We show that climate policy can unlock large environmental gains from trade by inducing economies to specialize according to their environmental comparative advantage. We make this point by exploring the effects of a carbon tax in a quantitative trade model. Our main result is that the environmental gains from trade account for around one-third of the total reduction in greenhouse gas emissions brought about by the carbon tax. This finding holds for a wide range of carbon tax rates and coverages.

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1 Introduction

In this paper, we show that climate policy can unlock large environmental gains from trade by inducing economies to specialize according to their environmental comparative advantage. The main idea is that global greenhouse gas emissions fall when economies specialize in industries where they have relatively low emissions, just like global real incomes rise when economies specialize in industries where they have relatively high productivity. While our notion of environmental comparative advantage therefore builds directly on the classic idea of economic comparative advantage, it has so far been largely absent from the trade and climate change debate.

This matters, since our results provide a strong counterpoint to the widespread view that international trade is an obstacle in the fight against climate change. While it is true that international trade causes transport emissions, our analysis shows that it can also be a powerful tool to reduce production emissions, which account for the lion's share of total emissions associated with traded goods.[1] More broadly, it also offers a more inclusive perspective on sustainable development by highlighting that economies do not need to sacrifice the economic gains from trade in the name of climate stewardship but can pursue both objectives concurrently.

We make this point by exploring the effects of a carbon tax in a multi-country, multi-industry quantitative trade model with input-output linkages, calibrated to 64 regions and 45 industries spanning the world economy. Our benchmark scenario is a uniform carbon tax of \$100/tCO_2eq on all goods in all economies, but our main result holds for a wide range of carbon tax rates and coverages. In this paper, we do not model how greenhouse gas emissions cause climate change, or how climate change affects economic activity. While these are important considerations, they are not essential for measuring the environmental gains from trade.[2]

[1] In our data, intermediate transport services account for only 4.2% of total greenhouse gas emissions.

[2] Well-known examples of integrated assessment models capturing these considerations include Nordhaus (1993), Nordhaus (2018), Golosov et al. (2014), and Boyce (2018).

Our main result is that the environmental gains from trade account for around one-third of the greenhouse gas emissions reductions brought about by the carbon tax. This result holds for a wide range of carbon tax rates and coverages thus suggesting that trade is a strong force multiplier for climate policy. Moreover, we find that increases in carbon tax rates – even extreme ones up to \$1,000/tCO_2eq - leave the volume of world trade relative to world gross production largely unchanged. This further corroborates the point that trade is part of the solution no matter how ambitious climate action becomes.

To isolate the environmental gains from trade, we decompose the greenhouse gas emissions reductions brought about by the carbon tax into three effects: (i) a reduction in the scale of global production (scale effect), (ii) a shift in economic activity towards greener sectors (composition effect), and (iii) a shift in economic activity towards greener economies (green sourcing effect). While the scale and composition effects also operate in a closed economy, the green sourcing effect exploits a margin that is only available with international trade and thus captures the environmental gains from trade. We hold emissions intensities fixed in our analysis so there is no technique effect.[3]

To the best of our knowledge, we provide the first estimate of the environmental gains from trade driven by environmental comparative advantage. We make this contribution leveraging well-known methods at the intersection of international and environmental economics. In particular, we use a standard quantitative trade model in the spirit of Caliendo and Parro (2015) and employ a variation of the familiar decomposition of greenhouse gas emissions changes into scale, composition, and technique effects dating back to Grossman and Krueger (1991). Hence, the novelty of our paper does not lie in the tools we develop but in the perspective we provide on the relationship between international trade and climate change.

Our paper follows in the footsteps of the pioneering work by Shapiro (2016), who spear-

[3]We are measuring the static environmental gains from trade. There may be additional dynamic environmental gains from trade, for example, if market size effects accelerate the green innovation spurred by carbon taxes.

headed the use of modern quantitative trade models in environmental economics. His main result is that international trade brings economic gains and emissions costs relative to autarky, with the economic gains far exceeding the emissions costs. We are approaching the issue from a different angle, essentially simulating the first-best pattern of trade, once environmental externalities are internalized by a carbon tax.

Our paper also has points of contact with the recent work by Farrokhi and Lashkaripour (Forthcoming), who explore to what extent trade policy can help solve the free-rider problem in international climate agreements. Their main finding is that a climate club could be highly effective, whereas border carbon adjustments have minimal impact. As part of this exercise, the authors also characterize optimal carbon taxes under various assumptions about international cooperation. In contrast, we do not derive optimal policy but simply examine the implications of a range of exogenous carbon tax regimes on greenhouse gas emissions and trade.

A closely related theme that has received much attention in the literature is carbon leakage[4]. The concern is that unilateral carbon measures in relatively green economies can lead to the relocation of emissions-intensive industries to relatively brown economies. The green sourcing effect identified in this paper essentially reverses this type of carbon leakage. However, it is important to keep in mind that a carbon tax induces specialization according to environmental comparative advantage, meaning that the adjustments extend beyond simple green sourcing in general equilibrium. One implication is that even the brownest economy is contributing to reducing greenhouse gas emissions by moving resources to its relatively low emissions sectors.

The remainder of the paper is structured as follows. Section 2 sketches the model and decomposition, Section 3 turns to the calibration and data, Section 4 presents the results, and Section 5 concludes.

[4]See, for example, Felder and Rutherford (1993); Larch and Wanner (2017); Kortum and Weisbach (2021).

2 Model

2.1 Setup

We work with a multi-economy, multi-industry Armington (1969) model with roundabout input-output linkages. It is now well understood that such a model has the same aggregate predictions as the model of Caliendo and Parro (2015), which is based on the Ricardian model of Eaton and Kortum (2002).

There are N economies indexed by i (for origin) and j (for destination) and S industries indexed by s (for supplying industry) and s' (for demanding industry). Each economy produces a unique variety within each industry and trade is subject to iceberg trade costs $\tau_{isj} \geq 1$ with $\tau_{isi} = 1$ for all i. Economies are endowed with an inelastic supply of workers L_i who are internationally immobile.

In our benchmark scenario, a uniform carbon tax is imposed on all products in all economies. It is levied in the economy of (final or intermediate) consumption and redistributed lump-sum to households in that economy.[5] To avoid double counting, the tax is applied only to the emissions directly caused by the production process (e.g., the chemical reaction resulting in cement) but not the emissions caused indirectly by the use of inputs (e.g., the electricity used to power the cement factory). For our calculations, we convert it into an ad valorem tax t^e_{isj} using nominal emissions intensities - that is, the emissions associated with one dollar's worth of a product. Note that a uniform tax per ton of carbon results in a varying tax per dollar of a product, as carbon intensities differ across products.

[5] Given that the carbon tax is imposed on all products in all economies, it is largely irrelevant whether it is imposed on consumers or producers. There are some differences in the allocation of tax revenues across economies but they have negligible effects on our results. We find it easier to illustrate the relative price effects of the carbon tax with a consumption-based approach.

2.2 Equilibrium

Consumption choices are made by representative households with Cobb-Douglas-CES preferences

$$U_j = \prod_s \left(U_{sj}\right)^{\beta_{sj}} \tag{1}$$

$$U_{sj} = \left[\sum_i \left(a_{is}\right)^{1/\sigma_s} \left(q^c_{isj}\right)^{(\sigma_s-1)/\sigma_s}\right]^{\sigma_s/(\sigma_s-1)}, \tag{2}$$

where β_{sj} are expenditure shares, a_{is} are demand shifters, σ_s are substitution elasticities, and q^c_{isj} are the final consumption quantities of varieties differentiated by economy of origin. As a result, household final demand is given by

$$q^c_{isj} = a_{is}\frac{\left[p_{isj}\left(1+t^e_{isj}\right)\right]^{-\sigma_s}}{\left(P^c_{sj}\right)^{1-\sigma_s}}\beta_{sj}I_j \tag{3}$$

$$I_j = w_j L_j + R_j + D_j, \tag{4}$$

where p_{isj} are delivered prices, P^c_{sj} are consumer price indices, $w_j L_j$ is labor income, R_j is tax revenue, and D_j is an exogenous transfer used to match aggregate trade deficits in the data, which we keep constant in our counterfactuals. Notice that the carbon tax makes browner varieties more expensive thus inducing households to make greener consumption choices.

Firms produce these varieties under perfect competition from labor and intermediate products using Cobb-Douglas-CES technologies

$$q_{js'} = A_{js'}\left(\frac{L_{js'}}{\gamma_{j,L_{s'}}}\right)^{\gamma_{j,L_{s'}}}\prod_s\left(\frac{q^p_{sjs'}}{\gamma_{sjs'}}\right)^{\gamma_{sjs'}} \tag{5}$$

$$q^p_{sjs'} = \left[\sum_i \left(b_{is}\right)^{1/\eta_s}\left(q^p_{isjs'}\right)^{(\eta_s-1)/\eta_s}\right]^{\eta_s/(\eta_s-1)}, \tag{6}$$

where $A_{js'}$ are total factor productivities, $\gamma_{sjs'}$ are cost shares, b_{is} are demand shifters, η_s are substitution elasticities, and $q^p_{sjs'}$ are the intermediate consumption quantities of the same

varieties also demanded by households. As a result, firm intermediate demand is given by

$$q^p_{isjs'} = b_{is} \frac{\left[p_{isj}\left(1+t^e_{isj}\right)\right]^{-\eta_s}}{\left(P^p_{sj}\right)^{1-\eta_s}} \gamma_{sjs'} E_{js'}, \tag{7}$$

where P^p_{sj} are producer price indices and $E_{js'}$ is the total expenditure of firms in industry s' of country j on intermediate products. Notice that the carbon tax makes browner varieties more expensive thus inducing firms to make greener production choices.

We close the model with a labor market clearing and trade balance condition:

$$\sum_s L_{js} = L_j \tag{8}$$

$$\underbrace{\sum_s \sum_{j \neq i} p_{isj} \left(q^c_{isj} + \sum_{s'} q^p_{isjs'} \right)}_{\text{exports of economy } i} + D_i = \underbrace{\sum_s \sum_{j \neq i} p_{jsi} \left(q^c_{jsi} + \sum_{s'} q^p_{jsis'} \right)}_{\text{imports of economy } i}. \tag{9}$$

To be clear, exports flow from supplying industries s in economy i to final consumers and demanding industries s' in economy j. Analogously, imports flow from supplying industries s in economies j to final consumers and demanding industries s' in economy i. D_i is therefore equal to the trade deficit (or trade surplus if negative).

2.3 Emissions

We distinguish between direct and indirect emissions associated with production. Direct emissions arise from the production process itself (e.g., the chemical reaction involved in cement production), while indirect emissions result from the use of intermediate inputs (e.g., the electricity required to power a cement plant).

We assume that there are constant returns to scale in emissions generation in the sense that direct emissions increase proportionally with output. We can therefore write total GHG

emissions as

$$GHG = \sum_i \sum_s q_{is} e_{is}, \tag{10}$$

where q_{is} is the quantity of industry s output produced in economy i and e_{is} are the associated direct emissions per unit of output. It is important to note that this assumption does not imply that total emissions also increase proportionately with output, as indirect emissions depend on the endogenously determined input mix.

Transport emissions are the emissions generated in the production of transport services. We capture these by explicitly incorporating land, sea, and air transportation into our input-output matrix. Because traded products are subject to iceberg trade costs - where a fraction melts away during transit - they require more resources per unit delivered. Consequently, the production of traded products generates more emissions per unit than that of non-traded products, other things equal.

2.4 Decomposition

Totally differentiating equation (10), holding emissions intensities constant, we can decompose total greenhouse gas emissions changes into a scale, composition, and green sourcing effect

$$d \ln GHG = \underbrace{d \ln q}_{\text{scale effect}} + \underbrace{\sum_s \epsilon_s d \ln \frac{q_s}{q}}_{\text{composition effect}} + \underbrace{\sum_i \sum_s \epsilon_{is} d \ln \frac{q_{is}}{q_s}}_{\text{green sourcing effect}}, \tag{11}$$

where the q's denote output and the ϵ's denote shares in worldwide emissions - overall, of industry s, or of industry s in economy i. This is the central equation of the paper, which we use to quantify the environmental gains from trade.[6]

It captures that carbon taxes reduce emissions for three reasons in our model. First, carbon taxes reduce world output by moving the economy away from the output-maximizing

[6]This decomposition is only exact for infinitesimally small changes. In our application, we therefore break any carbon tax change into a series of small changes.

laissez-faire equilibrium - this is the "scale effect".[7] Second, carbon taxes reallocate production towards greener industries by making browner products relatively more expensive for final and intermediate consumers - this is the "composition effect". Third, carbon taxes reallocate production towards greener economies by making products from browner economies relatively more expensive for final and intermediate consumers - this is the "green sourcing effect". While the scale effect and the composition effect also operate in a closed economy, the green sourcing effect is specific to international trade and thus captures the environmental gains from trade.

Our decomposition does not include a technique effect because we hold emissions intensities constant. This reflects our focus on measuring the static environmental gains from trade and does not imply that dynamic environmental gains from trade are impossible. For example, international trade might accelerate green innovation induced by carbon taxes by allowing firms to leverage their innovations in larger markets. Additionally, in a static model with firm heterogeneity, a technique effect could occur if international trade leads to a reallocation of resources across firms with different emissions intensities. We leave these potentially important extensions for future work.

We close this section by recalling the intuition of a basic 2×2 Ricardian trade model to see how the environmental comparative advantage logic plays out. Imagine thus a simplified version of our model with two economies, Green and Brown, and two industries, Clean and Dirty. Suppose that Green has lower emissions intensities in both Clean and Dirty, thus having an environmental absolute advantage in both goods. Additionally, suppose that Green's emissions intensity advantage is particularly pronounced in Clean, thereby giving it an environmental comparative advantage in Clean. For simplicity, also assume diversified production in the baseline.[8]

Consider now the effects of imposing a uniform carbon tax. Given that Green has an envi-

[7] In a neoclassical trade model like ours, the laissez-faire equilibrium maximizes world output. This would differ in a trade model with climate damages, where the laissez-faire equilibrium would be distorted.

[8] This is, of course, a knife-edge case in the basic 2×2 Ricardian model. To increase realism, one could consider a slightly extended version with differentiated products.

ronmental absolute advantage in both goods, the carbon tax makes Green more competitive in Clean and Dirty relative to Brown. Moreover, given that Green has an environmental comparative advantage in Clean, this competitiveness gain is particularly pronounced in Clean. To restore Brown's competitiveness in Dirty and ensure labor market clearing, Green's wage rises relative to Brown's thus neutralizing Green's environmental absolute advantage. The end result is specialization according to environmental comparative advantage: Green in Clean and Brown in Dirty.

3 Calibration

3.1 Methodology

To take the model to the data, we use the Dekle et al. (2007) "exact hat algebra", which has become standard in the literature. By expressing the equilibrium conditions in changes relative to the baseline, we eliminate the need to estimate the preference shifters $a_{is'}$ and $b_{is's}$, the productivity shifters A_{js}, and the iceberg trade costs $\tau_{is'j}$. This approach also ensures that the model perfectly matches the global pattern of production and international trade in the baseline scenario.

To solve for a counterfactual equilibrium given a schedule of carbon taxes, we reduce the model to a parsimonious $2 \times N \times S + 1$ system and solve it numerically using a nested fixed point routine. To calibrate the model, we need the $N \times N \times S$ matrix of trade flows in final goods, the $N \times N \times S \times S$ matrix of trade flows in intermediate goods, the $N \times S$ vector of greenhouse gas emissions, and estimates of the elasticities $\eta_{s'}$ and $\sigma_{s'}$.

One challenge we face when implementing equation (11) is that we only have reliable data on output values but not quantities. As a result, we cannot easily aggregate the economy-industry-specific output changes $d \ln q_{is}$ produced by our model into the aggregates $d \ln q_s$ and $d \ln q$ needed for the decomposition using the relationships $d \ln q_s = \sum_i \frac{q_{is}}{q_s} d \ln q_{is}$ and $d \ln q = \sum_s \frac{q_s}{q} d \ln q_s$.

We address this challenge by using expenditure shares instead, thus using the approximations $d\ln q_s \approx \sum_i \frac{x_{is}}{x_s} d\ln q_{is}$ and $d\ln q \approx \sum_s \frac{x_s}{x} d\ln q_s$. It is easy to verify that the resulting approximation error cancels out in the aggregate since decomposition (11) and its approximation can both be reduced to $d\ln GHG = \sum_i \sum_s \epsilon_{is} d\ln q_{is}$, which is measured without error.[9]

3.2 Data

Data on trade flows for both intermediate and final goods are sourced from the OECD Inter-Country Input-Output (ICIO) tables (OECD, 2023). These tables cover the entire world economy, broken down into 45 industries and 67 economies, including an aggregate Rest of the World, from 1995 to 2018. We calibrate the model using the 2018 data, but we utilize the entire dataset when estimating the key elasticities of the model, as explained below.

Data on greenhouse gas emissions in CO_2 equivalents are constructed by combining three different datasets: the OECD Carbon Dioxide Emissions Embodied in International Trade dataset (TECO2) (OECD, 2021), the FAOSTAT Emissions Totals dataset (FAO, 2023), and the European Commission's Emissions Database for Global Atmospheric Research (EDGAR) (European Commission, 2023). The TECO2 dataset provides CO_2 emissions from fuel combustion across the 45 industries and 67 economies included in the OECD ICIO tables.

To extend emissions coverage and include non-energy-related emissions, we incorporate CO_2, CH_4, and N_2O emissions from the remaining two datasets. Specifically, we use FAOSTAT data for emissions from agriculture, forestry, and land use, and the EDGAR database for emissions from industrial processes, product use, and fugitive emissions. Together, these datasets cover approximately 93% of worldwide greenhouse gas emissions.

[9] To see this, note that equation (11) can be rewritten as $d\ln GHG = d\ln q - \sum_s \epsilon_s d\ln q + \sum_s \epsilon_s d\ln q_s - \sum_i \sum_s \epsilon_{is} d\ln q_s + \sum_i \sum_s \epsilon_{is} d\ln q_{is}$, which reduces to $d\ln GHG = \sum_i \sum_s \epsilon_{is} d\ln q_{is}$ since $\sum_s \epsilon_s = 1$ and $\sum_i \sum_s \epsilon_{is} = \sum_s \epsilon_s$.

3.3 Estimation

We estimate the elasticities of substitution using the standard methodology of Caliendo and Parro (2015), assuming for simplicity that $\sigma_{s'} = \eta_{s's} = \eta_{s'}$. This approach involves using a fixed-effects model to identify the elasticities from the impact of import tariffs on trade flows, utilizing all available years in our dataset. Elasticities that are negatively signed, statistically insignificant, or unestimable due to insufficient tariff data (notably in the service sectors) are replaced with the mean value. Our estimates have a mean of 3.61, a minimum of 1.78 and a maximum of 5.86, thus falling within the usual range.[10]

4 Results

4.1 Aggregate effects of carbon taxes

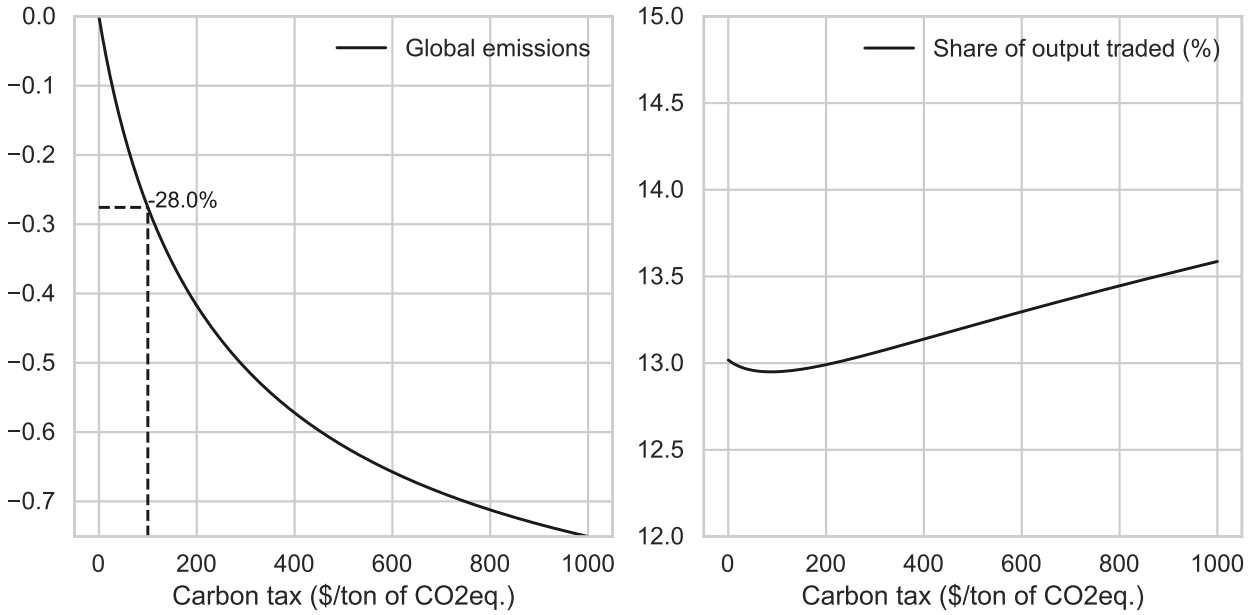
Figure 1 summarizes the aggregate effects of carbon taxes, relative to a no-carbon-tax benchmark in 2018. The left panel shows the proportional reduction in global greenhouse gas emissions for varying levels of carbon taxes. As one would expect, greenhouse gas emissions are strongly decreasing in the carbon tax, with the global emissions reduction reaching 28% for our benchmark carbon tax of \$100/tCO_2e. The right panel depicts world trade as a share of gross production for varying levels of carbon taxes. Strikingly, the trade share does not change much with carbon taxes, suggesting that trade is part of a sustainable economy no matter how ambitious climate policies become.

4.2 Environmental gains from trade

Figure 2 decomposes the aggregate effects of carbon taxes into a scale effect, a composition effect, and a green sourcing effect following decomposition (11). The left panel shows the proportional reduction in greenhouse gas emissions for varying levels of carbon taxes de-

[10] We have also experimented using the alternative methodology of Fontagné et al. (2022) and found that our main results were robust to this variation.

Figure 1: Aggregate effects of carbon taxes



Note: The left panel shows the proportional reduction in global greenhouse gas emissions for varying levels of carbon taxes. The right panel shows world trade as a share of gross production.

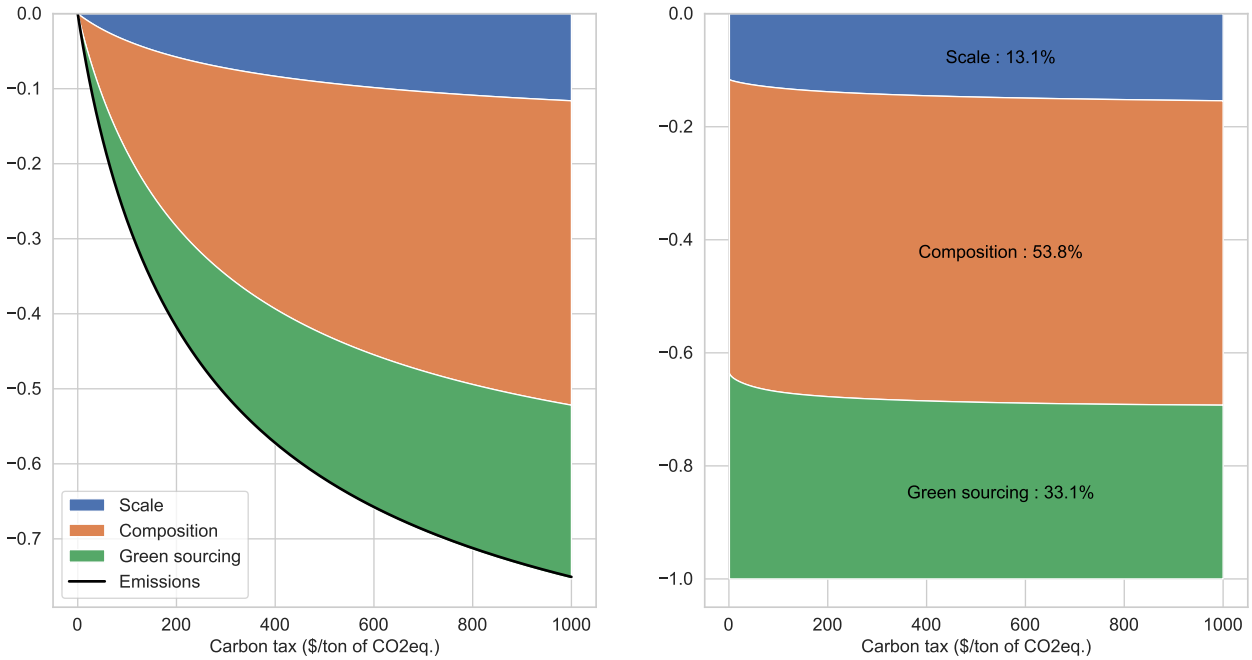
composed into these three effects. The right panel shows the contributions of each effect to the overall emissions reduction for varying levels of carbon taxes. Recall that the green sourcing effect captures the environmental gains from trade brought about by specialization according to environmental comparative advantage.

The green sourcing effect accounts for around one-third of the emissions reductions brought about by the carbon tax. This is the main result of the paper, suggesting that climate policies can unlock substantial environmental gains from trade. Specifically, the scale effect accounts for 13.1%, the composition effect for 53.8%, and the green sourcing effect for 33.1% of the overall emissions reduction on average. These shares remain relatively stable across the considered range of carbon tax rates.

4.3 Environmental comparative advantage

Figure 3 illustrates how the carbon tax reduces emissions by reallocating production across economies in two selected sectors. The left circles indicate where output grows (in green)

Figure 2: Decomposition of emissions reductions



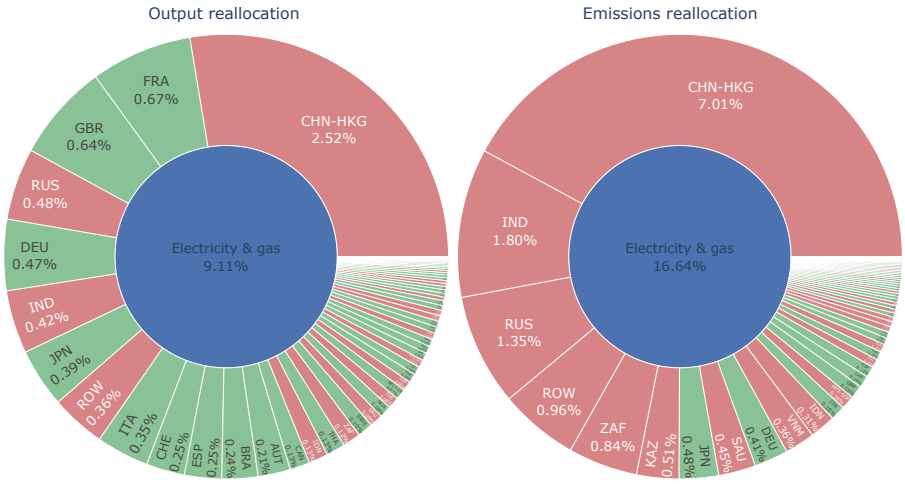
Note: The left panel shows the proportional reduction in greenhouse gas emissions for varying levels of carbon taxes decomposed into three effects. The right panel shows the contributions of each effect to the overall emissions reduction for varying levels of carbon taxes.

and falls (in red), with the number in the blue circle representing the share of output being reallocated. The right circles display the associated emissions reductions (in red) and emissions increases (in green), with the number in the blue circle showing the overall emissions reduction. To be clear, the output growth rates in the left circles are expressed in percentages of baseline world output in the sector and sum to zero. The emissions growth rates in the right circles are expressed in percentages of baseline world emissions in the sector and sum to the negative number shown in blue.

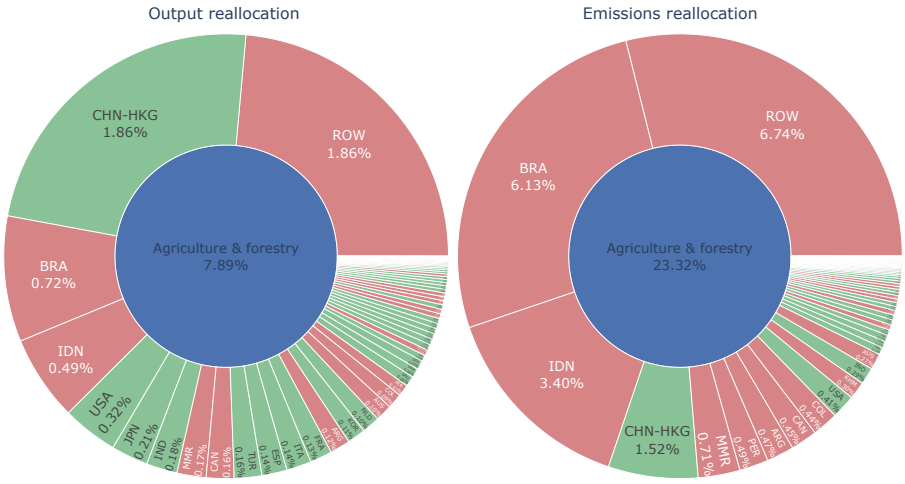
The top two circles show the adjustment in the electricity and gas sector, highlighting that a reallocation of 9.1% of sectoral output across economies results in a 16.6% reduction in sectoral emissions. The bottom two circles illustrate the adjustment in the agriculture and forestry sector, demonstrating that a reallocation of 7.9% of sectoral output across economies results in a 23.3% reduction in sectoral emissions.

This works because the output elasticity of emissions is systematically larger in economies

Figure 3: Environmental comparative advantage in selected sectors



(a) Electricity & gas sector



(b) Agriculture & forestry sector

Note: This figure illustrates how the carbon tax reduces emissions by reallocating production across economies in two selected sectors. The left circles indicate where output grows (in green) and falls (in red), with the number in the blue circle representing the share of output being reallocated. The right circles display the associated emissions reductions (in red) and emissions increases (in green), with the number in the blue circle showing the overall emissions reduction.

that lose market shares. For example, China's loss of 2.5% of world electricity and gas output leads to a 7.0% reduction in world electricity and gas emissions so that the elasticity is $7.0/2.5 = 2.8$. Conversely, France gains 0.67% of world electricity and gas output, leading to a 0.08% increase in emissions, with an elasticity of $0.08/0.67 = 0.1$. This is the essence of specialization according to environmental comparative advantage.

4.4 Incomplete tax coverage

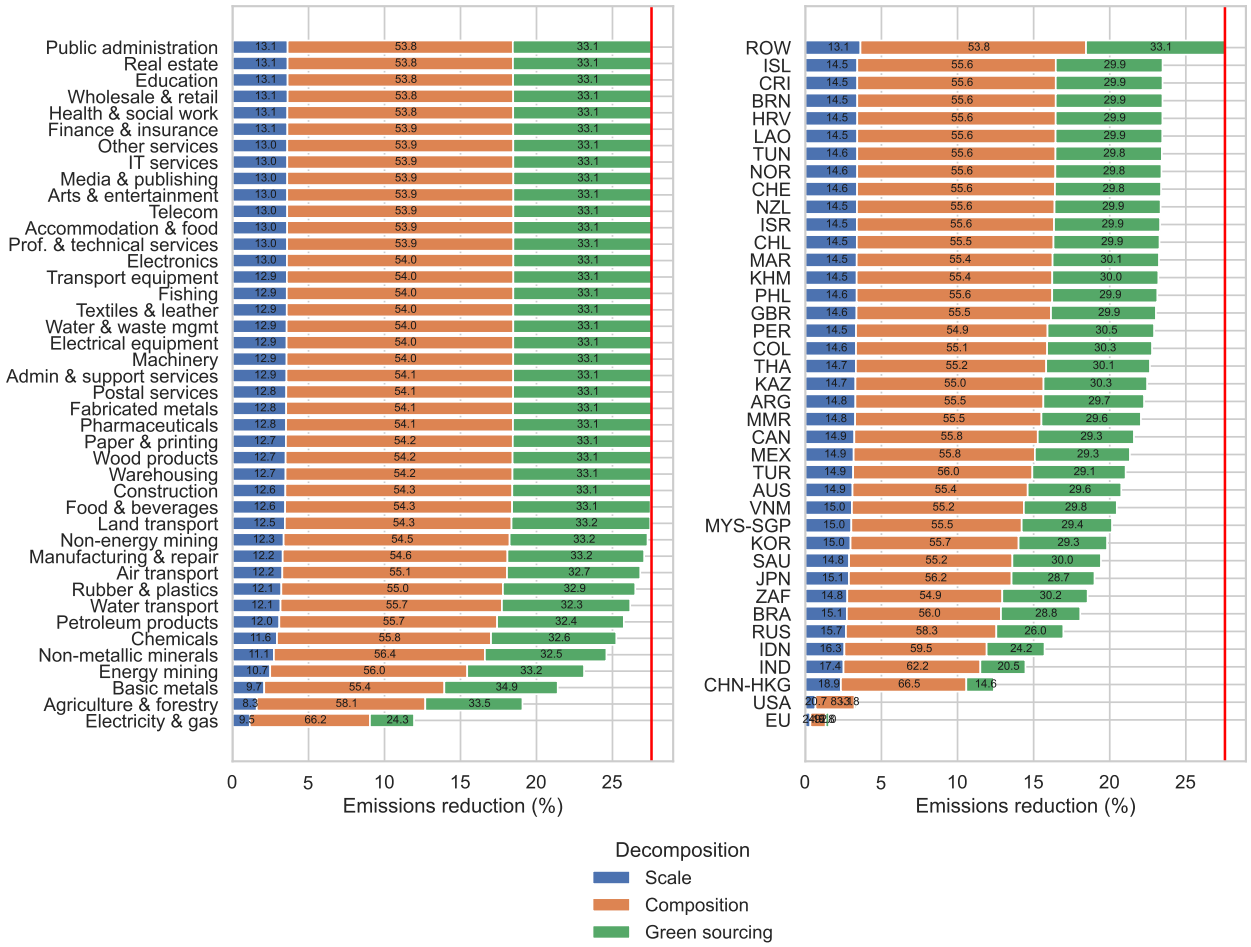
Figure 4 illustrates the emissions reductions resulting from a \$100/tCO_2e carbon tax rate applied only in a subset of industries or economies. The left panel examines carbon taxation schemes applying to all economies but only some industries, starting with the electricity and gas sector only and then adding other industries cumulatively. The right panel explores carbon taxation schemes applying to all industries but only some economies, starting with the European Union and then adding other economies cumulatively.

International trade remains a strong force multiplier for carbon taxes even with incomplete carbon tax coverage. Since the environmental gains from trade are brought about by a reallocation of market shares from relatively brown economies to relatively green economies, it is not surprising that a critical mass of economies is needed for the green sourcing effect to account for a meaningful share of the overall emissions reductions. In contrast, a critical mass of industries is not necessary for trade to play an important role.

5 Conclusion

In this paper, we demonstrate that climate policy can unlock substantial environmental gains from trade by encouraging economies to specialize according to their environmental comparative advantage. We illustrate this point by examining the effects of a carbon tax within a quantitative trade model. Our main finding is that the environmental gains from trade account for around one-third of the total reduction in greenhouse gas emissions brought

Figure 4: Incomplete tax coverage



Note: This figure illustrates the emissions reductions resulting from a \$100/tCO_2e carbon tax rate applied only in a subset of industries (left) or economies (right). Industries and economies are added cumulatively from bottom to top.

about by the carbon tax. This result holds across a wide range of carbon tax rates and coverages.

We identify two particularly promising avenues for future research. First, it would be valuable to explore a version of the model with heterogeneous firms. We hypothesize that this would reveal additional static environmental gains from trade, resulting from the reallocation of resources from browner firms to lower-emission greener firms. Second, it would be interesting to allow emissions intensities to respond endogenously to carbon taxes. We conjecture that this would uncover additional dynamic environmental gains from trade, driven by the diffusion of green technology or scale effects that make green innovation more profitable.

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