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**论文题目：Importing for Producing: The Net Effect of Carbon Regulation on Emission Reduction**

# Importing for Producing:

# The Net Effect of Carbon Regulation on Emission Reduction

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**Abstract:** This paper explores empirically the impacts of carbon tax adoption on the change in domestic and global $CO_2$ changes. With the understanding of the carbon leakage theory, it is shown that despite the effectiveness of carbon tax for decreasing domestic $CO_2$ pollution, the world is still experiencing an increase in carbon emission. The empirical evidence proves that the implementation of carbon tax will effectively reduce a nation's $CO_2$ emission. However, it also has a positive relationship with the change in import value of pollution-intensive products – as countries set up carbon regulations, it will cause an overall increase in import value, especially for products that are of the highest emission intensity. Specifically, the import value will increase the most in the case where the import country has carbon tax and the export country does not have carbon tax. We find that countries that adopt carbon tax will have greater imports of pollution-intensive products from non-carbon tax countries. Additionally, it is shown the increasing amount of carbon-intensive products are generating more emissions than the emissions reduced by carbon tax, indicating a net increase in global emissions and a need to establish globally coordinative environmental regulations.

**Keywords:** Carbon Tax; Carbon Leakage; Environmental Regulations; Cross-border Pollution; International Trade

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## 1. Introduction

Amongst the many challenges in environmental economics, the assessment of the actual impact of carbon tax on global emissions is one of the most important issues to be considered, especially under the global circumstance where evermore countries are implementing regulations to address carbon reduction but the global $CO_2$ emissions are continuing to increase. In particular, the possibility for carbon leakage, where domestically the emissions would decrease with emission regulations, but abroad, they might rise, raises the concern of how effective carbon tax can be. Thus, this paper addresses the following question: How does the adoption of the carbon tax affect domestic emissions and the import value of emission-intensive products originating from countries with lenient regulatory environments? Do the countries' imported products cause more pollution than the amount reduced by carbon regulations within these countries?

Answering this question is important because while carbon taxes may be effective at shrinking a country's domestic emission footprint, the unintended consequence of shifting pollution to other countries that have worse emission reduction technologies can undermine global climate goals. It is for this reason that comprehending such dynamics and especially evaluating the global (net) impacts of such policies are crucial in the creation of more effective and globally coordinated climate policies.

Therefore, we implemented the empirical analysis of datasets on international trade, carbon emissions, and carbon tax policies from 1998 to 2014. Several econometric models estimating the effect of carbon taxes on the value of carbon-intensive imports, in particular those products originating in countries with relatively lenient emission controls, were estimated. We can identify the relationship between carbon taxation, domestic pollution, and imports, especially products coming from more emission-intensive sectors. Our findings confirm the evidence of carbon leakage, as in the fact that while domestic emissions are reduced due to carbon taxes, carbon-intensive imports from nontax countries increase unequivocally.

Furthermore, we find that the pollution of the increased imported carbon-intensive products is much greater than the amount of pollution reduced by carbon tax, meaning that the net pollution is continuing to increase, rather than decrease. This does not correspond to the original intent of carbon tax and environmental regulation, nor does it achieve the global goal of net pollution reduction.

These results contribute to a thorough analysis of how global emissions trends are affected by different levels of carbon regulation between trading partners and how international cooperation is needed to avoid shifting emissions across borders. We encourage the countries of all economic status and all carbon taxation status to collaborate and coordinate for a solution that can effectively reduce carbon emissions, while not transferring it from one nation to another.

## 2. Background and Literature

The issue of climate change emerged as a political issue in the 1970s. With that, international policies on climate change have focused on cooperation and setting up international guidelines concerning global warming.

Throughout decades, many perspectives have been voiced by people or organizations of different perspectives, but all in the pursuit of a sustainable future for the human population. The 1972 UN Earth Summit in Stockholm was the first international attempt at considering problems with the environment. It provided a precedent for international cooperation on matters concerning the environment (Jackson 2007). Various milestone events have also been instituted in the call for climate action. The Chernobyl disaster in 1986 and the Fukushima nuclear accident in 2011 outlined the environmental hazards involved in the production of energy. In addition, flash floods that happened in Brazil are among climate-related disasters that have further reinforced the mitigation of global warming, with rapid deforestation due to human activities being one of the primary factors of such flash floods (Cotovio 2024). These events showed people's unawareness of the impact that their activities may have on their surrounding environment. The UNFCCC and the Kyoto Protocol of 1997 laid the concrete basis for the formal commitments of international climate policy (United Nations Climate Change 2021). Building upon these efforts, the Paris Agreement of 2015 rallied nearly every country to take action and to cap global temperature increases.

Interestingly, the foundation of all these years of conversations and actions is the UN Scientific Conference in 1949 where countries discussed the conservation and utilization of resources (United Nations 2024). It was the first UN body to address the depletion of the resources and their uses. Significantly, the focus was on how to manage them for economic and social development, rather than the conservation aspect. It was realized that pollution is strongly related to the economic development of nations, and thus, it was found necessary to emphasize the issue of pollution and resource depletion.

Decades later, economists, in understanding the effect of emissions on development, began to establish the connection between the emissions involved in the manufacturing process of products and their eventual trading process. This allowed economists to endow carbon with the characteristic of being able to be traded, and from then, developed the concept of carbon taxation. The concept is simply that since we want to reduce carbon emissions, the most effective way for people to use less of it is to raise the price of carbon usage, infringing the overusage of carbon without any direct consideration of the cost of manufacturing. The carbon tax came into a legal majority in 1990 when Finland passed the world's first version of the policy. The nation introduced a carbon tax of €1.12 ($1.41) per ton of $CO_2$, based on the carbon content of the fossil fuel (Nachmany et al. 2015). The cost of the tax increased exponentially over the years of amendments in 1997, 2011, and 2013, now reaching a high price of $77 per ton of carbon dioxide in 2018 (Khastar et al. 2020). The results of the Finnish carbon tax show that this effective measure is capable of reducing domestic emissions by big margins. Finnish emissions were 16% lower in 1995, 25% lower in 2000, and 30% lower in 2004 (Mideksa 2021).

The relentless efforts so far, have not called an end to the crisis as it seems to worsen by the day. Alarmingly, despite the decrease in emissions in countries such as Finland, the global emissions have increased by more than 50% compared to that of 1990 (US EPA 2016). This is particularly important because $CO_2$ accounts for 75% of the total global emissions. In much of the same vein, extreme weather events and pollution crises have seen to occur much more frequently, together with the environmental decline. This issue of continuous effort but no significant result has been brought to the attention of policymakers, alerting them to the potential reason for uncoordinated action and transfer of pollution. While many countries actively establish emission reduction policies, these regulations among different countries do not fully align with each other, causing gaps and holes in the coordination of pollution reduction (Acemoglu et al., 2012). Climate scientists used to concentrate on the individual emission reduction measures for each country, neglecting the gap between policy coordination, until recently when studies began to connect pollution emissions to international trade and country interactions (Berry et al., 2021). Literature has noticed that along the line of globalization, when countries impose carbon taxes on domestic firms, these firms, to circumvent the more expensive domestic products, tend to choose to import products from foreign countries, especially those with softer emission policies. This encourages production in foreign countries, eventually leading to an increase in carbon emissions. Copeland et al. refer to the increased carbon emissions caused by strict foreign emission regulations as carbon leakage, signifying a potential negative impact of enforcing unilateral carbon policies (Copeland et al., 2022).

The concept of carbon leakage took a more defined form when economists and environmentalists realized that the cost imposition on carbon emissions may incentivize industries to move to other countries with lower emission regulations. It was seen that while the environmental policies would reduce pollution in a country domestically, they may neutralize or worsen the global situation as production shifts to less regulated regions. This problem was accentuated during the 1990s as the world started to formalize international agreements on climate change, for example, the Kyoto Protocol of 1997 (United Nations Climate Change 2021). Countries that applied early carbon pricing mechanisms, for instance, Finland, Sweden, and Norway faced concerns that their industries would not be as competitive as those countries without such measures.

To showcase the actions aligning with global emissions reduction, despite the concerns of industries and firms, more countries decided to implement carbon throughout the past two decades. Controversially, research emphasizes the issue of carbon leakage by showing the implementation of carbon tax among European countries led to a decrease in emissions in their production while increasing the emissions among its imports (Kuusi et al. 2022). Similarly, it is shown that the implementation of regional carbon regulations in China caused reversed investment leakage and an increase in the emission intensity of imports within the nation (Du 2023).

However, both of these papers limit their scope of analysis within a certain area, the European Union and China. They were unable to incorporate the understanding of other stakeholders within the issue. Kuusi et al. (2022) only focused on the EU nations, which are mostly high-income nations as 17 out of 27 of the countries are classified as high-income countries by the World Bank. Thus, they did not include the countries that act as pollution havens, i.e. countries that have lenient environmental policies and those that are the destination of carbon leakage. In the paper by Du (2023), the investigation is limited to China and investigates the issue using firm-level data.

In this paper, we effectively resolve the issue of one-sided perspectives by using country-level data and focusing on a wider scope of trade to include all nations within the study. We offer a deeper understanding of the differences between the pollution and import trends of countries with different income levels, while also establishing understanding from the countries not only of high income but also those that are not as wealthy and have lenient emission regulation. Essentially, the concern with carbon leakage lies in the fact that, while carbon tax may lead to a decrease in domestic pollution, it might lead to an increase in global $CO_2$ emissions. In our integrated framework of investigation, we can discern not only the reduction of domestic emissions but also the emissions due to the imported goods from foreign countries, and thus we can provide the global perspective (the net effect) of unilateral regulations. By doing so, we evaluate the extent of carbon leakage in undermining the climate goals of environmental policies and provide a deeper understanding of the need for coordinated policies in all countries.

## 3. Data and Variables

### 3.1 Data

To explore the relationships between the implementation of one country's environmental taxation and the change in its emissions and import value, we use both country-level and industry-level data sets in this study: the import value data from the *UN Comtrade Database*, the taxation data that presents information on which countries have environment tax in which year, and the emission data that shows how much $CO_2$ the production of products is associated with from *Our World in Data*.

The UN Comtrade data provides detailed global annual and monthly trade statistics by product and trading partner. For our purpose and simplification from the general data, we extracted the data table that presents the year of trade, the HS 6-digits to 1996 of the products of trade, the export country, the import country, and the import value and quantity. The taxation data provides a comprehensive understanding of the accounting of the real costs of fossil fuels and production. We used its data that present which country in what year has implemented carbon tax. For specification, a country is marked as having a carbon emissions tax instrument if at least one sector has implemented one. Although it provides a great variety of data, including information on emissions by regions and per capita $CO_2$ emissions, we only used the data that accounts for the annual $CO_2$ emissions as we are looking at the question of pollution from a country-level perspective. The three datasets use different country identifiers, either by ISO_3 code or a UN-categorized numbered country code, and provide different categories of the country information, but it is fairly easy to generate country-level observations that encompass the trade and environmental activities of all countries.

To further support the research, we used the data provided by S&P Global to classify products into industry groups and connect their emission intensities as a characteristic of the products under their classified industry group. Additionally, we extracted the industry and product names of the HS 6-Digit codes from the World Bank's World Integrated Trade Solution (WITS) database.

Due to data availability, our sample runs from 1998 to 2014. Despite the first implementation of carbon tax in 1990 by Finland and Poland, the Comtrade data extends from 1998 to 2014 and thus only allows the analysis during the 17 years. This may cause a limitation in the analysis as it is in recent years when the world has started to give more emphasis on environmental sustainability and put forth actions and legislations to reduce carbon emissions. However, our analysis will offer a general scope and trend regarding the flow of carbon emissions and how there may exist carbon leakage between countries of different environmental policy levels.

### 3.2 Variable Construction

#### 3.2.1 Environmental Taxation, $CO_2$ Emissions, Import Value

To begin our variable construction, we developed the five layers of investigation: import country $\boldsymbol{i}$, export country $\boldsymbol{j}$, product $\boldsymbol{k}$, year $\boldsymbol{t}$, and HS Chapter $\boldsymbol{g}$ (a categorization of products into industry groups according to their HS 6-Digit). Bounded by the difficulties of quantifying qualitative characteristics of the "strictness" of environmental policies, we constructed a dummy variable to present the carbon tax. Simply stated, if country $\boldsymbol{i}$ implemented carbon tax in at least one hs chapter $\boldsymbol{g}$ in year $\boldsymbol{t}$, then the variable $dum\_tax$ will be assigned with a value of $\mathbf{1}$. Conversely, if the carbon tax data did not reflect its implementation of the tax, then the value will be assigned as 0.

We measure a country's pollution emissions with its annual $CO_2$ emissions, as it is one of the most important pollutants during the sample period from 1998 to 2014. The pollution emissions for each year of each country are represented by the variable $Emissions_{it}$. Additionally, we express the import value with the variable $Value_{ikt}$. Each of these variables presents the value (in thousand U.S. dollars) and quantity (in the unit of the specific product) of country $\boldsymbol{i}$ imports for product $\boldsymbol{k}$ in year $\boldsymbol{t}$.

### 3.2.2 Industry-level Pollution Intensity

As standardizing and specifying the emission intensity (weighted average by revenue) involved in the production of each product, we extracted the industry-level pollution intensity using the data provided by S&P Global and categorized each product from the Comtrade data into a specific industry that has evaluated emission intensity level.

We first extracted the first two digits of the products' HS 6-Digit, as they are the indicator of the category of the product. About the data provided by WITS, we can connect these two digits with a specific category. For example, those HS 6-Digit that start with 01 are classified as "animals; live." By doing so, we summarized and named the 97 types of HS 2-Digits into 15 different categories, which are the HS Chapters, including for example "Animal & Animal Products" and "Base Metals." Furthermore, we organized the hs chapters according to industries listed in the dataset from S&P Global, assigning each hs chapter with a specific industry emission intensity level.

Essentially, the emission intensity variable is a characteristic that we label to the product. Despite possible over-time changes, the ratio of emission intensity will generally remain at a similar level. For example, the industry group of utilities has shown the highest emission intensity every year throughout 2016 to 2021. It is much higher than all other industry groups. Thus, it is valid to identify the emission intensity of an industry group as a characteristic that only varies depending on the industry, rather than a variable that changes in response to any of the other layers, including the import country $\boldsymbol{i}$, the export country $j$ and the year of trade $\boldsymbol{t}$.

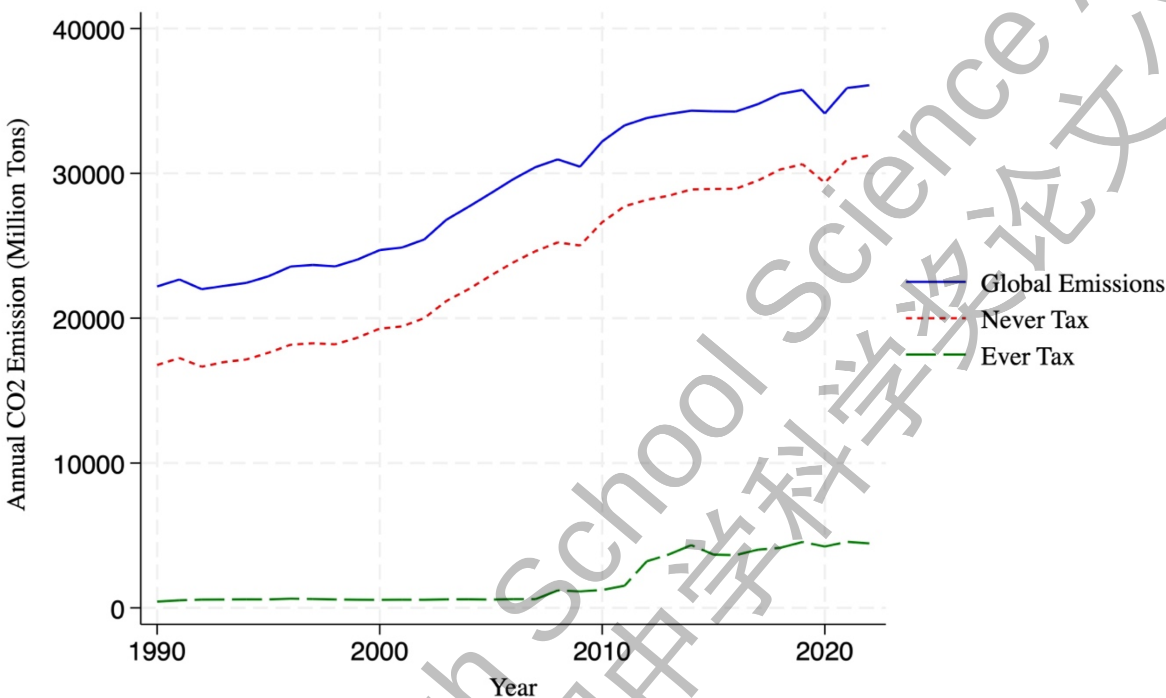
### 3.3 Summary Statistics

#### 3.3.1 Global CO2 Emissions and Tax Implementation Status

Prior to conducting empirical analysis, we delve into the global overview of $CO_2$ emissions, investigating the relationship between $CO_2$ emissions and the implementation of carbon taxes over time. We use the carbon tax data and organize countries into two groups, those that have never implemented carbon tax and those that have. By doing so, we are able to investigate how the trend of $CO_2$ emissions might be influenced by the implementation of carbon tax.

Figure 1 below shows the three emissions trends, each belonging to three subjects, the globe, countries that have never had carbon tax, and countries that have had tax. We observe that the global trend roughly aligns with the trend of $CO_2$ from countries that never had carbon tax; the emission trend of countries with carbon tax, however, is much lower compared to the other two and has not shown as significant of an increase compared to the other two lines. The analysis proves the major contributors to global emissions are countries without carbon tax – they appear to experience increases and decreases in the same rough period of time and are of similar growth rates. On the contrary, the green line, showing the $CO_2$ emissions of countries with carbon tax, experiences a much slower growth rate, while the only significant growth aligns with the growth of the other two lines after the 2008 global financial crisis. This strongly illustrates the causes of global emissions and signifies the importance of carbon tax to reduce emissions.

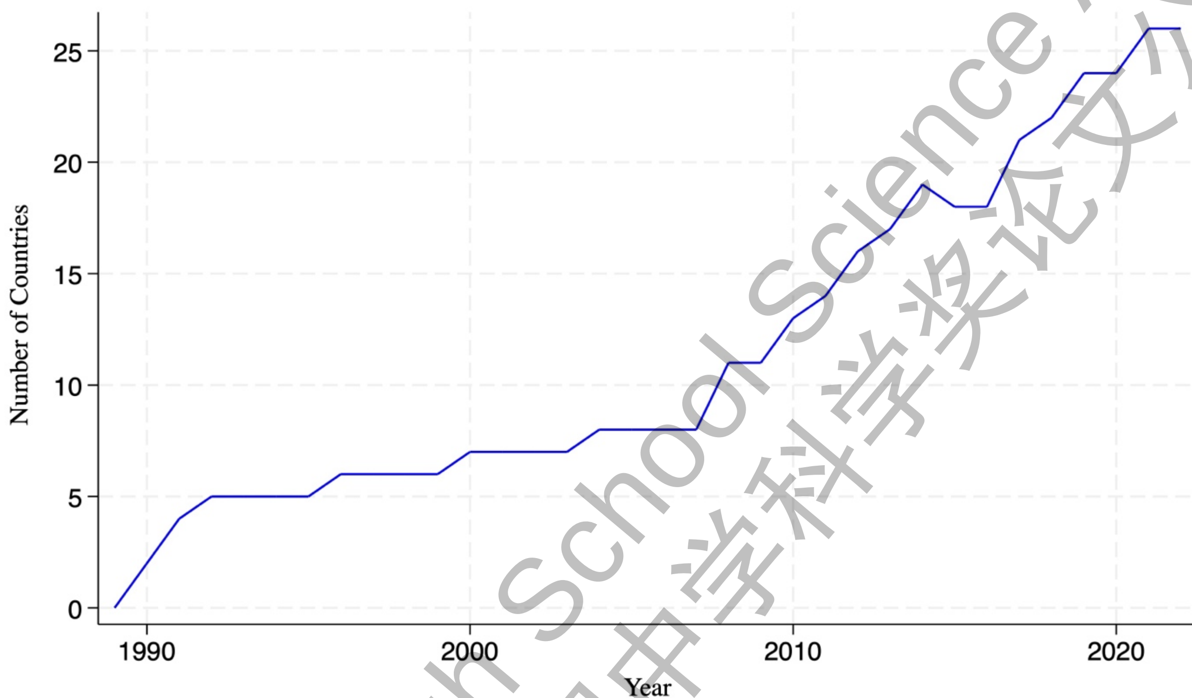
**Figure 1 Global CO2 Emissions and Tax Implementation Status**




### 3.3.2 Number of Countries with Carbon Tax by Year

We continue to understand the background of the case by presenting the number of countries that have carbon tax applied by year. Figure 2 shows that there exists a positive trend with carbon tax implementation. The first-ever carbon tax system was implemented in Finland and Poland. As of 2021, 26 nations have included carbon tax in their critical environmental policies, signifying the rising importance of the issue and the fact that more nations are willing to take action on the issue. An important time stamp to note is the post-2008 surge in the number of countries with carbon tax. This phenomenon is potentially influenced by the environmental and economic success of the revenue-neutral carbon tax in British Columbia, Canada (Elgie 2014). Several nations may have been influenced and strengthened the environmental policy coordination.

**Figure 2 Number of Countries with Carbon Tax by Year**




### 3.3.3 Country Characteristics by Carbon Tax Implementation Status

In understanding what types of countries have chosen to implement carbon tax, we produced Table 1 presenting the characteristics of countries that have implemented carbon tax and those that have not. We used data from Penn World Table to present the six country characteristics in the year 2000 that fell into consideration: GDP per Capita in million U.S. dollars, Output-side real GDP in million U.S. dollars, Human Capital Index, Capital Stocks in million U.S. dollars, Total Factor Productivity, and Share of gross capital formation. We also used the carbon tax data to organize all countries involved into two different groups, those that have ever implemented carbon tax (presented as $Ever\_Tax$) and those that have never implemented carbon tax (presented as $Never\_Tax$). With the two groups of countries, we took the mean value of the six variables and calculated the percentage difference between that of ever carbon tax countries and no carbon tax countries to observe the size of the difference.

**Table 1 Country Characteristics by Carbon Tax Status**

| **Carbon Tax Status** / **Characteristics** | ***Ever_Tax*** | ***Never_Tax*** | **Percentage Difference (%)** |
|---|---|---|---|
| ***GDP per Capita (million U.S. dollars)*** | 26710.56 | 9633.168 | 177.28 |
| ***Output-side real GDP (million U.S. dollars)*** | 605340.8 | 275747.1 | 119.53 |
| ***Human Capital Index*** | 1948807 | 832995 | 133.95 |
| ***Capital Stocks (million U.S. dollars)*** | 2.981966 | 2.179352 | 36.83 |
| ***Total Factor Productivity*** | 0.832692 | 0.6029463 | 38.10 |
| ***Share of Gross Capital Formation*** | 0.2379085 | 0.1872694 | 27.04 |

Table 1 reveals that countries that have ever implemented carbon tax generally have higher GDP per capita, larger economies, higher human capital, greater capital stocks, more efficient resource use (higher TFP), and a greater focus on long-term investments. These characteristics suggest that wealthier, more developed, and more forward-looking countries are more likely to adopt carbon taxes as part of their environmental and economic strategies. They also align with the environmental Kuznets Curve hypothesis, which suggests that as countries develop and reach higher income levels, they are more likely to implement carbon regulations as part of their strategy to balance economic growth with environmental sustainability (Stern 2018).

### 3.3.4 Carbon Intensive Import by Country Income Status

Finally, we analyzed the relationship between carbon-intensive imports based on country income status. This provides a different lens when looking at the effects of carbon taxes and offers an understanding of how carbon taxes might affect trade and emissions in different income groups. Following the classification by the World Bank, we categorized the nations into four groups: high-income countries, upper-middle-income countries, lower-middle-income countries, and low-income countries. We selected all products that were categorized into the most carbon-intensive sector – materials with an emission intensity level of 951.6 metric tons of $CO_2$ per million U.S. dollars in 2016, and present the trend of the total value of these $CO_2$ intensive imports of the four different categorized countries in Figure 3.

**Figure 3 Carbon Intensive Import by Country Income Status**

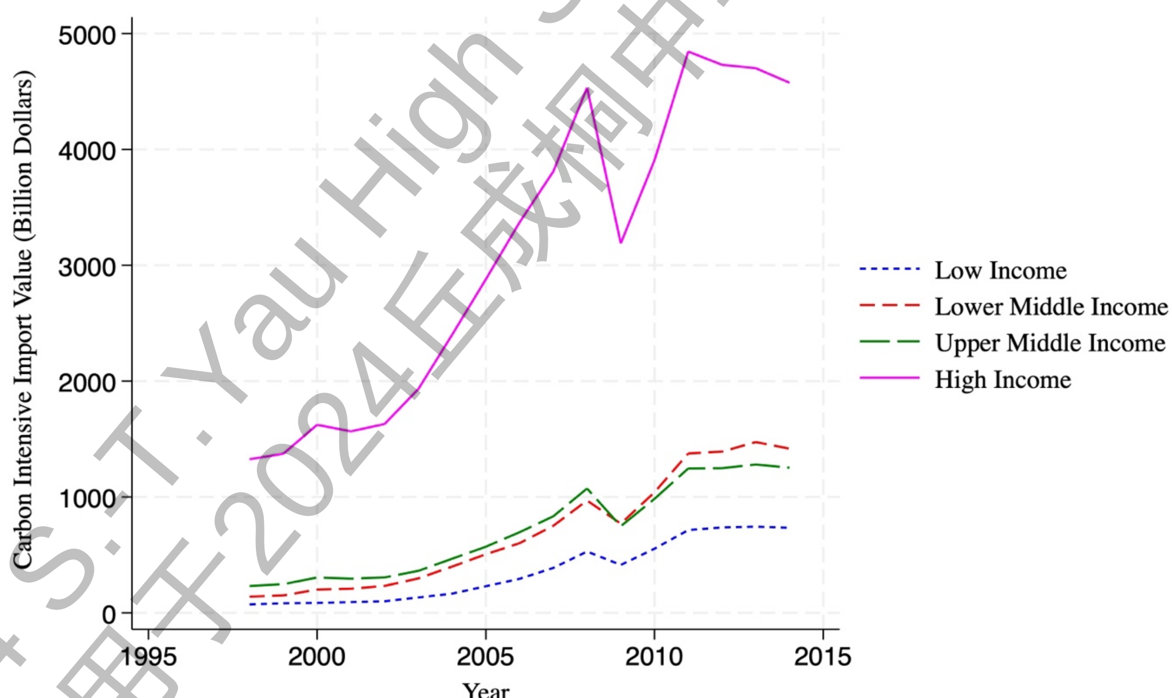


Figure 3 pinpoints the rapid increase of carbon-intensive imports to high-income countries. Although all four trend lines seem to experience increase and decrease at a relatively similar time frame, high-income Countries (represented in magenta) show a significant increase in carbon-intensive import values, peaking around 2011. This may suggest that these countries are importing more carbon-intensive products over time and that these carbon-intensive imports are concentrated within the high-income countries. It indicates a shift of emissions from production in these countries to the manufacturing of imports from lower-income countries, raising concerns about global trade practices and environmental responsibility.

Based on these results and observations, we find it necessary to further explore the story of carbon leakage and understand where the emissions are transferred to after countries implement carbon taxes.

## 4. Empirical Results

### 4.1 Countries with Carbon Regulations Reduce Domestic Pollution

### 4.1 Empirical Framework

As the basis of the story, we predict that, holding all else constant, those countries with carbon taxation will experience a decrease in their overall domestic pollution, despite the differences in the level of carbon tax and year of implementation. This prediction is not so straightforward, since as shown in Figure 1, the emission levels globally and in the countries that have implemented carbon tax all increased over time. This casts doubt on whether carbon tax implementation is effective or not.

We test this hypothesis with the following regression,

$$Emissions_{it} = \beta_1(dum\_tax_{it}) + \delta_i + \delta_t + \varepsilon_{it} \quad (1)$$

where $Emissions_{it}$ is the amount of $CO_2$ emissions of country $i$ in year $t$, measured in tonnes. $dum\_tax_{it}$ is the country's adoption of carbon tax, measured by a dummy variable that indicates whether a country has adopted carbon tax ($dum\_tax$) in the year $t$. We expect a country that implements carbon tax in year $t$ to have less carbon emissions than in years when the tax is not introduced, or alternatively, $\beta_1 < 0$.

$\delta_i$ and $\delta_t$ are country fixed effects and year fixed effects. $\delta_i$ controls the country features that affect a country's emission results, but do not vary over time; $\delta_t$ control the year-based factors or global environmental trends that vary across time but are not different across countries. Some examples of country fixed effects may include the geographical or climate features of a country, for example, a country with abundant coal resources may have more emissions, while a country higher up in the altitude may request more emissions to provide heat for citizens. It also includes the political and cultural features across different countries but does not change significantly over decades. Examples of year fixed effects include the introduction of global environmental policies that all countries need to abide by and are affected in a particular year. Other possibilities include technological advancements, global economic crisis, and environmental awareness trends, as they impact the entire world at the same time and do not levy towards different countries.

**4.1.2 Empirical Results**

Table 2 reports the baseline results of a country's carbon tax implementation on their $CO_2$ emissions. Columns (1) and (2) differ on their respective fixed effects: while column (1) only has the country fixed effect, column (2) includes both country and year fixed effect. It is important to note that the time frame of columns (1) and (2) is from 1998 to 2014 because the trade data is limited within that period. Column (3) however extends beyond the time frame and is from 1989 to 2022 because the relationship between carbon tax and $CO_2$ emissions acts effective since the first establishment of carbon tax in 1990 to the most recent year of data provided. For all three columns, the standard errors are clustered at the country level to account for possible serial correlation within the country. The dependent variable is winsorized at the 1st and 99th percentile to mitigate the impact of outliers.

**Table 2 Carbon Tax on $CO_2$ Emissions**

| | (1) | (2) | (3) |
|---|---|---|---|
| VARIABLES | $CO_2$ Emissions | $CO_2$ Emissions | $CO_2$ Emissions |
| Tax Dummy | -3,208.882 | -15,907.046** | -35,248.199** |
| | (5,852.67) | (7,105.49) | (14,257.61) |
| Observations | 3,326 | 3,326 | 6,632 |
| R-squared | 0.992 | 0.993 | 0.966 |
| Country FE | Y | Y | Y |
| Year FE | N | Y | Y |
| Time Period | 1998 - 2014 | 1998 - 2014 | 1989 - 2022 |

Notes: (1) Robust standard errors are corrected for clustering at the country level in parentheses;
(2) The dependent variable is winsorized at the 1st and 99th percentile;
(3) *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

As expected, a country that adopts carbon tax will be able to reduce its $CO_2$ emissions. The estimate coefficients in all columns are negative. Although column (1) is not significant, both columns (2) and (3), which are more stringent in fixed effects specifications, show significance at 5% significance level. According to column (2), within the time frame of the provided trade data, when a country moves from no carbon tax to yes carbon tax, its $CO_2$ emissions will decrease by 15,907.046 thousand tonnes; if we expand the scope of the investigation to 1989 to 2022, we find that the $CO_2$ emissions will decrease by 35,248.199 thousand tonnes.

However, it is necessary to note that despite the negative relationship between carbon tax and a country's domestic $CO_2$ pollution, global $CO_2$ pollution has been experiencing continuous increase over the past few decades – it does not seem to have been influenced by the domestic reduction of $CO_2$ emissions. This pushes forth the question of, is the domestic reduction of $CO_2$ effective in reducing global emissions? If countries are attempting to decrease their pollution, where does the increasing global emissions come from?

### 4.2 With Carbon Regulations, Countries Will Import More Carbon-Intensive Products

#### 4.2.1 Import Value on Tax Dummy: Empirical Framework

Continuing with the story of carbon leakage, we hypothesize that when countries implement carbon tax, it would be more costly for them to produce products domestically compared to importing goods from abroad. Thus, when they implement carbon tax, the total value will increase, with carbon-intensive imports increasing significantly. We test this hypothesis with the following regression,

$$Value_{it} = \beta_1(dum\_tax_{it}) + \delta_i + \delta_t + \varepsilon_{it} \quad (2)$$

where $Value_{it}$ is the total value of imports for country $i$ in year $t$. $Value_{it}$, being the dependent variable of interest is considered in three scenarios: the total import value of all products,

products that have an emission intensity above the mean intensity, and products that are below the mean intensity level. We expect that, due to the potential transfer of production, $Value_{it}$ will continue to increase. Henceforth, it is expected that $\beta_1 > 0$ for all three cases.

### 4.2.2 Import Value on Tax Dummy: Empirical Results

**Table 3 Carbon Tax on Emission Intensive Import Products**

| | (1) | (2) | (3) |
|---|---|---|---|
| VARIABLES | Import Value | Import Value (Intensity Above Mean) | Import Value (Intensity Below Mean) |
| Tax Dummy | 49,821.430* | 37,305.997** | 12,486.178 |
| | (25,991.90) | (18,126.22) | (8,502.61) |
| Observations | 3,148 | 3,147 | 3,146 |
| R-squared | 0.877 | 0.844 | 0.912 |
| Country FE | Y | Y | Y |
| Year FE | Y | Y | Y |

Notes: (1) Robust standard errors are corrected for clustering at the country level in parentheses.
(2) *** p<0.01, ** p<0.05, * p<0.1

Table 3 shows the results of the regression of the import value on carbon tax implementation. All columns have completely fixed effects on both country and year levels. Columns (1) – (3) reflect the import value of different products: all products, products that have an emission intensity above the mean intensity, and products below the emission intensity, respectively. The estimated coefficients are all positive. Coefficients for columns (1) and (2) are significant at 10% and 5% significance respectively; the coefficient of column (3) is not significant.

Confirming the expectation, we find that following the implementation of carbon tax in one country, it will experience an increase in its import value. In particular, the products with higher carbon emission intensity will experience a significant increase in import value. As shown in Column (1), the total import value of all products will increase by 49,821.430 million U.S. dollars. The total import value is broken into two components, products with pollution intensity above the mean intensity () and those with pollution intensity below the mean intensity. Column (2) shows that the import value of pollution-intensive products will significantly increase by 37,305.997 million U.S. dollars. Column (3), however, shows a statistically insignificant coefficient for low-emission products, indicating that the change in carbon tax does not affect their import value.

We see that the emission-intensive sectors and goods have a much larger and more significant increase in import value when a country implements carbon tax. Carbon tax tends to be stricter towards those products that are more carbon emission intensive, and therefore lead to a rise in its price. Thus, domestic businesses will reach towards foreign goods that are of a lower price, leading to an increase in imports of these products.

**4.2.3 Import Value on Emission Intensity with Tax Dummy: Empirical Framework**

With the understanding that carbon tax leads to an increase import value of emission-intensive products, we further investigate the relationship between the emission intensity of products and their change in import value. We hypothesize that given that a country has implemented carbon tax, when the carbon intensity of a product increases, it will have greater import value. We test this hypothesis with the following regression,

$$Value_{ikt} = \beta_1(dum\_tax_{it}) + \beta_2(Intensity_k * dum\_tax_{it}) + \delta_{ik} + \delta_t + \varepsilon_{ikt} \qquad (3)$$

where $Value_{ikt}$ is the logarithm of the total value of imports for an HS 6-Digit product $k$ to country $i$ in year $t$. In this regression, we grouped all considered products according to their emission intensity as mentioned in the data section. We use the interaction term $Intensity_k * dum\_tax_{it}$ to demonstrate the influence of product emission intensity on its import changes, where $Intensity_k$ specifies the product of different emission intensities. Due to the complexity between direct and indirect reasons for import changes, we do not have a specific expectation. $\beta_1$. However, we expect that for all products, when their pollution intensity increases, their import value will also increase, i.e. $\beta_2 > 0$.

**4.2.4 Import Value on Emission Intensity with Tax Dummy: Empirical Results**

Table 4 shows the results of the regression of the import value on the product emission intensity given the implementation of carbon tax. Although we applied different fixed effects to the three columns, they show consistency with the signs of the coefficient. All estimate coefficients for the interaction term are positive and significant at 1%, 5%, and 10% significance levels for columns (1) – (3) respectively.

These empirical results correspond to the prediction – given that the country has implemented carbon tax, when the emission intensity of a product increases by 1 tonne per million U.S. dollars, the import value of this product increases by 10 to 19 thousand U.S. dollars. Connecting to the previous results, we find that when carbon tax is implemented, countries will import more carbon-intensive products, and the import value of these products will increase in response to the increase in their emission intensity. This implies the increased carbon emissions caused by trade and the alarming need for coordinated international climate policies to effectively reduce global carbon emissions.

**Table 4 Carbon Tax on Emission Intensive Import Products**

| | (1) | (2) | (3) |
|---|---|---|---|
| VARIABLES | Import Value | Import Value | Import Value |
| Tax Dummy | -0.140 | | |
| | (1.18) | | |
| Intensity*Tax Dummy | 0.019*** | 0.019*** | 0.010* |
| | (0.01) | (0.01) | (0.00) |
| Observations | 10,426,360 | 10,426,360 | 10,426,157 |
| R-squared | 0.715 | 0.716 | 0.739 |
| Country*HS6 FE | Y | Y | Y |
| Year FE | Y | N | N |
| Country*year FE | N | Y | Y |
| HS6*year FE | N | N | Y |

Notes: (1) Robust standard errors are corrected for clustering at the country*HS6 level in parentheses;

(2) *** p<0.01, ** p<0.05, * p<0.1.

### 4.3 Carbon Intensive Products are Imported from Countries with Lenient Carbon Policies

#### 4.3.1 Empirical Framework

Looking at the issue with further depth and exploring the trade aspect of the issue, we hypothesize that those firms from countries with strict carbon tax regulations will import more emission-intensive products from foreign countries, especially those that do not have carbon tax and are much more lenient towards carbon emissions, which are the pollution haven countries. We test this hypothesis with the following regression,

$$Value_{ijgt} = \beta_1(dum\_tax_{it}) + \beta_2(dum\_haven_{jt}) + \beta_3(haven\_tax_{ijt}) + \beta_4(dum\_IAM_g * haven\_tax_{ijt}) + \delta_{ijg} + \delta_t + \varepsilon_{ijgt} \quad (4)$$

where $Value_{iegt}$ presents the value of products from the hs chapters $g$ that country $i$ imported from country $e$ in year $t$, $dum\_tax_{it}$ remains to be its meaning as stated in 4.1.1.

Different from the previous regressions, we included three new dummy variables.

$dum\_haven_{jt}$ is a dummy variable that possesses the exact opposite meaning of $dum\_tax_{it}$ – if the export country $j$ does not have carbon tax in year $t$, then its value of $dum\_haven_{jt}$ will be 1, as it is perceived as a pollution haven for other countries.

$haven\_tax_{ijt}$ is given by multiplying $dum\_tax_{it}$ and $dum\_haven_{jt}$ together to produce combinations of trading partners. If $haven\_tax_{ijt} = 1$, then within the two trading countries, the import country must have carbon tax and the export country must not.

$dum\_IAM_g$ is used to identify the emission intensity of different hs chapters. If the intensity of HS Chapter is greater than 0, then $dum\_IAM_g = 1$. Therefore, if $dum\_IAM_g * haven\_tax_{ijt} = 1$, then we are considering products from the hs chapters with emission intensity above the intensity means that are imported by countries with carbon tax and exported from countries without carbon tax when analyzing $\beta_4$. Because of the prior investigation, we predict that when the import country has carbon tax and the export country does not, the import volume of carbon-intensive products will increase. Hence, $\beta_4 > 0$.

#### 4.3.2 Empirical Results

**Table 5 Carbon Tax on Emission Intensive Import Products**

| VARIABLES | (1)<br>Import Value | (2)<br>Import Value | (3)<br>Import Value |
|---|---|---|---|
| Tax Dummy | -3.911 | -2.318 | |
| | (9.72) | (9.69) | |
| Haven Dummy | -1.690 | -0.577 | |
| | (8.04) | (8.00) | |
| Tax Dummy*Haven Dummy | 1.026 | 11.384 | 12.577 |
| | (10.61) | (10.73) | (10.69) |
| Intensity Above Mean Dummy*Tax Dummy*Haven Dummy | 48.753*** | 27.724** | 20.957** |
| | (10.99) | (10.78) | (10.65) |
| Observations | 2,716,549 | 2,716,549 | 2,716,549 |
| R-squared | 0.803 | 0.804 | 0.810 |
| Importer*Exporter*HSChapter FE | Y | Y | Y |
| Year FE | Y | Y | Y |
| HSChapter*year FE | N | Y | Y |
| Importer*year FE | N | N | Y |
| Exporter*year FE | N | N | Y |

Notes: (1) Robust standard errors are corrected for clustering at the importer*exporter level in parentheses.

(2) *** p<0.01, ** p<0.05, * p<0.1

Table 5 presents the results of how the difference between import and export country policies may influence the import value of carbon-intensive products. We specifically focus on line 4, presented with the independent variable of "Intensity Above Mean Dummy*Tax Dummy*Haven Dummy" (i.e. $dum\_IAM_g * haven\_tax_{ijt}$). We find that for this variable, all coefficients are positive and significant at 1% significance for columns (1) and 5% significance for columns (2) and (3). We apply different fixed effects for all three columns, with column (3) having the harshest fixed effect.

The coefficients presented in the table strictly correspond with the expected results. We find that for a pair of trading partners where the import country has carbon tax and the export country does not, the import value of carbon-intensive products will increase by 20.957 to 48.753 million U.S. dollars. This proves the issue of carbon leakage and the transfer of emission-intensive good production to pollution haven countries to be significant and is in emergent need to be addressed.

**4.4 Countries' Imports are Generating more Emissions than They are Reducing**

To further advance the understanding of the current issue and bring the global scope into consideration, we calculate the estimated amount of domestically reduced $CO_2$ emissions and compare them with the estimated amount of $CO_2$ emissions the increased imports will bring to the country. We calculate the net change in $CO_2$ emissions with the following equation,

$$Net\_Emission = Value\_Import * Intensity_{mean} - Domestically\ Decrease\ Carbon\ Emission \quad (5)$$

where $Value\_Import$ is the change in import value of the emission-intensive products in response to the change in carbon tax, $Intensity_{mean}$ represents the average intensity of all products that belong to the two most carbon-intensive sectors whose intensities are above the overall mean intensity, and the $Domestically\ Decrease\ Carbon\ Emission$ is provided by the estimated amount in 4.1.2. Note that in this calculation, we exclude the change in import value of low-emission products because it is proven to be insignificant in 4.2.2.

We plug in 37,305.997 million U.S. dollars for $Value\_Import$ as estimated in 4.2.2, calculate $Intensity_{mean}$ to be 925.5 metric tons per million U.S. dollars, and plug in 15,907.046 thousand tonnes for $Domestically\ Decrease\ Carbon\ Emission$ as estimated in 4.1.2. With these values, we calculate $Net\_Emission$ to be equal to 18,619.654 thousand tonnes – it is much larger than 0. This result reveals the cruel fact that although the implementation of carbon tax and environmental regulations does reduce the domestic emissions, the emissions produced by the increased import products stand larger than the reduced emissions, refuting the effectiveness of the current carbon tax status in reducing global pollution. Carbon leakage remains a serious issue where domestic firms choose to import carbon-intensive products that produce much more emissions than the reduced amount within the nation to circumvent the carbon tax within the nation. Nations must be alerted of such issues and collaborate to develop a coordinative and comprehensive plan that does not only focus on domestic pollution reduction but emphasizes the goal of global emission reduction.

## 5. Conclusion

To conclude, in this paper, we explore the actual impacts of carbon tax and the future implications of implementing carbon regulation with the consistent goal of reaching a globally decreasing $CO_2$ emissions for protection of the sustainable future. We find that through the past few decades, although carbon tax is very effective in supporting nations in reducing their domestic pollution emissions, the global $CO_2$ emissions have continued to rise with no significant caesurae or decrease. Our empirical results explain that the implementation of carbon tax in one nation is not only followed by a decrease in domestic emissions, but also an increase in the volume of emissions-intensive imports. This signifies the transfer of pollution: the domestic firms, in attempt to circumvent the carbon tax, choose to opt out of domestic production and utilize the now relatively cheaper imports to minimize its cost. This is extremely alerting considering all the effort that has been put forth to reduce carbon emissions. To provide more depth of information, we further analyzed the country characteristics of those that import more emission-intensive products as they implement carbon tax and those that act as pollution havens and the destination of the transfer of manufacturing and pollution.

The findings in this study emphasize the need for greater international coordination to address climate change, reduce emissions, and limit its impact. Carbon leakage is lessening the effectiveness of the unilateral climate policy and causing eventually further addition to the global emissions. Our results indicate that only comprehensive harmonized policies across borders could reduce the global impact of carbon leakage and ensure that carbon taxes meet their environmental objectives without merely shifting the pollution burden elsewhere.

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At school, I am greatly involved in school communities and clubs that emphasizes the importance of sustainability and maintenance of the environment. By conducting small-scale projects with my peers on topics of sand-mining, water pollution, and urban development, I gradually developed an interest for the environment. Throughout this process, I have encountered the relationship between environmental sustainability and how it is related to the world's economic development. With these questions in mind, I contacted Professor Chen one and a half year ago, seeking for guidance on another project that I wish to investigate on. With his support, I decided to land that project on the topic of automation and green investment choices, and participated in the 2024 S.-T. Yau High School Science Award with that project. This year, I encountered the concept of carbon leakage while roaming through the internet for a Model United Nations debate based in the environmental committee. The idea of carbon leakage and pollution haven immediately led me to consider what are the political and economic implications of these activities. Thus, I decided to further investigate the area of environmental economics and seek for a deeper understanding of the environmental and economic implications of environmental regulation such as carbon tax.

With the decided research topic, Professor Chen provided me with thorough support on how to further proceed the project. Having prior experience of working under his guidance, I discussed the areas of exploration within the story of carbon tax with him and established the

general framework of the project. He helped me greatly with the usage of data: I was able to find relevant information on $CO_2$ emissions and carbon tax implementation, but struggled to download the trade data from WITS. Professor Chen offered me an important set of Comtrade data that covered a large variety of needed information and instructions on how to use Stata to merge data sets in order to create the most effective usage of code. He also guided me on the development of empirical frameworks and how to understand those results. I was capable of advancing my coding abilities and thus able to develop the do-file, but had slight trouble connecting all coefficients from regressions together to develop a more holistic framework and understanding of my results. Therefore, Professor Chen helped me with the interpretation of the results, specifically on how the coefficients reflected changes in the dependent variable according to changes in the independent variable. After the basic work of developing the framework and processing data is done, I completed the research paper while seeking for guidance when needed. With the research paper itself, Professor Chen advised me on the structure of the paper and pointed out logical flaws that were necessary to explain or diminish.

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