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Paving the Way to Sustainability: Assessing the Impacts of Carbon Border Tariffs on the Steel Industry

by

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Abstract This paper seeks to provide insights into the effects of carbon border tariffs and to offer guidance for policymakers. The focus is directed towards the steel sector - a major contributor to carbon dioxide emissions, where production practices vary significantly among countries, leading to differences in pollution levels. Our primary focus is on the proposed carbon border tariff by the United States, which aims to extend its reach to the EU as well. To investigate this topic, the structural gravity model is employed, which is a widely used model for assessing the effects of policy measures on trade flows. Our findings highlight the effectiveness of steel tariffs in reducing imports, which potentially can redirect production and contribute to a reduction of CO_2 emissions. Additionally, it can alter trade patterns and address the concern of carbon leakage. Furthermore, the elasticities vary among steel products. Hence, considering different taxation levels depending on the steel product could be recommended in order to achieve the desired outcome.

Keywords: Carbon border tariffs, trade, steel, the structural gravity model, CO_2 emissions, environmental policy

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1 Introduction

We are living in a world where the prominence of global warming is on the rise, and emerging as one of the greatest challenges of our time. It is imperative that we take greater action and utilize all available means to mitigate the warming.

The opening lines of the latest report from the Intergovernmental Panel on Climate Change (IPCC) in March 2023 states that, within the time frame of 2011-2020, the global surface temperature has increased by 1.1°C above the 1850-1900 average. This escalation is a direct result of human activities, through the emission of greenhouse gasses (IPCC, 2023). Given the urgent environmental concerns, The Paris Agreement established in 2015 set a target of limiting the increase to 1.5 °C above pre-industrial levels (UNFCCC, 2023). Nonetheless, projections indicate that this threshold could be surpassed already within the next ten years (Andersson, 2023).

While it is encouraging that an increasing number of nations are setting carbon neutrality targets to slow down global warming (UNFCCC, 2023), the problem of carbon leakage has begun to rise. It occurs when companies, due to the higher costs associated with climate policies, move their production to countries with less stringent regulations (European Commission, 2023b). Assessing the risk of carbon leakage is challenging; nonetheless, a report from the Nordic Council of Ministers indicates that some of the Nordic industries with the greatest risk of carbon leakage are paper, pure iron and steel, as well as cement. These sectors are all characterized by high energy intensity (Helge Sigurd Næss-Schmidt, Holm, & Lumby, 2019).

When excluding the energy sector, the iron and steel industries emerge as the largest emitters of fossil fuel emissions globally (Pooler, 2021). However, producing so-called clean steel is possible. For instance, SSAB, a Swedish company, has developed an almost emissions-free process for iron production (Gearino, 2021). This steel and iron producer is anticipated to achieve an annual output of 5 million tonnes of green steel by 2030 which can be compared to the worldwide annual steel production of approximately 2 000 million tonnes (Savage, 2021). According to the World Steel Association (2021a), the steel industry aims to reduce their emissions through initiatives like efficiency enhancements, circular economy practices, as well as developing advanced steel products to facilitate a societal transformation towards achieving carbon neutrality (World Steel Association, 2021a). Advanced steel products are utilized across various domains where the conventional materials are replaced with innovative steel solutions. These new applications can reduce the

CO_2 emissions throughout the life cycle of the product and e.g., be used in trains, rails and infrastructure. One example is how the weight of a typical 5 passenger family car can decrease by 100 kilograms, which corresponds to savings of 3 to 4.5 tonnes of greenhouse gases over the car's life cycle (World Steel Association, 2021b).

As shown in Table 1, both China and the United States are in the top ten steel producing countries globally (World Steel Association, 2023).

Table 1: Top 10 Steel Producing Countries in the World in December 2022

Countries	**Amount (Mt)**
China	77.9
India	10.6
Japan	6.9
United States	6.5
Russia	5.5
South Korea	5.2
Germany	2.7
Turkey	2.7
Brazil	2.5
Iran	2.7

Worth noting is that China is the largest emitter of fossil fuel emissions in the world (Blokhin, 2023), contributing to approximately 17 percent of the total annual emissions coming from the production of steel (Hsueh, 2023). One of the main reasons why the steel production in China is highly polluting is the predominant use of coal-fired blast furnaces for melting iron, compared to e.g., the United States, which adopts a more environmentally friendly approach, where the steel production primarily relies on electrical furnaces using scrap iron (Lawder, 2022).

Carbon border tariffs have recently been proposed as a way to combat carbon leakage and mitigate climate change. The concept entails that industries manufacturing goods with a substantial carbon footprint, will have to pay a tax in proportion to the emissions associated with the goods when exporting their products into certain countries (European Commission, 2023a). In Europe, a similar mechanism is about to be established and is referred to as the CBAM - The EU's Carbon Border Adjustment Mechanism. The regulation will come into force in October 2023 and be fully in place by January 1st, 2026. CBAM will target all countries outside the European Union (EU), and be applied to imports of specific products and goods that have a significant greenhouse gas footprint and do not meet the required standards, such as cement, iron, steel, aluminum, fertilizers, and the production of electricity and hydrogen (European Commission, 2023a). The aim of the regulation is to counteract the risk of carbon leakage by making firms that manufacture carbon-intensive products outside the EU to purchase certificates proportional to their emissions. The cost of these certificates is determined by the prevailing price of emission rights within the EU Emission Trading System (EU ETS), measured in €/tonne of emitted CO_2 (European Commission, 2023a).

A rather similar policy proposal has been developed within the United States but is mainly focusing on the steel and aluminum industry. The policy would imply implementing a carbon border tariff, where countries engaging in a more carbon intensive production, are expected to be significantly affected (Lawder, 2022).

The United States Representative's office seeks to negotiate their proposal with the EU with the aim of establishing a club for countries striving to reduce carbon emissions from their steel production. The club intends to implement emission-sensitive standards, where all countries exceeding the standards will have to pay a tariff when exporting steel and aluminum to countries with superior production practices (Lawder, 2022).

Since this policy is not yet in place, and there is no similar regulations to draw conclusions from, this thesis aims to provide insights of the potential impact of implementing such a policy, where we will examine the effectiveness of steel tariffs by answering the following questions: What impact does a carbon border import tariff on steel have on the quantity of imported steel? How do the elasticities differ across various steel products?

Even though the American policy is our primary focus, we have decided to include more countries in the data set, in order to build a more robust data set. We believe that this broader perspective allows for a more comprehensive analysis, based on a wider range of data. Furthermore, we also believe that it would be beneficial to examine specific steel products, as the carbon footprint varies across different products, owing to differences in the production processes. Hence, it could be justifiable to apply different tariff rates depending on the specific type of steel product.

According to the neoclassical trade theory, a tariff is classified as a trade barrier leading to a rise in price. Following this theory, we believe that an import tariff on steel will result in lower demand and reduced import (Brent, 2023). According to the New Trade Theory, an import tariff could also result in trade diversion, where trade is shifted from more efficient foreign suppliers to less efficient domestic producers, resulting in welfare losses (ESCWA, 2023). However, we believe this could be offset by benefits from reducing the carbon footprint globally. The New Trade Theory also underlines that Regional Trade Agreements (RTA) stimulate trade flows (Gammadigbe, 2021). Accordingly, we expect to observe a positive effect of RTAs on imports.

In this study, the gravity model is conducted. This is a common model to use when analyzing bilateral trade, and was first introduced in 1962 (Feenstra, 2002). However, there have been discussions about how to best estimate this model. Using log-linearized gravity models, estimated through ordinary least squares (OLS) have led to results that have the potential to be biased and misleading. By instead using the Poisson Pseudo-Maximum-Likelihood (PPML), the problem of biased results is resolved (Mnasri & Nechi, 2021). This will be further discussed in the theory section.

The data is collected from various sources. Since our paper is mainly focused on the effect of the tariffs at the product level, we are including 14 different steel products that all have individual HS codes. HS stands for "*Harmonized Systems (HS)*" and these codes are used worldwide to identify different products (International Trade Administration, 2023). Furthermore, we include 9 of the greatest steel producing countries in our data set, with data on every third year from 1990 to 2014. The primary sources utilized to gather the data are United Nations Comtrade, the CEPII as well as the World Bank.

The results show that import tariffs on steel have a significant negative impact on trade. Consequently, the implementation of a carbon border tariff on steel products could be a viable and effective measure. Considering the substantial role of the United States as a major steel producer and trader, the adoption of such a policy might significantly influence trade patterns and global carbon emissions. For instance, countries like China, characterized by less eco-friendly steel production (Hsueh, 2023), could face diminished export opportunities. If import tariffs on steel gain broader prevalence, nations with environmentally unfriendly production methods might be compelled to reconsider their practices to maintain competitiveness in the steel market.

When reviewing previous literature, we find no studies - examining the effect of import tariffs on different steel products using the structural gravity model and focusing on the effects on specific types of steel - as we do in this thesis. Consequently, we believe that our approach will provide valuable insights into the elasticity of different steel products and if tariffs could be effective to alter production and trade patterns of steel. We also believe it could encourage countries to adopt cleaner production measures. Furthermore, we believe that studying some of the most prominent global traders of steel will serve the purpose of illustrating what could be expected in reality. Lastly, there is a scarcity of existing research to rely upon, which emphasizes the significance of conducting studies in this research area. This not only contributes to a more solid foundation for the current United States policy proposal, but also paves the way for similar strategies in other countries.

The remainder of the paper is structured accordingly: Chapter 2 covers the literature review. Chapter 3 provides a description of our data; data sources and collection, included variables, issues regarding the data set, descriptive statistics etc. In Chapter 4, the theory behind the gravity model is provided. Chapter 5 outlines the methodology and presents the model specification. Chapter 6 shows the results. Lastly, in Chapter 7, a discussion about the findings and conclusions is presented, along with suggestions for improvements, as well as areas of interest for further studies.

2 Literature Review

2.1 Previous Literature

The preceding literature review is relatively limited due to the scarcity of existing research on the impact of border tariffs on the steel sector. Nonetheless, the investigation of the broader impact of border tariffs is more readily available and will primarily constitute the content of this section of the paper.

In the study "*The Trade Impact of EU Tariff Margins: An Empirical Assessment*" the authors examine how tariffs applied to the EU-market affect imports into the EU (Cipollina & Salvatici, 2019). This study estimates elasticities using the structural gravity model and incorporates domestic trade flows. Instead of focusing solely on the steel sector, the authors consider various sectors to assess the overall impact of this trade policy. The findings of the study suggest that a decrease in border tariffs on country i will lead to an increase in the imports of that country. Furthermore, the study also highlights that such tariff reductions affect relative demand, due to changes in relative prices. Additionally, the authors show that protectionist policies, such as import tariffs, have a more significant impact on trade compared to preferential policies. They define preferences as the reduction or elimination of trade barriers. Furthermore, the study solely uses cross-sectional data for the year 2017 (Cipollina & Salvatici, 2019). While this approach has the advantage of having fewer missing values, which is often experienced in tariff data, it may suffer from measurement issues. By only including data from a single year and not lagging any variables, it might overlook the time it typically takes for adjustments to occur and actually notice an impact of the policy in real life (Cipollina & Salvatici, 2019).

Another study utilizes a computable general equilibrium (CGE) model, instead of the gravity model to examine the economic impacts of carbon tariffs (Zhang, Xu, He, Sharp, Zhao, & Wang, 2019). Their research specifically applies to the effect on China from the United States border policy in an ex ante perspective. The authors identify a substantial impact of the tariff, resulting in a significant reduction in steel exports from China to the United States. Consequently, they anticipate that China will adjust its trade pattern and increase its exports to other countries. The result highlights the importance that more countries with cleaner production practices join the club so that it becomes more challenging to shift the burden of exploitation elsewhere (Zhang et al., 2019).

The working paper titled "*The Impact of US Tariffs Against China on US Imports: Evidence for Trade Diversion*" (Cigna, Meinen, Schulte, & Steinhoff, 2022) also investigates the impact on total imports from China in response to the high tariffs implemented in 2018 during the beginning of the trade war. According to their research, the targeted products experienced an average growth rate that was 30 percentage points lower compared to the products unaffected by the tariff. Furthermore, the study does not find significant evidence of trade diversion, at least not in the short run. However, this may be attributed to the relatively limited time frame analyzed and that it can take time before new trading partners are established (Cigna et al., 2022).

Amiti, Redding, and Weinstein, 2019 delves more into the welfare effects of tariffs, also by looking at the impact of tariffs introduced by the Trump administration in 2018. Their findings reveal a noteworthy surge in purchases of both intermediate and final goods within the United States. There was also a decline in import varieties, and an increase in the prices of imported goods. Consequently, the burden of this policy fell primarily on domestic consumers and importers (Amiti, Redding, & Weinstein, 2019). Moreover, the aggregate US real income level experienced a decline. Cox, 2023 is another study investigating the welfare effects of border tariffs and observes that it has an adverse effect on production as well as employment (Cox, 2023). Zhang et al., 2019 also conclude in their paper that carbon tariffs have a negative effect on social welfare.

3 Data

3.1 Data Collection

The disaggregated data on tariffs is collected from the World Bank which provides data on all countries in the world through their comprehensive database *Trade Analysis Information System (TRAINS)* (The World Bank, 2023), covering the years 1988 to 2014. By incorporating the specific tariffs for each product instead of collecting data at an aggregated level, heterogeneity across sectors can be considered and generate more precise results. The availability of comprehensive data on tariffs is limited without having specific access and it is also lacking for many years. To work around these limitations, data on tariffs is collected from the period with the most substantial observations available. In order to both include enough years and to not go too far back in time, we gather data between the years 1990 and 2014, including data on every third year.

The Centre d'Études Prospectives et d'Informations Internationales (CEPII) was founded in 1978 and is a research institution providing data on international trade and the world economy. Their data set called *Gravity* contains valuable information for estimating gravity equations and is widely used by researchers studying trade flows. It includes variables such as GDP, trade agreements and population for all country pairs during the years 1948 to 2020. For this study, data on population, distance, GDP and diplomatic disagreements is gathered from the CEPII database (Conte & Mayer, 2022). Moreover, data on the various countries import of steel is obtained from the United Nations Comtrade Database (UN Comtrade, 2023).

Lastly, data on Regional Trade Agreement (RTA) is gathered from the data set *Mario Larch's Regional Trade Agreements Database* from the University of Bayreuth. The data set includes multilateral and bilateral regional trade agreements between the years 1950 to 2022 (Universität Bayreuth, 2023).

The reason for having intervals and excluding certain years is because it takes time for trade flows to adjust after changes in trade policies. Consequently, including estimates over consecutive years can lead to biased results. According to Cheng and Wall, 2005, this issue becomes even more pronounced when incorporating fixed effects, as the dependent and independent variables cannot instantaneously fully adjust. Consequently, they recommend using panel data with intervals to avoid this issue (Yotov, Piermartini, Monteiro, & Larch, 2016).

We construct our own data set (using Excel) since no available study with data that matches this research is to be found.

Table 2: Included Countries in the Data Set

Countries
Brazil
Canada
China
France
India
Japan
Russia
United States of America
Ukraine

As can be seen in Table 2, we have decided to use 9 countries in our study. To maintain a representative sample, we specifically select countries that rank among the top steel traders. Each of the chosen countries consistently falls within the top 15 steel-producing nations over the designated time frame (World Steel Association, 2023). Ideally, more countries would be included to have a more comprehensive data set. However, due to time limitations, we are unable to do so. Furthermore, tariff data is even more challenging to find for countries that are not among the top producers.

We have also decided to exclude the year 1990 of Russia and Ukraine. This is due to their identical values up until the dissolution of the USSR in 1991 which, if included, would cause measurement errors.

3.2 Included Variables

Table 3 shows all the variables that are included into the data set, as well as their representation, unit of measurement and source.

Table 3: Variable Description

Variable	Description	Unit	Level	Source
Impofsteel	Import of steel	Kilograms	Unilateral	UN Comtrade
Country_o	Country of origin		Unilateral	CEPII
Country_d	Country of destination		Unilateral	CEPII
HS-code	Type of product		Unilateral	US ITC*
Distance	Distance between the capitals	Kilometers	Bilateral	CEPII
Tariff	The level of the import tariff	Decimal form	Unilateral	The World Bank
GDP_o	Gross domestic production for the origin country	Thousands of USD	Unilateral	CEPII
GDP_d	Gross domestic production for the destination country	Thousands of USD	Unilateral	CEPII
Pop_o	Population in the origin country	Thousands	Unilateral	CEPII
Pop_d	Population in the destination country	Thousands	Unilateral	CEPII
Diplodisagree	United Nations diplomatic disagreement score		Bilateral	CEPII
RTA	Dummy variable with a value of 1 if a pair of countries have a RTA		Bilateral	Uni of Bayreuth

[a] [b]

[a]*United States International Trade Commission (US ITC)
[b]Origin = Reporter = Exporter, Partner = Importer = Destination

"*Harmonized Systems (HS)*" codes are utilized worldwide and serves as a tool for customs authorities to identify products when for example assessing applicable taxes and duties for imported and exported goods. The *World Customs Organization (WCO)* administers these codes and they are usually updated every five years. Furthermore, the HS system assigns 6-digit codes to the different products.

Chapter 72 of the HS codes belongs to the *Iron and Steel* products (World Customs Organization, 2022). Since chapter 72 includes all of the iron and steel products, and this paper aims to analyse solely steel products, we have decided to focus on 14 different HS-codes representing different steel variaties. These products are presented in Table 4 (The World Bank, 2023).

Table 4: The Different Steel Products

HS-Code	Description
7206	Iron and nonalloy steel in ingots or other primary forms (excluding iron of heading 7203)
7207	Semifinished products of iron or nonalloy steel
7218	Stainless steel in ingots or other primary forms; semi-finished products of stainless steel
7219	Flat-rolled products of stainless steel, of a width of 600 mm or more
7220	Flat-rolled products of stainless steel, of a width of less than 600 mm
7221	Bars and rods, hot-rolled, in irregularly wound coils, of stainless steel
7222	Other bars and rods of stainless steel; angles, shapes and sections of stainless steel
7223	Wire of stainless steel
7224	Other alloy steel in ingots or other primary forms; semi-finished products of other alloy steel
7225	Flat-rolled products of other alloy steel, of a width of 600 mm or more
7226	Flat-rolled products of other alloy steel, of a width of less than 600 mm
7227	Bars and rods, hot-rolled, in irregularly wound coils, of other alloy steel
7228	Other bars and rods of other alloy steel; angles, shapes and sections, of other alloy steel
7229	Wire of other alloy steel

3.3 Correlation Analysis

To assess if certain variables need to be excluded because of too high correlation, Pearson's correlation table is constructed. Table 5 shows the results of the correlation matrix. The table reveals that none of the continous independent variables have a large linear relationship. Thus, multicollinearity is unlikely to be present.

Table 5: Pearson's Correlation Table

	GDP_d	**Tariff**	**Diplodisagree**	**Pop_d**	**Distance**
GDP_d	1.000				
Tariff	-0.0144	1.000			
Diplodisagree	0.1913	0.0932	1.000		
Pop_d	0.0391	-0.0493	0.0904	1.000	
Distance	0.018	0.1305	0.285	0.0535	1.000

Also a Variance Inflation Factor (VIF) table is constructed (Table 6), which reveals that none of the variables has a value exceeding the threshold for multicollinearity.

Table 6: Assessing Multicollinearity Among Predictor Variables

Variable	**VIF**	**1/VIF**
Diplodisagree	1.14	0.875423
Distance	1.10	0.905536
GDP_d	1.04	0.960677
Tariff	1.03	0.975067
Pop_d	1.01	0.986743
Mean VIF	*1.07*	

Further details about the included variables are available in Table 7, providing a summary of statistics.

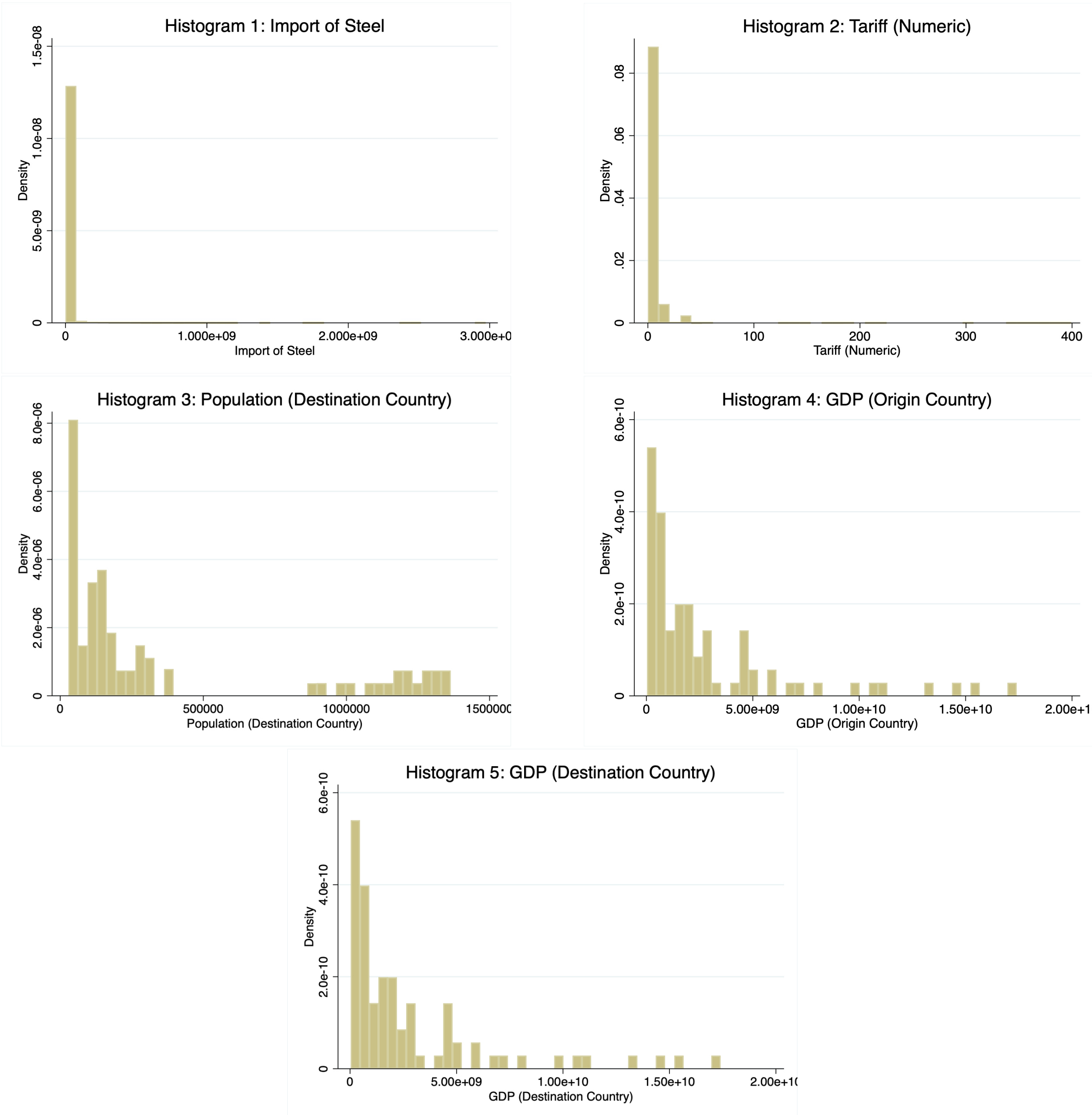
Table 7: Descriptive Statistics

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Impofsteel	9,757	1.64E+07	9.13E+07	0	2.97E+09
GDP	9,757	2.89E+09	3.79E+09	3.16E+07	1.74E+10
RTA	9,757	0.0918315	0.2888028	0	1
Distance	9,757	6966.482	4159.36	0	16934
Tariff	9,757	7.045341	16.32663	0	399.1781
HTS Code	9,757	7.500637	4.03101	1	14
Diplodisagree	9,757	1.255269	0.9598682	0	4.69
Pop_d	9,757	364978.2	450162.6	28833.41	1364270

3.4 A Logarithmic Transformation

The histograms in Figure 1 show the distribution of all the various continuous variables.

Figure 1: Histograms of the Included Continuous Variables



As could be seen, most of them have a highly skewed distribution. Using the logarithmic transformation could therefore be preferable.

By taking the logarithm of skewed variables, we achieve a distribution that is more symmetric, where the influence of outliers, also known as extreme values, will be reduced. Consequently, the data tends to exhibit a distribution that aligns more closely with a normal distribution. This transformation can enhance the stability and robustness of our statistical results (Wooldridge, 2009).

Logging all the continuous independent variables when using PPML is also prompted by Joao Santos Silva, one of the authors of the paper " *The Log of Gravity*" (2006). Since the gravity model is exponential and the dependent variable is in levels, while many of the independent variables are in logarithmic form, transforming the continuous variables into log form enables us to interpret the model as a log-log regression, facilitating the representation of elasticities (Silva & Tenreyro, 2006).

3.5 Unbalanced Dataset

Due to missing observations in some variables, the data set is unbalanced, meaning an unequal distribution of data points in the different classes. The variables with most missing values are the dependent variable (import of steel) and the tariff covariate. Although countries like Germany and South Korea were intended to be included since they are among the top producers during the time period of interest, they have to be dropped. This is done to mitigate the dataset's imbalance caused by insufficient available observations, which could potentially introduce bias into the analysis. Additionally, the use of fixed effects helps to control for the unbalanced data set by accounting for unobserved heterogeneity and controlling for time-invariant characteristics.

4 Theoretical Foundation

4.1 The Gravity Model

The gravity model is a commonly used empirical model for analyzing bilateral trade flows, and was first presented by Jan Tinbergen in 1962 (Feenstra, 2002). The model describes trade as a function of the economic size of the trading partners and their distance to each other. Thus, countries with a large production and a short distance tend to trade more. However, trade is not only influenced by the distance between the trading partners but also by the distance between the analyzing countries and all other countries. Therefore, Anderson and Van Wincoop (2003) extended the model by including multilateral trade resistance terms, which gave the model a theoretical foundation.

The structural gravity model, which is the theoretically approved version of the gravity model, is defined as follows:

$$X_{ij} = Y_i Y_j / Y^w (t_{ij} / P_i P_j)^{(1-\sigma)} \tag{1}$$

Where X_{ij} represents exports from country i to country j, Y_i and Y_j denote GDP in the respective countries, and Y^w represents the total world production. Moreover, t_{ij} depicts the trade cost between the two countries of interest, accounting for distance and other trade barriers. Lastly P_i and P_j are referred to as the multilateral resistance terms where the price indices are functions of all bilateral resistances (t_{ij}). P_j is representing the inward multilateral resistance term, which measures the level of market accessibility for the importer j. On the other hand, P_i is defined as the outward multilateral resistance term, which assesses the degree of market accessibility for the exporter i (Yotov et al., 2016). The expression that describes the structural gravity model in its entirety raised to $1 - \sigma$, where σ is the elasticity of substitutions for all available goods (Anderson & Wincoop, 2003).

One of the most fundamental ways to model the unobservable trade cost factor (t_{ij}) was proposed by Anderson and Wincoop (2003) where t_{ij} is hypothesized to be a log linear function with the following specification:

$$t_{ij} = b_{ij} d_{i\,j}^{\rho} \quad (2)$$

This equation indicates that the trade cost factor is a function of bilateral distance, observable factors, and the presence of an international border between country i and j. The variable b_{ij} demonstrates the border barrier between region i and j and is equal to $1+\pi$, where π is the tariff between the countries. For the benchmark scenario, without an introduction of a carbon tariff, $\pi_{ij} = 1$. If the cross-border trade restrictions increase, it will push all price measures above their current levels.

Furthermore, the gravity equation can be transformed into a log-linear specification that is easy to estimate empirically. Since the elasticity is 1 for GDP and -1 for distance (Söderlund, 2023) we end up with the following specification:

$$lnX_{ij} = \sigma + lnY_j + (1-\sigma)lnt_{ij} - (1-\sigma)lnP_i - (1-\sigma)lnP_j + \epsilon_{ij,}t \quad (3)$$

Comparing the bilateral barrier between the two countries to the average trade barriers that both countries face with all of their trading partners, is of importance to understand trade patterns (Anderson & Wincoop, 2003). To control for the fact that the relative trade barriers between two countries not only significantly impact the trade flows between them, but also have an influence on the trade flows with all of their trading partners, multilateral resistance terms can be included. Incorporating these terms helps the model to account for the impact of unobserved trade barriers, resulting in more precise results. Accounting for multilateral resistance terms can be challenging, but various techniques have been developed to tackle this issue. One of the commonly used approaches is to incorporate importer and exporter fixed effects. When using panel data importer-time and exporter-time fixed effects should be incorporated. By including these effects, all time-variant and invariant country-specific characteristics, both observable and unobservable are absorbed (Yotov et al., 2016).

4.2 Comparing Estimators

In the paper "*The Log of Gravity*" the authors criticize the conventional practices when estimating the gravity model and explain why the Poisson Pseudo Maximum Likelihood (PPML) estimator is a better choice (Silva & Tenreyro, 2006).

They start by pointing out how under heteroscedasticity, which gravity models often suffer from, the elasticities of the log-linearized models estimated by ordinary least squares (OLS) will be biased. According to Jensen's inequality the mean of the logarithm of a random variable is not generally equal to the logarithm of its mean (as seen in equation 4). Yet, the expected value will depend on the mean and the variance of the random variables. As a consequence, the results will be biased when the variance of the error term in the multiplicative gravity model is correlated with the independent variables ((Silva & Tenreyro, 2006) (Mnasri & Nechi, 2021)).

$$E(lny) \neq lnE(y) \tag{4}$$

To reduce the bias arising from using OLS, Silva and Tenreyro (2006) argue that constant elasticity models, such as the gravity equation, should be estimated with PPML, where the model is estimated in its multiplicative form. As a result, heteroscedasticity will be controlled for providing more accurate results. To strengthen their argument they compare their results with the estimates of the OLS regression by Tinbergen, 1962 and Anderson and Wincoop, 2003 where they find significant differences in the estimates. E.g., the elasticity of the distance variable, regressing the log-linearized model with OLS by Anderson and Wincoop, 2003 is almost twice as large as when estimating the gravity equation with PPML (Silva & Tenreyro, 2006). Another example of how estimating the log-linearized gravity model with OLS can be misleading is presented in the paper "*Are Distance Effects Really a Puzzle?*", where the result shows an overestimated negative impact of distance on trade over time. A result that is argued to have risen from neglect of Jensen's inequality (Faqin, 2013).

Silva and Tenreyro (2006) continue by discussing the shortcomings of log-linear models estimated by OLS in handling zero trade flows where the natural logarithm of zero is not defined. For instance, in the context of international trade, some country pairs may not engage in trade during certain periods, resulting in zero trade flows. When using OLS, this information is not appropriately controlled for. One common approach to address this issue is to drop the pairs with zero trade flows from the data set. However, Silva and Tenreyro, 2006 criticize this method, as it can introduce measurement errors and inconsistencies in the analysis. Hence, using the PPML estimator will not only control for heteroskedasticity but it also naturally accounts for zero trade flows (Silva & Tenreyro, 2006).

4.3 The Concept of Elasticity

The price elasticity of demand (ϵ) measures the responsiveness of demand to changes in price, expressed in percentage terms. The formula is defined as follows:

$$\epsilon = \frac{\Delta q}{\Delta p} \times \frac{p}{q} \tag{5}$$

I.e., the ratio of price divided by quantity multiplied by the slope of the demand function.

The elasticity of demand generally has a negative sign. Therefore, if the price rises, the demand is expected to decrease (Varian, 2010).

When the price increases, it causes a change in the consumer's purchasing power. This happens due to the decrease in real income resulting from the price increase, which is commonly known as the income effect. In response to this, a rational consumer with a fixed budget would choose to purchase the relatively cheaper alternative when the price of a certain good increases. This is referred to as the substitution effect. The extent of this effect depends on the availability of similar substitutable goods. I.e., if numerous substitutes exist, the elasticity of substitution will be high and vice versa.

The elasticity of a product depends on the interplay between the income and substitution effects, and is influenced by factors such as tariffs and taxes. Since the cost of trade is typically borne by the exporter, an increase in the export cost can dampen the motivation to export the specific good. Consequently, in the context of trade of steel products, the elasticity of substitution between steel varieties can significantly impact the trade of these goods between countries (Jehle & Reny, 2011). Hence, the substitution effect plays a role in shaping trade patterns, as illustrated in the definition of the structural gravity model presented earlier.

5 Empirical Strategy

5.1 Choice of Model

We believe that the structural gravity model with fixed effects will be suitable for our study since it allows us to examine the effect of a policy change on trade flows based on theoretically approved theory. By following the structure of the base model presented by Anderson and Wincoop, 2003 and slightly moderate it to fit our research questions, we will be able to see how the trade flow fluctuates as a response to tariff changes and obtain the elasticity of demand of steel from the included products of interest.

Furthermore, we have chosen to apply the structural gravity model because it has a strong theoretical foundation, is commonly used when analyzing bilateral trade flows, and is known to perform well empirically for these types of estimations. Additionally, this model can be applied to an extensive variety of goods and makes it possible to include fixed effects to account for multilateral resistance. In comparison to Computable General Equilibrium (CGE) models, which also can be used in this type of research, the gravity model demands less extensive data and relies on fewer assumptions. Hence, given our constrained data set, opting for the structural gravity model is a favorable choice. Additionally, gravity models have a stronger link between theory and empirical analysis, are easier to grasp and do not imply complex equations (Larch & Wanner, 2017).

5.2 Model Specification

The model will be estimated in multiplicative form by the Poisson Pseudo-Maximum Likelihood (PPML) estimator and is specified as follows:

$$X_{ij,t} = exp[\alpha_1 lnt_{ij,t} + \alpha_2 RTA_{ij,t} + \alpha_3 lnD_{ij,t} +$$

$$\alpha_4 HScodes_{i,t} + \gamma_{i,t} + \sigma_{j,t} + \zeta_{ij,t}] + \epsilon_{ij,t} (6)$$

The dependent variable X_{ij} represents the steel imports from country i to country j. Moreover, t_{ij}, depicts the tariff which is the independent variable of main interest. RTA is a time-varying variable included to control for bilateral regional trade agreements. This variable is expected to have a positive impact on trade. Diplomatic disagreement is an additional bilateral covariate that varies over time. It signifies situations in which two countries find themselves in conflict, disputes, or facing disagreements. It is measured through examining the distance between the average ideal points within a specific country pair in a given year, where a higher value signifies more tension between the countries of interest. The HSCodes serves as dummy variables representing various steel products, effectively capturing the product fixed effects. These fixed effects control for inherent differences between the various types of steel products. Furthermore, γ_{it} and σ_{jt} depict the importer-time and the exporter-time fixed effects and account for the inwards and outwards multilateral resistance, while $\zeta_{ij,t}$ represents the country-pair fixed effects. The country-pair fixed effects are incorporated in order to account for unobserved heterogeneity specific to each pair of countries during the included years. Incorporating the pair-fixed effects will enable to control for all factors that are unobserved and related to each country pair, such as common border, common language, common religion, social connectedness index and other institutional and cultural variables. Lastly, ϵ_{ij},t represents the stochastic error term. Conventional gravity variables such as distance, GDP, and population are captured by the multilateral resistance terms. Consequently, they should not be included as independent variables in the regression model.

5.3 Controlling for Endogeneity

In the paper "*Trade Liberalization and the Theory of Endogenous Protection: An Econometric Study of U.S. Import Policy*" the author addresses endogeneity as one of the major challenges in obtaining reliable estimates in the gravity model, which arises when trade policy variables are correlated with unobservable cross-sectional trade costs. For example, two countries may be more likely to engage in trade liberalization if they are already significant trading partners. This can lead to issues such as reverse causality, where not only the independent variables explain the dependent variable, but the dependent variable also has a causal effect on the independent variable. One way to address this issue is by incorporating country-pair fixed effects, which helps eliminate the unobservable relationship between the endogenous trade policy covariate and the error term (Trefler, 1993).

5.4 Robustness Check

In order to assess the validity of our approach, a sensitivity analysis is performed where three additional regressions in addition to the PPML are conducted.

The first regression is estimated with the OLS estimator but without any fixed effects since the estimator is not strong enough to account for those effects (Silva & Tenreyro, 2006). Since no fixed effects are applied, the conventional gravity variables such as GDP and distance are included, with the aim of accounting for factors expected to have a causal effect on import. Secondly, we estimate a fixed effects model utilized for analyzing panel data. This model enables us to include fixed effects in one dimension at a time. Since multilateral resistance will not fully be controlled for, the gravity variables will be included in this regression as well. The result is subsequently compared to using a more powerful estimator with a higher capability of accounting for fixed effects. This estimator allows for high-dimensional fixed effects, where both importer/exporter fixed effects, as well as product- and pair fixed effects can be incorporated. As a result, the gravity variables such as GDP and population will be absorbed by the multilateral resistance terms and are therefore not included. However, the variables "RTA" and "diplomatic disagreement" remain in the regression, as the country-pair fixed effects do not account for bilateral time-varying variables. Lastly, the PPML estimator is applied which also allows for the inclusion of all types of fixed effects. By using monte carlo simulations the estimator has proven to behave well for constant elasticity models (Larch & Wanner, 2017).

5.5 Cluster Standard Errors

Normally, independent and identically distributed (IID) error terms are assumed. However, in this regression analysis, we are specifically interested in examining the effects of different clusters represented by steel products and country pairs. Consequently, the regression model is specified with cluster standard errors in order to obtain more reliable results, considering the potential dependence within each cluster, by accounting for serially correlated errors within country pairs over time (Mckenzie, 2017).

5.6 Heteroscedasticity Test

To see if heteroskedasticity is present the White's test is performed (see Table 8). The null hypothesis, which asserts the presence of homoscedasticity is not rejected (p-value of 0,0065). As a result, there is no indication of heteroskedasticity.

Table 8: White's Test of Heteroscedasticity: Cameron and Trivedi's Decomposition of IM-test

Source	**Chi2**	**Df**	**p**
Heteroskedasticity	182.67	138	0.0065
Skewness	.	20	.
Kurtosis	.	1	.
Total	.	*159*	.

6 Results

Table 9: Regression Table Including all Four Regressions

VARIABLES	OLS Regression Log_Impofsteel	1 dim. FE Regression Log_Impofsteel	High dim. FE Regression Log_Impofsteel	PPML Impofsteel
Log_Tariff_Numeric	-0.187***	-0.189***	-0.0491	-0.489***
	(0.0717)	(0.0719)	(0.112)	(0.183)
HS Code				
7207			0.0941	1.035***
			(0.183)	(0.262)
7218			-0.967***	-0.486**
			(0.190)	(0.222)
7219			-1.179***	-0.568***
			(0.185)	(0.205)
7220			-1.324***	-0.625***
			(0.181)	(0.197)
7221			-0.798***	-0.463**
			(0.182)	(0.193)
7222			-2.035***	-0.856***
			(0.194)	(0.197)
7223			-2.185***	-0.763***
			(0.210)	(0.200)
7224			-0.750***	-0.409*
			(0.189)	(0.246)
7225			-0.230	0.130
			(0.179)	(0.285)
7226			-1.222***	-0.657***
			(0.187)	(0.234)
7227			-0.203	-0.204
			(0.178)	(0.231)
7228			-1.422***	-0.348
			(0.185)	(0.250)
7229			-1.472***	-0.596***
			(0.188)	(0.187)
RTA	-0.365***	-0.195	0.992***	0.263
	(0.137)	(0.163)	(0.272)	(0.167)
Log_Diplodisagree	-0.136***	-0.139***	0.0721	0.0752
	(0.0319)	(0.0411)	(0.0521)	(0.0588)
Distance	-000061***	-.000023*		
	(.000012)	(.000013)		
Log_Pop_d	0.205***	0.361		
	(0.0359)	(0.371)		
Log_Gdp_d	-0.415***	-2.674		
	(0.0259)	(4.136)		
Exp_time		0.0116***		
		(0.00209)		
Constant	21.51***	65.60	15.45***	17.84***
	(0.602)	(85.64)	(0.256)	(0.500)
Observations	7,326	6,538	6,538	6,540
R-squared	0.039	0.012	0.267	
Number of panel_id		78		

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

Table 9 shows the results from including all variables and using different estimators. The first column depicts the results from the regression estimated by OLS, followed by the two fixed effects models in the second and third column and lastly the regression estimated using PPML in the fourth column.

In the first regression, estimated with OLS, the impact of the tariff on import is statistically significant at a confidence level of 99%. However the R-squared value is low, indicating that the model poorly explains the variation in the level of import of steel. Note that R-squared is not applicable to nonlinear regression models. Therefore, comparing R-squared values in this study becomes meaningless. The remaining gravity variables largely confirm the expectations set by trade theory. The Regional Trade Agreement (RTA) variable is significant at a 99 % confidence level and indicates that if the countries are part of a Regional Trade Agreement, trade of steel is expected to increase as much as 30.6 % holding all other factors constant. Diplomatic disagreement is also highly significant and demonstrates a negative relationship. Furthermore, distance is significant at a 99 % confidence level but only shows a moderate negative impact on import within this model. Additionally, the population variable shows that a 1% increase in population is associated with a 0.2% increase in imports. Lastly, if the destination country increases its GDP by 1 %, the import of steel is expected to be reduced by 0.4 %.

Moving on to the second regression, the tariff variable is somewhat more statistically significant (a t-value of -2.86 compared to -2.60). Also in this regression, the coefficient shows a negative relationship, which is consistent with the expected relationship. The level of significance diminishes for certain gravity covariates. This could potentially indicate that the significance of variables in the OLS estimation is overstated, which could partly be due to a higher degree of omitted variable bias.

In the third regression, which incorporates additional fixed effects, the coefficient of the RTA variable aligns with the anticipated direction of the effect and most of the coefficients of the product varieties are significant. Nevertheless, the coefficient of the tariff variable is statistically insignificant. It could possibly be caused by the high amount of fixed effects in comparison to the number of observations.

Lastly, in the fourth regression where the PPML estimator is applied, the tariff is significant at a 99% level and maintains a negative relationship. Furthermore, the significance of other regressors diminishes. The higher number of fixed effects reduces the degrees of freedom and could thus be the reason why the variables RTA and diplomatic disagreement are insignificant by causing an overfitted model (Shepherd, 2019). However, the stronger power of the estimator effectively addresses factors such as zero trade flows. Since this is not controlled for in the other models, it can cause biased results and incorrect significance levels. Since the PPML also allows us to include a high dimension of fixed effects, it reduces the risk of omitted variable bias which speaks in favor of this model. Moreover, this could also explain why the significance of variables differs and thus provide more precise results. Another advantage is the capacity to incorporate clustering based on country pairs. Furthermore, the impact of the tariff is most pronounced comparing the coefficients of all 4 regressions in Table 9.

We proceed by delving further into the analysis of the PPML regression. The coefficient of -0.489 associated with the tariff variable signifies that, holding all other factors constant, a 1% rise in the tariff of the reporting country is projected to correspond to an approximate 0.49% reduction in the import of the destination country for the average steel product. The finding in this regression regarding the tariff variable is aligned with the general conclusions of Cipollina and Salvatici (2019), Shang et al. (2019), and Cigna et al. (2019), that all have reported a significant impact of tariffs. Moreover, it is likely that constructing our own data set from scratch and thus having a relatively small sample size contributes to the insignificance of the RTA and diplomatic disagreement variables in this regression.

All of the various steel products exhibit significance either at a 95 % or 99 % confidence level, except for the products with HS codes 7225, 7227 and 7228. For these products, the variance is too high to indicate a significant effect.

Table 10 displays the steel products' elasticities, compared to the reference group which is the product with HS-code 7206. The interpretation of the dummy variables can be obtained using the following formula:

$$(e^{\beta-1})100 = xx\% \tag{7}$$

Where β corresponds to the coefficient of the specific steel product. The diverse products show notable variations in their sensitivity to tariffs. For instance, the elasticity of product 7206 is 57.5 % higher compared to product 7222 and 48.2 % higher compared to product 7226. The only product with a greater elasticity than 7206 is product 7207. This product code, which corresponds to semifinished nonalloy steel products, demonstrates a noticeable distinction with an elasticity that is 181.5 % higher compared to the second most responsive commodity.

Table 10: Elasticities of Different Steel Products

7224	-33.5%
7221	-37.1%
7218	-38.5%
7219	-43.3%
7229	-44.9%
7220	-46.5%
7226	-48.2%
7223	-53.4%%
7222	-57.5%
7207	+181.5%

We also conducted a targeted regression analysis, centering on the United States as the importing country, and dropping all exporters except for one, to assess the impact on a bilateral level. Nevertheless, our findings showed insignificant results. This underscores the importance of encompassing a wider range of countries and data when applying this model.

7 Conclusion

In this study, the structural gravity model has been applied to estimate the impact of carbon border tariffs on the steel sector, including data on 9 of the world's largest steel producers.

By analyzing the result it becomes clear that various steel products respond differently to tariff levels and possess differing elasticities. Therefore, the justification for implementing import tariffs at varying levels to achieve the intended outcome is supported. The results also reveal that import tariffs on steel can be an effective measure for reducing imports. Utilizing this policy to reduce the import from countries with a carbon intensive production and to relocate the production to countries with a more sustainable production could thus have a substantial influence on the total global emissions. Especially since steel is one of the major contributors to global warming. Furthermore, the policy proposal of implementing a carbon border tariff in the United States appears both valid and promising in terms of its potential impact on the climate. Given the limitations of the manually constructed data set used in this study, a more comprehensive analysis involving a wider range of countries and including all types of steel products could provide valuable insights of the true impact and consequently a more accurate assessment of what tariff rate to apply. To narrow the study's focus, by particularly examining the tariff levels in the United States and Europe, would also provide valuable insights regarding the policy proposal in the United States and the intended collaboration between the United States and the European Union. We also tried to look specifically at the United States as the importing country, while including various exporting countries. However, this approach yielded insignificant results, likely due to the even more limited amount of data. In order to delve deeper into the effects of bilateral trade flows, it might be more appropriate to explore alternative modeling approaches.

Considering that the impact of policy decisions, such as implementing tariffs, usually takes time to manifest in reality, it would have been beneficial to incorporate lagged variables. This adjustment would account for the time delay it takes to adjust and yield a more accurate representation of the time-dependent relationship. Another way to control for the time delay could have been to include more years within each interval, instead of including data on every third year.

If this study were to be conducted again and the time aspect would be less critical, we would also encompass more countries and years. The significance of having an extensive data set becomes even more pronounced when analyzing tariff data, given its limited availability for numerous years and countries. Incorporating intra-specific variables would also have added value. Benedikt, Mario, and Yotov, 2021 argue for the inclusion of intra-specific data in addition to international trade data when performing the structural gravity model with fixed effects and non-discriminatory trade policy. The reason for this is that these variables can be included without the risk of being absorbed by the importer and exporter fixed effects, which in turn need to be included to control for multilateral resistance (Benedikt, Mario, & Yotov, 2021). In this paper, we include data on discriminatory tariffs (selected tariffs for different countries) instead of non-discriminatory policies like Most Favored Nation (MFN) tariffs. However, we believe that the inclusion of intra-specific data could still have been beneficial, since those variables would not be captured by the fixed effects and thus allow us to account for intra-national heterogeneity. Furthermore, performing the same study using an alternative methodology, such as CGE models, could also be valuable as a robustness check to assess the alignment of the results.

What holds significant importance when designing new policies is to consider how other countries could react. If the United States and the EU form a trade agreement where the tariffs of the steel products will be lower for the participating countries, trade diversion could arise. This could cause a shift in trade patterns, moving away from more efficient producers outside the Union to higher-cost producers within the Union. However, considering that both the United States and Europe are prominent players in the trade of steel and use efficient and environmentally friendly production methods, this effect might still be rather limited and can also have a positive effect from an environmental perspective. In addition, if taxation measures are overly stringent, there is a potential risk of e.g., triggering trade wars. Nevertheless, interests are not always aligned, and despite the potential negative outcomes it could lead to, the significance of taking a stand for the climate might still outweigh other negative consequences. Additionally, even if countries react in a negative manner, the United States would still be able to engage in trade within the agreement with the EU, where all countries adhere to clean production practices. Subsequently, the adverse effects might not be as severe as it would be for countries lacking strong trade relationships.

Employing discriminatory tariffs could be effective if the goal is to target specific countries, like China, due to their carbon intensive production and substantial market share (Lawder, 2022). According to Zhang et al., 2019, if the US were to impose a \$50 carbon tariff on Chinese exports in the oil and nuclear industries, it would have resulted in a 32% reduction in exports in 2020, which would then decline to 15% by 2030 when the country has adjusted. This significant effect demonstrates the power of the policy. However, such a move might also trigger retaliatory measures and would not be as powerful as non-discriminatory tariffs when it comes to carbon leakage. Thus, a non-discriminatory tariff as discussed in the United States, targeting all countries in a uniform manner would make sure that the higher emitting countries pay for their pollution while the same terms are applied to all countries.

Another factor that should not be overlooked is the impact on developing countries that are striving to industrialize. These countries are likely to be negatively affected by the tariff policy in the short-run. However, we believe that since there is only a matter of time before all countries will have to adjust to cleaner technology practices, countries in the process of industrializing could benefit from adopting the most advanced and environmentally friendly technology from the outset. Accordingly, we believe that it can give them advantages over countries that have consistently utilized polluting techniques from the start, and might be less willing to modify their production methods. Additionally, since many developing countries are at a greater risk of climate catastrophes, they have much to gain by promoting cleaner production processes.

For further studies in this field of research, it would be interesting to delve more into the assessment of whether discriminatory or non-discriminatory tariff policies appear more advantageous, both from a societal and environmental perspective. It would also be valuable to get more insight into the CBAM, and to evaluate how well it performs when it has been in place for a certain period. Considering that there are additional industries, like the food sector, which also contribute significantly to emissions, it would be interesting to compare the effect of border tariffs between highly polluting sectors. Consequently, expanding the scope of the United States Green Steel Club by including more critical sectors might yield additional environmental benefits.

As discussed in the literature review, while tariffs might generate favorable outcomes in terms of reducing the globally carbon footprint, it may also lead to unemployment and other negative effects on social welfare. Even if import tariffs are applied to foreign countries and businesses, the costs are often borne by consumers in the tariff-imposing-country (Tax Foundation, 2023). Hence, delving deeper into the welfare effects would provide valuable insights, since it is an essential factor to be aware of during policy decisions.

If we were to expand the study, it would also have been interesting to run the same regression, but with export as the dependent variable to ascertain whether export decreases in the originating country or if the exporting nations are intensifying trade with alternative partners or discovering new trading dynamics. Furthermore, a valuable addition would involve calculating the exact carbon footprint for each product, considering various production practices. This would enable the examination of how the total emissions coming from steel production differs among countries.

Finally, since steel tariffs is a remarkably unexplored area of research, further investigation in this field is important. Global warming has progressively intensified and is emerging as one of the greatest challenges of our time. It is time to take action and utilize all available means to mitigate the warming if we want to sustain our presence on this planet.

References

Amiti, Mary, Stephen J. Redding, and David E. Weinstein (Nov. 2019). The Impact of the 2018 Tariffs on Prices and Welfare, in: *Journal of Economic Perspectives*, vol. 33, no. 4, pp. 187–210 (cit. on p. 7)

Anderson, James E. and Eric van Wincoop (2003). Gravity with Gravitas: A Solution to the Border Puzzle, in: *The American Economic Review*, vol. 93, no. 1, pp. 170–192 (cit. on pp. 17–19, 21)

Andersson, Marja (2023). Stor klimatrapport släppt. URL: `https://www.svt.se/nyheter/nyhetstecken/stor-klimatrapport-slappt` (cit. on p. 1)

Benedikt, Heid, Larch Mario, and Yoto Yotov (2021). Estimating the effects of non-discriminatory trade policies within structural gravity models, in: *Canadian Journal of Economics/Revue canadienne d'économique*, vol. 54, no. 1, pp. 376–409 (cit. on p. 30)

Blokhin, Andriy (2023). The 5 Countries That Produce the Most Carbon Dioxide (CO2). URL: `https://www.investopedia.com/articles/investing/092915/5-countries-produce-most-carbon-dioxide-co2.asp` (visited on 08/12/2023) (cit. on p. 2)

Brent, Radcliffe (2023). The Basics of Tariffs and Trade Barriers. URL: `https://www.investopedia.com/articles/economics/08/tariff-trade-barrier-basics.asp` (visited on 08/14/2023) (cit. on p. 3)

Cheng, I-Hui and Howard J. Wall (2005). Controlling for Heterogeneity in Gravity Models of Trade and Integration, in: *FEDERAL RESERVE BANK OF ST. LOUIS REVIEW*, vol. 87, pp. 49–63 (cit. on p. 8)

Cigna, Simone, Philipp Meinen, Patrick Schulte, and Nils Steinhoff (Jan. 2022). The impact of US tariffs against China on US imports: Evidence for trade diversion?, in: *Economic Inquiry*, vol. 60, no. 1, pp. 162–173 (cit. on p. 7)

Cipollina, Maria and Luca Salvatici (Sept. 2019). The Trade Impact of EU Tariff Margins: An Empirical Assessment, in: *Social Sciences*, vol. 8, no. 9, p. 261 (cit. on p. 6)

Conte M., P. Cotterlaz and T. Mayer (2022). The CEPII Gravity database. URL: http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele_item.asp?id=8 (cit. on p. 8)

Cox, Lydia (Feb. 2023). The Long-Term Impact of Steel Tariffs on U.S. Manufacturing, in: *Yale University*, (cit. on p. 7)

ESCWA (2023). trade diversion. URL: https://archive.unescwa.org/ (visited on 08/14/2023) (cit. on p. 3)

European Commission (2023a). Carbon Border Adjustment Mechanism. URL: https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en (visited on 08/12/2023) (cit. on pp. 2, 3)

European Commission (2023b). Carbon leakage. URL: https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/free-allocation/carbon-leakage_en (visited on 08/12/2023) (cit. on p. 1)

Faqin, Lin (2013). Are distance effects really a puzzle?, in: *Economic Modelling*, vol. 31, pp. 684–689 (cit. on p. 19)

Feenstra, Robert (Feb. 2002). Border Effects and the Gravity Equation: Consistent Methods for Estimation, in: *Scottish Journal of Political Economy*, vol. 49, pp. 491–506 (cit. on pp. 4, 17)

Gammadigbe, Vigninou (2021). Is Regional Trade Integration a Growth and Convergence Engine in Africa? (Cit. on p. 3)

Gearino, Dan (2021). Inside Clean Energy: From Sweden, a Potential Breakthrough for Clean Steel. URL: https://insideclimatenews.org/news/24062021/inside-clean-energy-clean-steel-sweden/ (cit. on p. 1)

Helge Sigurd Næss-Schmidt, Martin Bo Westh Hansen, Sixten Rygner Holm, and Bjarke Modvig Lumby (2019). Carbon leakage in the Nordic countries What are the risks and how to design effective preventive policies? URL: https://norden.diva-portal.org/smash/get/diva2:1306902/FULLTEXT01.pdf (visited on 08/12/2023) (cit. on p. 1)

Hsueh, Chin (2023). China's 3 Pathways to Green Steel. URL: https://thediplomat.com/2023/02/chinas-3-pathways-to-green-steel/ (cit. on pp. 2, 4)

International Trade Administration (2023). Harmonized System (HS) Codes. URL: https://www.trade.gov/harmonized-system-hs-codes (visited on 08/12/2023) (cit. on p. 4)

IPCC (2023). Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. URL: https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf (visited on 08/12/2023) (cit. on p. 1)

Jehle, Geoffrey A. and Philip J. Reny (2011). Advanced Microeconomic Theory, : Pearson (cit. on p. 20)

Larch, Mario and Joschka Wanner (2017). Carbon tariffs: An analysis of the trade, welfare, and emission effects, in: *Journal of International Economics*, vol. 109, pp. 195–213 (cit. on pp. 21, 23)

Lawder, David (2022). U.S. floats new steel, aluminum tariffs based on carbon emissions. URL: https://www.reuters.com/business/sustainable-business/us-floats-new-steel-aluminum-tariffs-based-carbon-emissions-2022-12-08/ (cit. on pp. 2, 3, 30)

Mckenzie, David (2017). When should you cluster standard errors? New wisdom from the econometrics oracle. URL: https://www.ewf.uni-bayreuth.de/en/research/RTA-data/index.htmhttps://blogs.worldbank.org/impactevaluations/when-should-you-cluster-standard-errors-new-wisdom-econometrics-oracle (cit. on p. 23)

Mnasri, Ayman and Salem Nechi (2021). New nonlinear estimators of the gravity equation, in: *Economic Modelling*, vol. 95, pp. 192–202 (cit. on pp. 4, 19)

Pooler, Michael (2021). 'Green steel': the race to clean up one of the world's dirtiest industries. URL: https://www.ft.com/content/46d4727c-761d-43ee-8084-ee46edba491a (cit. on p. 1)

Savage, Maddy (2021). The race across Europe to build green steel plants. URL: https://www.bbc.com/news/business-64538296 (cit. on p. 1)

Shepherd, Ben (2019). The Gravity Model of International Trade: A User Guide. URL: https://www.unescap.org/sites/default/files/Gravity-model-in-R_1.pdf (visited on 08/12/2023) (cit. on p. 26)

Silva, J. M. C. Santos and Silvana Tenreyro (Nov. 2006). The Log of Gravity, in: *The Review of Economics and Statistics*, vol. 88, no. 4, pp. 641–658 (cit. on pp. 16, 18, 19, 23)

Söderlund, Bengt (2023). Lecture notes in Computer Assisted Diagnosis. Advanced Trade Theory (NEKN72) Gravity and the Empirical Assignment (cit. on p. 18)

Tax Foundation (2023). Tariff. URL: https://taxfoundation.org/taxedu/glossary/tariffs/ (visited on 08/14/2023) (cit. on p. 31)

The World Bank (2023). Trade Analysis Information System (TRAINS). URL: https://databank.worldbank.org/source/unctad-%5E-trade-analysis-information-system-(trains)# (cit. on pp. 8, 11)

Tinbergen, Jan (Jan. 1962). Shaping the World Economy; Suggestions for an International Economic Policy, : T (cit. on p. 19)

Trefler, Daniel (1993). Trade Liberalization and the Theory of Endogenous Protection: An Econometric Study of U.S. Import Policy, in: *Journal of Political Economy*, vol. 101, no. 1, pp. 138–160 (cit. on p. 22)

UN Comtrade (2023). Trade Data. URL: https://comtradeplus.un.org/TradeFlow (cit. on p. 8)

UNFCCC (2023). The Paris Agreement. What is the Paris Agreement? URL: https://unfccc.int/process-and-meetings/the-paris-agreement (visited on 08/12/2023) (cit. on p. 1)

Universität Bayreuth (2023). RTA Data. URL: https://www.ewf.uni-bayreuth.de/en/research/RTA-data/index.html (cit. on p. 8)

Varian, Hal R. (2010). Intermediate Microeconomics: A Modern Approach, : W. W. Norton Company (cit. on p. 20)

Wooldridge, Jeffrey Marc (2009). Introductory Econometrics: A Modern Approach, : South-Western (cit. on p. 15)

World Customs Organization (2022). Chapter 72: Iron and Steel. URL: https://www.wcoomd.org/-/media/wco/public/global/pdf/topics/nomenclature/instruments-and-tools/hs-nomenclature-2022/2022/1572_2022e.pdf?la=en (visited on 08/14/2023) (cit. on p. 11)

World Steel Association (2021a). Climate change and the production of iron and steel. URL: https://worldsteel.org/wp-content/uploads/Climate-policy-paper-2021-1.pdf (visited on 08/12/2023) (cit. on p. 1)

World Steel Association (2021b). Fact Sheet: Advanced steel applications. URL: https://worldsteel.org/wp-content/uploads/Fact-sheet-Advanced-steel-applications.pdf (visited on 08/14/2023) (cit. on p. 2)

World Steel Association (2023). December 2022 crude steel production and 2022 global crude steel production totals. URL: https://worldsteel.org/media-centre/press-releases/2023/december-2022-crude-steel-production-and-2022-global-totals/ (visited on 08/12/2023) (cit. on pp. 2, 9)

Yotov, Yoto V., Roberta Piermartini, José-Antonio Monteiro, and Mario Larch (2016). An Advanced Guide to Trade Policy Analysis: The Structural Gravity Model. URL: https://www.wto.org/english/res_e/booksp_e/advancedwtounctad2016_e.pdf (visited on 08/12/2023) (cit. on pp. 9, 17, 18)

Zhang, Wenwen, Shichun Xu, Zhengxia He, Basil Sharp, Bin Zhao, and Shuziao Wang (2019). Impacts of U.S. Carbon Tariffs on China's Foreign Trade and Social Welfare, in: *Sustainability*, vol. 11, no. 19, (cit. on pp. 6, 7, 30)