Climate Wars and Climate Talks:

The Effect of the Carbon Border Adjustment Mechanism on Global Emissions and Trade

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Abstract

This study investigates the effect of the carbon border adjustment mechanism (CBAM) on global emissions and trade. We begin with a scenario in which the European Union (EU) increases its emission tax by 20 percent and imposes the CBAM by raising import tariffs 50 percent unilaterally. The increase in the emission tax causes carbon leakage that induces foreign exports to increase in the EU and then CBAM restores the EU's domestic production. Then, we investigate the possibility of retaliation by other regions creating a trade war as a noncooperative tariff-setting equilibrium. This climate-initiated trade war or "climate war" leads to a large 62 percent decline in the volume world trade, exceeding the reduction that would occur in the case of a trade war without climate concerns. The effective method of reducing global emissions is the climate talks scenario, under which all regions raise emission taxes equally. Under this scenario, global emissions decrease by 73 percent and world trade by only 2.9 percent. We examine another form of climate talks, which is the CBAM scheme consistent with the procedure of General Agreement on Tariffs and Trade Article 23 in the World Trade Organization (WTO). This process reduces emissions by 45 percent, although it decreases trade by 17 percent. These results suggest that global cooperation on carbon reduction needs to be achieved through the multilateral free trade system under the WTO rules.

Key Words: *Climate changes, emission taxes, carbon leakage, carbon border adjustment mechanism, trade wars, global emissions*

JEL Classification Number: F13, F18, Q54, Q58

1. Introduction

To tackle global warming, reducing worldwide carbon emissions is a key target of the international community. In addition to innovations in carbon emission abatement technology and offset activities, such as planting, a direct policy such as a carbon or emission tax must be adopted. The inherent problem in the international world is carbon leakage: Carbon emissions decrease in stringent emission policy regions, whereas they may increase in countries with less strong emission policies. Rigorous regulations may hamper domestic production, and lead to an increase in imports from the countries with less stringent policies. As a result, the worldwide level of carbon emissions may increase due to the boom in less-regulated countries. The purpose of the carbon border adjustment mechanism (CBAM) is to mitigate the carbon leakage problem.

A CBAM is intended to equalize the burden of carbon emissions within and across regions. It effectively takes the form of an import tariff. A CBAM is implemented on the imports from countries where carbon regulation is less stringent than in the importing countries. This reduces such imports and thus dampens their output, which achieves the lower emission level, and restores the competitiveness of domestic industries affected by high regulation. However, such a policy has an impact not only on emissions but also on trade. If importing countries make CBAMs discretionary, then the cost and uncertainty of international trade increase. The transparency of trade policy is ascertained by the multilateral trading system of which the World Trade Organization (WTO) is the foundation. A unilateral trade burden increase may initiate WTO disputes. It is not clear whether CBAMs can be treated as a general exception in the General Agreement on Tariffs and Trade (GATT) Article 20 of the WTO. Nor is it clear whether there is a procedure for introducing CBAMs that is consistent with WTO rules. Thus, the degree of the burden that a CBAM imposes on trade needs to be understood to evaluate the effective policy instruments to tackle global warming.

Global warming and international trade have been studied extensively (Copeland and Taylor 2005). Carbon leakage is the key issue in analyzing the interaction between emissions and trade. Our study investigates environmental policy, trade policy, and international coordination in a quantitative general equilibrium model with trade policy. The quantitative general model of international trade has been a workhorse of the research on trade and environment (Larch and Wanne 2017, Shapiro and Walker 2018, Duan et al. 2021, Klotz and Sharma 2023). The literature has examined the effect of a carbon tariff on carbon leakage (Larch and Wanne 2017) and the validity of the pollution haven hypothesis (Duan et al. 2021). The issue of carbon leakage that we study is similar, but we investigate the trade negotiation aspects by employing the framework of Ossa (2014) with carbon emissions incorporated. Because international cooperation and negotiation is a key aspect of international climate policy, incorporating trade negotiations in the analysis is essential to understand the implications of trade policy for global emissions. In this sense, we consider the international negotiations at the WTO as well as the United Nations Framework Convention on Climate Change (UNFCCC) and Conference of the Parties (COP). Although Duan et al. (2021) demonstrate the case in which pollution taxes are set as a Nash equilibrium, to our knowledge, trade policy negotiations and cooperation have not been examined in the global warming context. Thus, this paper contributes to the literature by demonstrating the influence of negotiations on world trade and the environment on global emissions and international trade quantitatively.

We consider five hypothetical scenarios. First, we consider the situation in which the EU increases the emission tax within the region by 50 U.S. dollars per ton (approximately 20 percent). This leads to carbon leakage and thus increases foreign exports to the EU. Then, the second scenario is that the EU introduces a CBAM to restore domestic production, which involves a 50 percent import tariff. This type of emission content tariff or carbon tariff has been examined in the literature (Copeland 1994, Larch and Wanne 2017). We extend the analysis of possible outcomes one step further because, although a CBAM may reduce global emission levels, it may cause retaliation by other regions. This third scenario can be referred to as a "climate war" because the trade war that ensues is motivated by climate policy. We describe this climate war in which countries impose their optimal tariffs and explain how equilibrium is attained as a noncooperative tariff-setting equilibrium. This climate war reduces global emissions by 2.5 percent, but it significantly dampens world trade, leading to a 63 percent decline.

The fourth scenario is climate talks, under which all regions raise the emission tax level equally by 50 U.S. dollars per ton. It is well known that an efficient policy affects the target directly; thus, emission taxes are the most efficient policy to reduce global emissions. This scenario reduces emissions by 73 percent.

Finally, we consider a fifth scenario in which countries introduce CBAMs in a consistent manner with the guidance of the WTO. As mentioned, trade negotiations at the WTO are a key feature of the multilateral trading system. Thus, it is possible that the negotiations over climate policy take place under the WTO rules. A WTO-consistent CBAM procedure has been proposed by Staiger (2022), who stated that GATT Article 23 describes the procedure for tariff renegotiations, and that a procedure consistent with Article 23 does not violate the WTO rule. That is, if countries imposing CBAMs set most-favored-nation (MFN) tariffs to keep market access at the pre-CBAMs level, such tariffs offsetting disadvantages caused by domestic carbon taxes are consistent with the WTO tariff renegotiation rule. Although in Staiger (2022), one more step is proposed (cutting the CBAMs of the industrialized countries associated with tariff reductions in emerging economies), we analyze the first two steps: the introduction of a CBAM and then the imposition of tariffs that restore the market access of CBAM-imposing countries. We consider that four major countries and regions, China, the EU, Japan, and the U.S., raise their own carbon taxes and we attempt to solve the tariff rates that make those countries export the same level as before the carbon tax increases. As a result, under this scenario, although world trade decreases by 17 percent, global emissions decline by 45 percent, suggesting that such a WTO-consistent procedure is a useful mechanism for carbon reduction and avoiding climate wars.

The analysis implies that the effective way of tackling global warming is to raise emission taxes coordinately worldwide. Thus, the goal of the UNFCCC and COP is an efficient way of dealing with carbon reductions. However, incorporating trade policies into the solution to climate change leads to the deterioration of world trade and may cause unnecessary harm to the world economy. Thus, another option, that is, the WTO-consistent

CBAM, can be a potential solution for an international cooperation scheme. The cooperation on emission reductions under the UNFCCC-COP and WTO frameworks is a key element of a feasible solution to global warming.

The risk of climate wars is realistic. On April 25, 2023, the Council of the EU adopted a CBAM.[1] U.S. and China raised their concerns that the CBAM may lead to disguised trade protection. If countries try to solve CBAM problems and the WTO fails to do so because of the halting of the Appellate Body of Dispute Settlement mechanism, trading partners may take retaliatory actions. As a result, the goal to reduce global emissions entails unnecessary turmoil in international trade and the world economy. Our results suggest that such climate wars are not an efficient method of reducing global emissions. Rather, coordinated emission reduction is the most efficient policy. Thus, CBAMs should be kept to a minimum to ensure consensus on uniform reductions in carbon emissions worldwide. Furthermore, a CBAM scheme that is consistent with the WTO rules reduces global emissions substantially without severely dampening world trade. Hence, efforts under both the UNFCCC-COP and WTO frameworks may yield a reasonable solution.

2. Model

This study is based on the model of Ossa (2014), which analyzes global trade policy effects with emissions incorporated following Copeland and Taylor (1994). The world consists of seven regions, Brazil, China, the EU, India, Japan, the U.S., and the rest of the world (ROW). The governments of each region can adopt trade and emission policies. Trade policy takes the form of import tariffs, and the emission policy is an emission tax.

Consumer preferences in each region are expressed by the following constant elasticity of substitution utility function:

$$U_j = \Pi_s(\sum_i \int_0^{M_{is}} x_{ijs}(\nu_{is})^{(\sigma_s-1)/\sigma_s} d\nu_{is})^{\frac{\sigma_s}{\sigma_s-1}\mu_{js}} - \Gamma(\sum_i e_i), \tag{1}$$

[1]Press Release: https://www.consilium.europa.eu/en/press/press-releases/2023/04/25/fit-for-55-council-adopts-key-pieces-of-legislation-delivering-on-2030-climate-targets/

where x_{ijs} is the quantity of goods produced by industry s in country i that are imported by country j, M_{is} is the mass of industry s in country i, σ_s is the elasticity of substitution, and μ_{js} is the expenditure share of industry s goods in country j. The function Γ captures the damage from climate change. This depends on the world emission level, not individual regional emissions.

Firms compete in a monopolistically competitive fashion. They are homogeneous and use labor for production or emission abatement. Their technology is summarized by the simplified version of Copeland and Taylor (1994), where firms use labor resources from production to reduce emissions:

$$d_{ijs}x_{ijs} = (1 - \theta_{ijs})l_{ijs}\psi_{is} \tag{2}$$

$$e_{ijs} = (1 - \theta_{ijs})^{1/\alpha_{ijs}} l_{is}\psi_{is}, \tag{3}$$

where d_{ijs} is iceberg trade costs, θ is the share of resources devoted to abate emissions, l_{ijs} is labor inputs, ψ_{is} is a productivity parameter, and the parameter α_{ijs} is referred to as the pollution elasticity. The pollution elasticity represents the elasticity of emission intensity with respect to emission abatement intensity (Shapiro and Walker 2018).

Then, the emission intensity is derived by eliminating the labor share devoted to reducing emissions:

$$d_{ijs}x_{ijs}/e_{ijs}^{\alpha_{ijs}} = (\psi_{is}l_{ijs})^{1-\alpha_{ijs}} \tag{4}$$

The introduction of emissions in the model is discussed in the literature (Copeland and Taylor 2003, Shapiro and Walker 2018). In principle, we allow α_{ijs} to vary over origin countries, destination countries, and sectors. However, as a first step and for brevity, we set the common α, such that $\alpha_{ijs} = \alpha$. Firms in region i in sector s pay emission tax, ϵ_{ijs}, for one unit of production to market j. For the same reason, we set $\epsilon_{ijs} = \epsilon$.

A firm's total production and emission costs are characterized by a cost function

(Forslid et al. 2018). Cost minimization yields the following cost function:

$$c(x_{ijs}) = \epsilon_i^{\alpha_{is}} w_i^{1-\alpha_{is}} \kappa \psi_{is}^{\alpha-1} d_{ijs} x_{ijs} \tag{5}$$

Shephard's lemma provides us with the emission level:

$$\partial c(x_{ijs})/\partial \epsilon_{is} = e_{ijs} = \alpha_{is} \epsilon_i^{\alpha-1} w_i^{1-\alpha} \kappa \psi_{is}^{\alpha-1} d_{ijs} x_{ijs} \tag{6}$$

Governments impose an ad valorem import tariff with tariff rate, t_{ijs}, and let denote $\tau_{ijs} = 1+t_{ijs}$. Thus, firms in region i face the demand in market j: $x_{ijs} = (p_{is} d_{ijs} \tau_{ijs})^{-\sigma} \mu_{js} X_j / P_{js}^{1-\sigma}$. Firms maximize the following profits with respect to price:

$$\pi_{ijs} = p_{is} d_{ijs} x_{ijs} - \epsilon_i^{\alpha} w_i^{1-\alpha} \kappa \psi_{is}^{\alpha-1} d_{ijs} x_{ijs} \tag{7}$$

Then, the resulting optimal free-on-board price is:

$$p_{is} = \frac{\sigma_s}{\sigma_s - 1} \epsilon_i^{\alpha_s} w_i^{1-\alpha_s} \kappa \psi_{is}^{\alpha_s - 1} \tag{8}$$

This is the markup price over the production and emission costs.

Substituting this into profits yields:

$$\begin{aligned} \pi_{is} &= \sum_j M_{is} (p_{is} d_{ijs} x_{ijs} - \epsilon_i^{\alpha} w_i^{1-\alpha} \kappa \psi_{is}^{\alpha-1} d_{ijs} x_{ijs}) \\ &= \frac{1}{\sigma_s} \sum_j M_{is} \tau_{ijs}^{-\sigma_s} \left(\frac{\sigma_s}{\sigma_s - 1} \frac{d_{ij} \epsilon_i^{\alpha_s} w_i^{1-\alpha_s} \kappa \psi_{is}^{\alpha_s - 1}}{P_{js}} \right)^{1-\sigma_s} \mu_{js} X_j \end{aligned} \tag{9}$$

This is a profit function, and we assume a fixed number of market entries, with the number of producer equal to M_{is}. Thus, in equilibrium, there is positive profit, and this profit is considered by the government in its optimization exercise.

Let L_i denote the labor supply in region i. The wage rate is determined by the labor market clearing condition:

$$
\begin{aligned}
L_i &= \sum_s M_{is} \sum_j l_{ijs} \qquad (10)\\
&= \sum_s M_{is} \sum_j (1-\alpha_s)\epsilon^{\alpha} w_i^{-\alpha} \kappa \psi_{is}^{\alpha-1} d_{ijs} x_{ijs}\\
&= \sum_s M_{is} \sum_j (1-\alpha_s)\epsilon^{\alpha} w_i^{-\alpha} \kappa \psi_{is}^{\alpha-1} d_{ijs} \frac{(p_{is} d_{ijs} \tau_{ijs})^{-\sigma_2}}{P_{js}^{1-\sigma}} \mu_j X_j\\
&= \sum_s M_{is} \sum_j (1-\alpha_s)\epsilon^{\alpha} \frac{w_i}{w_i} w_i^{-\alpha} \kappa \psi_{is}^{\alpha-1} d_{ijs} \frac{\frac{\sigma}{\sigma-1}}{\frac{\sigma}{\sigma-1}} (\frac{\sigma}{\sigma-1})^{-\sigma} \frac{(\epsilon^{\alpha} w_i^{1-\alpha} \psi^{\alpha-1} \kappa)^{-\sigma_s} d_{ijs}^{-\sigma} \tau_{ijs}^{-\sigma}}{P_{js}^{1-\sigma_s}} \mu_j X_j\\
&= \sum_s \sum_j (1-\alpha_s)(\sigma-1)\pi_{ijs} w_i^{-1}
\end{aligned}
$$

The trade volume is expressed by:

$$
T_{ijs} = M_{is}(\frac{\sigma_s}{\sigma-1}\frac{\epsilon^{\alpha} w_i^{1-\alpha} \psi^{\alpha-1} \kappa d_{ij}}{P_{js}})^{1-\sigma_s} \tau_{ijs}^{-\sigma} \mu_{js} X_j. \qquad (11)
$$

Because $\pi_{ijs} = T_{ijs}/\sigma_s$, the above condition is expressed by: $w_i L_i = \sum_s (1-\alpha_s)(\sigma_s - 1)\sum_j \pi_{ijs} = \sum_s (1-\alpha_s)(\sigma_s-1)\sum_j (1/\sigma_s) T_{ijs}$.

The price index is:

$$
P_{js} = (\sum_i M_{is}(\frac{\sigma}{\sigma-1}\epsilon^{\alpha} w_i^{1-\alpha} \psi_{is}^{\alpha-1} \kappa d_{ijs} \tau_{ijs})^{1-\sigma_s})^{1/(1-\sigma)} = (\sum_i T_{ijs} \tau_{ijs} \frac{P_j}{\mu_{js} X_j})^{1/(1-\sigma)} \qquad (12)
$$

The budget constraint is:

$$
X_j = w_j L_j + \sum_i \sum_s t_{ijs} M_{is} \tau_{ijs}^{-\sigma} (\frac{\sigma_s}{\sigma_s - 1} d_{ijs} \epsilon_i^{\alpha} w_i^{1-\alpha} \psi_{is}^{1-\alpha} \kappa / P_{is})^{1-\sigma} \mu_{js} X_j + \sum_s \pi_{js} + \sum_s \sum_i M_{js} \epsilon_{jis} e_{jis} \qquad (13)
$$

Finally, as shown, the emission level is derived from Shephard's lemma:

$$
M_{is} e_{is} = \sum_j M_{is} e_{ijs} = \sum_j M_{is} \alpha_s \frac{1}{\epsilon} \frac{\sigma-1}{\sigma} p_{is} d_{ijs} x_{ijs} \qquad (14)
$$

The equilibrium conditions are equation (10), (11), (12), (13), and (14). There are N times S conditions for profits, N conditions for wages, N times S conditions for the price index, N conditions for budget constraints, and N times S conditions for emissions. Thus, in total, there are N(3S+2) equations and N(3S+2) unknowns. This system of equations is solved with a numeraire and one equation is redundant. We set the world wage rate as the numeraire.

As shown, the original equilibrium conditions depend on the unknown parameters, M_{js}, d_{ij}, and ψ_{js}. To reduce the number of unknown parameters, we consider the changes in equilibrium, which is common when analyzing counterfactuals in quantitative general equilibrium models. That is, we analyze the ratio of the counterfactual value to the original one, using the "exact hat" formula introduced by Dekle et al. (2007), $\hat{Y} = Y'/Y$. Thus, the analysis uses the changes in variables. Using the Dekle et al. (2007) formula, we obtain the expression for the changes in profits:

$$\hat{\pi}_{is} = \sum_j \alpha_{ijs} \hat{\tau}_{ijs}^{-\sigma} \left(\frac{\hat{\epsilon}_i^{\alpha} \hat{w}_i^{1-\alpha}}{\hat{P}_{js}}\right)^{1-\sigma_s} \hat{X}_j \tag{15}$$

For the labor market clearing condition, using the Dekle et al. (2007) formula, we obtain the following condition:

$$\begin{aligned} \hat{w}_i w_i L_i &= \sum_s \hat{\pi}_{is} (1-\alpha)(\sigma - 1)\pi_{is} \\ &= \sum_s \hat{\pi}_{is} (1-\alpha)(\sigma - 1) \sum_n (1/\sigma_s) T_{ins} \\ \iff \hat{w}_i &= \sum_s \hat{\pi}_{is} \frac{(1-\alpha_s)(\sigma_s - 1)(1/\sigma_s) \sum_n T_{ins}}{\sum_s (1-\alpha_s)(\sigma_s - 1) \sum_j (1/\sigma_s) T_{ijs}} \end{aligned} \tag{16}$$

The Dekle et al. (2007) formula for the price index is:

$$\hat{P}_{js}P_{js} = (\sum_i M_{is}(\frac{\sigma}{\sigma-1}\epsilon_i^{\alpha_{is}} w_i^{1-\alpha_{is}}\psi_{is}^{\alpha_{is}-1}\kappa d_{ijs}\tau_{ijs})^{1-\sigma_s}\hat{\epsilon_i}^{\alpha_{is}(1-\sigma)}\hat{w_i}^{(1-\sigma)(1-\alpha_{is})}\hat{\tau}_{ijs}^{1-\sigma})^{1/(1-\sigma)} \tag{17}$$

$$\iff \hat{P}_{js} = (\sum_i \frac{T_{ijs}\tau_{ijs}}{\sum_m \tau_{mjs}T_{mjs}}\hat{\epsilon_i}^{\alpha_s(1-\sigma)}\hat{w_i}^{(1-\sigma)(1-\alpha_s)}\hat{\tau}_{ijs}^{1-\sigma})^{1/(1-\sigma)}$$

With regard to the budget constraint, the first and third terms of the Dekle et al. (2007) formula of (13) are $w_j L_j \hat{w}_j / X_j$ and $\sum_s \hat{\pi}_{js}\pi_{js}/X_j$, respectively.

The second term is:

$$\sum_s\sum_i \hat{t}_{ijs}t_{ijs}M_{is}\hat{\tau}_{ijs}^{-\sigma}\tau_{ijs}^{-\sigma}(\frac{\hat{\epsilon}^{\alpha}\hat{w}_i^{1-\alpha}}{\hat{P}_{js}})^{1-\sigma}\hat{X}_j(\frac{\sigma_s}{\sigma_s-1}d_{ijs}\epsilon_i^{\alpha}w_i^{1-\alpha}\psi_{is}^{1-\alpha}\kappa/P_{is})^{1-\sigma}\mu_{js}X_j \tag{18}$$

$$= \sum_s\sum_i \hat{t}_{ijs}\hat{\tau}_{ijs}^{-\sigma}(\frac{\hat{\epsilon}^{\alpha}\hat{w}_i^{1-\alpha}}{\hat{P}_{js}})^{1-\sigma}\hat{X}_j t_{ijs}T_{ijs}/X_j$$

The last term is:

$$\sum_s M_{js}\sum_i \hat{\epsilon}_{jis}\epsilon_{jis}\hat{e}_{jis}e_{jis} = \sum_s\sum_i \alpha_s((\sigma_s-1)/\sigma_s)T_{jis}\hat{\epsilon}_j\hat{e}_{js} \tag{19}$$

Finally, the Dekle et al. (2007) formula for emissions is:

$$e_j = \sum_i M_{js}\hat{e}_{jis}e_{jis} = \sum_i M_{js}\alpha_s\hat{\epsilon_j}^{\alpha-1-\alpha\sigma}\hat{w_j}^{1-\alpha-(1-\alpha)\sigma}\hat{\tau}_{jis}^{-\sigma}\frac{\sigma-1}{\sigma}p_{js}d_{jis}x_{jis}\frac{1}{\epsilon_s} \tag{20}$$

$$\iff \hat{e}_{js} = \sum_i \hat{\epsilon_j}^{\alpha-1-\alpha\sigma}\hat{w_j}^{1-\alpha-(1-\alpha)\sigma}\hat{\tau}_{jis}^{-\sigma}\frac{\hat{X}_i}{\hat{P_i}^{1-\sigma}}\frac{\frac{\alpha_s(\sigma-1)}{\sigma}\frac{1}{\epsilon_s}T_{jis}}{\sum_j\frac{\alpha_s(\sigma-1)}{\sigma}\frac{1}{\epsilon_s}T_{jis}},$$

because:

$$e_{jis} = \hat{\epsilon_j}^{\alpha-1-\alpha\sigma}\hat{w_j}^{1-\alpha-(1-\alpha)\sigma}\hat{\tau}_{jis}^{-\sigma}\frac{\hat{X}_i}{\hat{P_i}^{1-\sigma}}. \tag{21}$$

Other variables in equilibrium conditions are calculated from actual trade data:

$$X_j = \sum_i \sum_s \tau_{ijs} T_{ijs} \tag{22}$$

$$w_j L_j = X_j - \sum_i \sum_s t_{ijs} T_{ijs} - \sum_s \pi_{js} - \sum \frac{\alpha_s(\sigma - 1)}{\sigma} T_{ijs} \tag{23}$$

$$\pi_{js} = \sum_i \pi_{ijs} = \sum_i T_{ijs}/\sigma_s. \tag{24}$$

The value of ϵ_{jis} is calibrated by the fact that emission revenue is equal to emission tax rate times emission volume:

$$ER_j = \sum_i M_{js} \epsilon_j e_{jis}, \tag{25}$$

where ER_i is emission tax revenue, which can be calculated from actual trade data using $ER_j = \sum \frac{\alpha_s(\sigma-1)}{\sigma} T_{jis}$.

There are several remarks. First, as in Ossa (2014), we create counterfactual trade flows given that trade imbalances are set to zero. The emission tax rates are calibrated by using emission tax revenue derived from trade data and the data on emission levels, as explained in the next section.

Second, governments impose tariffs and emission taxes. Ad valorem tariffs are denoted by t_{ijs}, and $\tau_{ijs} = 1 + t_{ijs}$. The governments can also raise emission taxes, ϵ_{js}. The objective function of governments is $G_j = \sum_s \lambda_{js} W_{js}$, where $W_{js} = X_{js}/P_j$ is real income and λ_{js} is the political economy weight. For simplicity, we assume that the governments treat all industries equally, and hence $\lambda_{js} = 1$. We discuss the effect of green politics in the concluding remarks section. We assume that when the governments set their import tariffs, they do not consider the utility loss from climate change, $-\Gamma(\sum_i e_i)$. We can incorporate utility loss as an isoelastic function of emissions, as in Copeland and Taylor (1994). The sensitivity of the functional form is an intriguing issue that we leave for future research.

To examine the tightening of emission regulations, we consider two cases, one where the EU government raises its emission tax and another where all regions increase their emission taxes equally. In these scenarios, we do not consider the governments' objective function but simply derive the resulting trade and emission levels to address the impact of such regulations on global emissions and trade.

As mentioned in the introduction, unilateral trade protection may lead to retaliation and thus all regions raise their import tariffs. Under such a Nash tariff-setting equilibrium, to focus on the trade policy dimension, we consider that the only policy variable is tariffs. That is, regions do not adjust their emission tax levels. Thus, we derive the Nash import tariff equilibrium given the emission tax levels. Furthermore, as mentioned, we consider that the governments do not consider climate change damage when imposing tariffs. Thus, we are concerned with the upper limit of welfare because climate changes affect welfare negatively.

With regard to the WTO-consistent CBAMs, we first introduce emission tax increases in China, EU, Japan, and the U.S. Then, we solve the above equilibrium condition with respect to tariffs with an additional constraint, which is the difference in export volume between the pre- and post-emission-tax cases. That is, in addition to the equilibrium conditions, we add the following constraint:

$$\sum_j \sum_s T'_{cjs} - \sum_j \sum_s T_{cjs} = 0, \text{for all } c \in C \tag{26}$$

where C is the set of countries introducing CBAMs and T' is the trade volume after the CBAMs. Because this system of equations is nonlinear and has a large number of equations and unknowns (145), we search for the solution by minimizing the sum of squares. The solution that we report is the WTO-consistent CBAM tariff.

3. Data and Calibrated Parameters

The data and codes used here are from Ossa (2014) based on the Global Trade Analysis (GTAP) 8 database, taken from the data deposit. The primary purpose of using the same data as in Ossa (2014) is to compare the cases with and without emissions and derive implications for trade policy under global environment concerns. We can examine how environmental aspects affect trade policies. Thus, our analysis is illustrative rather than ascertainable in terms of global trade policy in a quantitative global general equilibrium model.

We use the same industry classification and regions as in Ossa (2014); that is, there are seven regions (Brazil, China, the EU, India, Japan, the U.S., and the ROW) and 33 sectors. The GTAP 8 database includes emission level data, and we use the emissions data of each sector. The trade policy data are also taken from Ossa (2014) based on the Market Access Map database (MAcMap) of the International Trade Centre. The tariff rate data are aggregated to the GTAP sector level from the harmonized system six-digit level.

The GTAP sectors used in Ossa (2014) are utilized to investigate political influences on global tariff scheme. Thus, for example, Ossa includes a fine classification of the agricultural sector but not the energy sector. This may not be ideal for carbon emission analysis, in which energy intensive industries are likely to be subject to carbon pricing policies. However, because our primary focus is not on rigorous policy evaluation, but to provide an idea of the quantitative impact of these climate policies, we use the same data as in Ossa (2014) to compare the results with and without environmental concerns. In other words, we seek to answer the following question: How relevant are trade policies in the presence of emission policy considerations? To address this basic question, we demonstrate the difference in the results obtained here and those in Ossa (2014). For example, how much does world trade decrease under the trade war, or how much lower (or higher) is the optimal level of Nash tariffs with emissions than without emissions?

Using more recent and relevant industry classifications requires future research. A focus on the energy and carbon-intensive industries, such as the steel and aluminum industries, is necessary. Furthermore, not only the carbon intensity but also the level of abatement technology differs across industries. Thus, it is important to account for such industry heterogeneity to evaluate climate policies.

Because it is difficult to summarize various environmental regulations and construct emission taxes reflecting those regulatory policies, we calibrate the emission tax by dividing emission tax revenue by the emission level. Emission tax revenue is calculated using the trade theory formula and trade data. As mentioned, the emission level is taken from the GTAP 8 database. Thus, this is a hypothetical emission tax rate, which is consistent with the theory-driven value of revenue and actual emission level. As we will show below, the median carbon tax rate used in this study is approximately 60 U.S. dollars per ton.

There are two important parameters in the model. One is the technical parameter of abatement technology, α_s. Theoretically, this parameter takes a value between zero and one. A lower value implies that abatement technology is advanced and thus the emission level is low. For example, Forslid et al. (2018) set a value of α_s 0.2. The value of α_s is a key factor in determining the level of emission tax revenue, as shown by equation (14): $M_{is}\epsilon_i e_{is} = \sum_j M_{is}\alpha_s \frac{\sigma-1}{\sigma} p_{is} d_{ijs} x_{ijs} = \alpha_s \frac{\sigma-1}{\sigma} T_{ij}$. Thus, a large value of α_s generates a substantial level of emission tax revenue. If α_s is set to 0.4 (40 percent), the emission tax revenue reaches approximately 20 percent of total income. The current emission tax revenue is far below such a level. Table 1 reports the relationship between the tax revenue share of income and the level of α_s. As the value of α_s increases, the tax revenue share rises. If the share of tax revenue is large, then the incentive to increase import tariffs is high because the increase in domestic production caused by the high level of import tariffs induces higher tax revenue. We calibrate the value of α_s to obtain a realistic value of the tax level. As the carbon tax level differs among nations, as a first approach, we consider the average carbon tax rate, which is approximately 30 euros per ton (60 euros per ton among OECD countries). We use 0.005 (0.5 percent) as the value of α_s, which creates a median emission tax rate of 61.919 U.S. dollars per ton. As we will show in the analysis section, the median Nash tariff under $\alpha_{si} = 0.005$ is 61.3 percent, which is higher than the median tariff rate without emissions, the 58.1 percent in Ossa (2014). Using a similar functional form for industry-level data on an air pollutant, e.g., nitrogen oxide, Shapiro and Walker (2018) estimate α_{ijs}. Their estimates range from 0.0014 (0.14 %) to 0.0557 (5.57 %) among industries. Thus, our parameter value is comparable with their values.

Another important parameter is the elasticity of substitution, σ_s. This is a key parameter in trade models because it determines how the model behaves in association with the trade policy. We take these values from Ossa (2014), where trade elasticities are estimated using the method of Feenstra (1994). In Ossa (2014), there are several elasticity candidates for low, middle, and high elasticities. We take the conservative elasticity, which is the middle one.

4. Analysis

First, we introduce emission tax changes in the EU to understand the impact on global emissions, in particular the carbon leakage effects. This stringent carbon policy can be considered a part of the EU's Fit for 55 program. We raise the EU emission tax by 50 U.S. dollars per ton. In the EU, the initial calibrated emission tax rate is 277.41 U.S. dollars, indicating an emission tax increase of 18.024 percent. Column 1 of Table 2 reports that EU production decreases, whereas other regions increase their outputs. While the global emission level decreases, the policy may severely affect EU industries, and the introduction of a CBAM may be justified.

The effects of the CBAM are examined by raising the EU's tariffs. For simplicity, we assume that the EU imposes MFN tariffs on all imported goods. To reduce foreign emissions, this policy can be regarded as involving emission content tariffs similar to the policy studied by Copeland (1996). As Staiger (2022) argued and we will analyze below, an MFN-type tariff increase might not violate WTO rules as it is nondiscriminatory and ensures the market access level that existed before the carbon tax was imposed in the EU. In practice, a CBAM is introduced to raise import tariffs on carbon-intensive industries, such as the cement and energy sectors, which equalizes the carbon tax rate among regions (Larch and Wanner 2017). However, as we intend to compare the results with the result of Ossa (2014) that exclude environmental concerns, for simplicity, we impose uniform tariff increases among goods, as in Klotz and Sharma (2023). We examine the effect of a 50 percent tariff increase with the higher EU emission tax imposed. The results are reported in Column 2 of Table 2. The imports of the EU decline and the domestic output level of the EU is restored. Thus, the purpose of the CBAM is achieved, as in Larch and Wanner (2017).

One possible consequence of the EU's CBAM is that other regions may introduce

CBAMs as well. They may be motivated by retaliation or may simply consider that it is necessary to impose tariffs to reduce emissions and carbon leakage. We analyze the case where all other countries introduce CBAMs. We compute a noncooperative tariff-setting equilibrium and calculate the trade and emission levels. The resulting Nash tariffs are high: the average tariff rates are 61.3 percent, which is 55 percent higher than the original rates. This climate war reduces world trade by 62 percent, which is a costly means of achieving the global emissions reduction. In fact, most importantly, the world emission level declines by only 2.5 percent. Although the EU's emissions fall substantially because of its carbon tax and the high tariffs worldwide, the emission levels rise in other regions, such as Japan and the U.S. As a result, the climate war does not effectively stop the deterioration of the global climate.

One important remark here is that Japan's extremely high tariff on the rice sector is reduced substantially under the Nash tariff scheme (from approximately 300 percent to 53 percent). This creates an opportunity for China and the U.S. to increase rice exports and thus their emissions rise as a result of those export increases. However, the abolition of the high tariff on rice by the Japanese government is not a reasonable assumption. Hence, instead of using Nash tariffs, we attempt to analyze the impact on emissions using the actual tariffs for the rice sector. Then, the increase in emissions due to the export expansion in this sector is mitigated and the world emission level decreases by 2.5 percent, as mentioned, whereas the U.S. emission levels still increase. To provide an idea of the effectiveness of each scenario, calculating the elasticity of the international trade reduction with respect to the global emission reduction yields the burden on global trade from reducing emissions: in the emission tax case, this elasticity is 1.022, in the CBAM case, 2.216, and in the climate war case, 25.12. Thus, climate wars impose a significant burden on trade.

Next, instead of CBAMs, we examine the case in which all regions agree to raise emission taxes equally. We consider the same increase in the emission tax as the EU emission tax in the above scenario, that is, 50 U.S. dollars per ton. The impact of this universal emission tax surge is effective: it reduces global emissions substantially, whereas world trade does not deteriorate to a large extent. Global emissions decline by 73 percent, whereas world trade decreases only 3 percent. Hence, to tackle the global warming problem, it is essential for countries to cooperate at COP to reduce their own emissions. Furthermore, this cooperation needs to be achieved with the WTO's multilateral trading system to avoid tariff wars caused by climate motivations. The elasticity of the trade reduction with respect to the emission reduction in this climate talk case is 0.04, which is far better than under the other scenarios.

Finally, our analysis shows that the WTO-consistent CBAMs are effective. Because the median tariff rate is moderately higher (17 percent) than the initial tariff (3.9 percent), world trade decreases by 17.849 percent. As the new tariff schedule contains negative tariffs, import subsidies are imposed on some goods. These new tariffs (subsidies) alter domestic prices and wages to restore market access to the pre-CBAM levels. The change in world trade is moderate, and the level of global emissions falls by 45.617 percent. This emission reduction is considerable owing to emission tax increases in the four major markets. Furthermore, these countries do not simply raise tariffs optimally as in the Nash tariff situation, as they are constrained by the market access principle. If the CBAMs are used as offsetting tools to restore the trade volume in a coordinated manner, then the CBAMs dampen world trade only moderately. Thus, the negotiations over climate policy at the WTO have a significant potential to reduce global emissions while limiting the severity of the effect on trade.

As noted in the previous section, a comparison with the case without emission concerns, as in Ossa (2014), is important. The question is whether there is a difference in optimal tariffs between the no-emission and emission cases. This leads to a similar question of whether there is a difference in Nash tariffs between these cases and how cooperative tariffs are different. This comparison indicates how useful the WTO is in tackling global warming in a multilateral cooperative system. With emissions, under trade wars, the median tariff rate is 61.3 percent. The median tariff level reported in Ossa (2014) is 58.1 percent, which is the Nash tariff without emission concerns. Thus, the median tariff is higher under the emissions case than in the absence of environmental concerns. This is because, under the emissions case, raising tariffs leads to a contraction of foreign output while increasing domestic production, which increases the emission tax revenue. The emission tax revenue provides an incentive for government authorities to further increase tariffs because governments can increase their revenues from an expansion of domestic production under tariff protection. Then, world trade decreases to a large extent. Moreover, under a trade war, the increase in domestic production in the U.S. exceeds the decreases in exports, overall production rises, and thus emissions also rise. Note that in Ossa (2014), trade wars increase domestic production in the U.S. Thus, in a global emissions context, trade wars have the additional consequences of uneven impacts on international society.

5. Concluding Remarks

This study analyzes the impact of trade measures associated with reducing carbon emissions on international trade and the global carbon emission level. The analysis using the quantitative world trade model demonstrates that when carbon leakage exists, CBAMs are not an effective method to decrease emission levels worldwide. In particular, if one region's unilateral trade protection causes trade wars, the goal of emission reduction is achieved at a large cost to trade and the economy. The effective policy is climate talks yielding worldwide efforts at reducing emissions by, for example, imposing an equal carbon tax across regions. Another form of climate talks is also effective: even if countries use CBAMs, when they behave consistently with the WTO/GATT Article 23, global emissions decline significantly, with only a moderate reduction in trade. These results suggest that to solve the global warming problem without sacrificing current economic activities to a large extent, we need joint operation and cooperation under both the UNFCC-COP and WTO.

Our investigations have several limitations. First, we do not argue about the evaluation of the damage caused by climate change. As the governments set their optimal tariffs, they only care about national real income. This is partly due to the difficulty of evaluating the uncertain climate change damage. Moreover, the damages are heterogeneous among regions. An examination of sensitivity to the functional form of utility loss is an interesting exercise. Although considering these natural environmental issues is very important, we leave this task for future research.

Furthermore, our analysis is preliminary, with further analysis required. As discussed in the data section, it is desirable to use industry classifications to consider the heterogeneity of carbon intensity and targeted policies. Then, we can evaluate more realistic policy effects in practice. Furthermore, other environmental policies can be examined in this framework. For example, international emission quota trading is a key market-based mechanism to control the level of global emissions. Whether and how much the universal carbon price affects world output and emissions are essential issue regarding the effectiveness of such a mechanism.

Political factors motivated by environmental concerns may also be crucial. The public pays attention to climate change and there are political parties focusing on environmental problems. Although industrial lobbies may have an impact on the trade protection of the associated sectors (Ossa 2014), environment-motivated policies may enhance or reduce industry output because such policies may involve attempts to raise the carbon tax and, simultaneously, attempts to increase import tariffs to reduce not just domestic but also foreign emissions. Such environmental lobby effects may provide us with an intriguing insight into climate change and international trade.

Finally, we restrict our policy variables to tariffs. However, as we suggest coordination between the UNFCC-COP and WTO, it is necessary to account for a larger set of policy variables, namely, tariffs and emission taxes, simultaneously when considering climate wars and talks. This may also demonstrate the trade-off between trade policy and environmental policy in a global context.

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α_{is}	tax revenue/income	median Nash tariff
0.1 percent	0.07 percent	0.586
0.25 percent	0.16 percent	0.594
0.5 percent	0.3 percent	0.613
1 percent	0.65 percent	0.65
2.5 percent	1.64 percent	0.667

Table 1: α_{is} and tax revenue share

	Emission Tax	CBAM	Wars	Talks	WTO
Brazil	0.036	-7.870	-2.848	-63.934	-0.505
China	0.023	-6.822	-0.449	-81.740	-81.833
EU	-45.462	-31.951	-44.815	-45.330	-43.317
India	0.038	-7.164	-12.016	-80.391	0.381
Japan	0.025	-5.828	1.748	-52.207	-51.378
ROW	0.050	-7.551	1.501	-73.388	-1.351
U.S.	0.031	-6.435	6.418	-61.569	-62.481

Table 2: Emission Level: percent changes
The percent changes for CBAM, Wars, and Talks denote the changes under each of these scenarios compared with the purged (trade balance) case.

	Emission Tax	CBAM	Wars	Talks	WTO
Brazil	0.039	-11.432	-60.411	0.003	-6.544
China	0.005	-10.286	-58.399	-0.021	1.39
EU	-0.021	-34.036	-63.616	0.046	3.09
India	0.016	-11.682	-53.661	-0.075	-5.2
Japan	0.009	-8.262	-61.057	0.030	2.23
ROW	0.009	-14.593	-62.180	-0.029	-6.04
U.S.	0.015	-9.692	-62.419	-0.012	3.38

Table 3: Trade percent changes

The percent changes for CBAM, Wars, and Talks denote the changes under each of these scenarios compared with the purged (trade balance) case.

	Emission Tax	CBAM	Wars	Talks	WTO
Emission	-2.875	-8.610	-2.498	-73.152	-45.617
Trade	0.38	-19.077	-62.797	-2.946	-17.849

Table 4: World Level: Percent changes

The percent changes for CBAM, Wars, and Talks denote the changes under each of these scenarios compared with the purged (trade balance) case.