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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 carbon border adjustment mechanisms (CBAMs) on global emissions and trade. We initiate our analysis by envisioning a scenario where the European Union raises its emission tax by approximately 30 percent and enforces a CBAM through heightened import tariffs on carbon-intensive industries. We investigate the possibility of retaliation by other regions creating a trade war as a noncooperative tariff-setting equilibrium. This climate-initiated trade war, which we refer to as a "climate war," leads to a large 64.4 percent decline in the volume of world trade, exceeding the reduction that would occur without climate concerns. Considering the World Trade Organization (WTO) as a platform for trade negotiations, we consider a scenario in which major markets introduce a CBAM scheme consistent with the procedure of Article 28 of the General Agreement on Tariffs and Trade in the WTO. This global initiative, referred to as "climate talks," results in a 28.3 percent reduction in emissions, albeit accompanied by a 6 percent decrease in trade. These findings underscore the importance of achieving global cooperation on carbon reductions through the multilateral trade system under the WTO.

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

JEL Classification Number: F13, F18, Q54, Q58

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1. Introduction

A reduction in carbon emissions worldwide is a key target of the international community to address global warming. In addition to innovations in carbon emission abatement technologies and carbon offset activities, such as planting, a direct policy, namely, 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, but may increase in countries with less stringent emission policies. Rigorous regulations can hamper domestic production while leading to an increase in imports from the countries with less stringent policies. As a result, the worldwide level of carbon emissions may increase as a result of a boom in less-regulated countries. The purpose of a carbon border adjustment mechanism (CBAM) is to mitigate this carbon leakage problem.

CBAMs aim to equalize the burden of carbon emissions within and across regions. They effectively take the form of import tariffs. CBAMs are implemented on imports from countries where carbon regulation is less stringent compared with importing countries. This reduces such imports and thus dampens their production, which achieves a lower emission level and restores the competitiveness of domestic industries affected by high regulation. However, such a policy impacts not only emissions, but also trade. If importing countries make CBAMs discretionary, 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. CBAMs may not be treated as a general exception under Article 20 of the General Agreement on Tariffs and Trade (GATT) of the WTO. Thus, to evaluate which policy instruments are effective in tackling global warming, the degree of the burden that a CBAM imposes on trade needs to be understood.

Global warming and international trade have been studied extensively (e.g., Copeland and Taylor 2005). Carbon leakage is the key issue in analyzing the interaction between emissions and trade. The present 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 central to research on trade and the environment (Larch and Wanne 2017; Shapiro and Walker 2018; Duan et al. 2021; Farrokhi and Lashkaripour 2021; Klotz and Sharma 2023). In part, this is because it is appropriate to deal with carbon leakage in an international general equilibrium context. The literature examines the effect of a carbon tariff on carbon leakage (Larch and Wanne 2017), the validity of the pollution haven hypothesis (Duan et al. 2021), and noncooperative carbon tariff and climate clubs (Farrokhi and Lashkaripour 2021). This paper builds on such research and extends the discussion to the role of the WTO by employing the framework of Ossa (2014) with carbon emissions incorporated.

Because international cooperation and negotiation is a key aspect of international trade and climate policies, it is essential to incorporate the role of WTO rules in the analysis to understand the implications of trade policy for global emissions, as discussed by Staiger (2022). 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 the WTO (GATT Article 20) and UNFCCC (Article 3) state that climate policies should not be disguised restrictions on trade, excessive use of trade protection may take place. Studies have examined noncooperative outcomes of climate policies. Duan et al. (2021) demonstrate a case in which pollution taxes are set as a Nash equilibrium, and Farrokhi and Lashkaripour (2021) examine the Nash carbon tariffs using the intriguing envelop theorem technique of Lashkaripour and Lugovskyy (2023). However, to our knowledge, WTO-consistent trade policy negotiations and cooperation have not been examined in the quantitative general equilibrium global warming context. Thus, this paper contributes to the literature by demonstrating quantitatively the influence of international negotiations on world trade and global emissions.

We consider five hypothetical scenarios leading to trade wars and three scenarios with WTO-consistent CBAMs. First, we consider a situation in which the European Union (EU) tightens emissions policy by increasing the emission tax within the EU region by approximately 5 percent (10 US dollars per ton) for all industries, as, for example, the effect on the electricity and transport sector could affect all industries. Furthermore, the EU increases the carbon tax by approximately 21 percent (to 40 US dollars) for carbon-intensive industries such as chemicals and metals. This leads to carbon leakage and thus increases foreign exports to the EU. In the second scenario, to restore domestic production, the EU introduces a CBAM that involves an import tariff that offsets the carbon price differentials between the EU and its trading partners. This type of emission content or carbon tariff has been examined in the literature (Copeland 1994; Larch and Wanne 2017). We also derive the EU's unilaterally optimal tariffs on the imports of carbon-intensive industries. CBAM tariffs reduce global emissions by 2.7 percent but decrease world trade by 3 percent.

We extend the analysis of possible outcomes one step further by considering a scenario in which other regions retaliate. Although a CBAM may reduce global emission levels and may be regarded as "a charge equivalent to an internal tax" (GATT Article 2 (a)), other regions may take their own unilateral actions leading to a noncooperative tariff equilibrium. We refer to this third scenario 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 Nash equilibrium. First, we consider that the climate war takes place within carbon-intensive industries only. Then, we examine the full climate war case where a noncooperative tariff-setting Nash equilibrium occurs for all industries. This full climate war reduces global emissions by 0.7 percent, but also significantly dampens world trade, leading to a 64.4 percent decline. The magnitude of this trade reduction is larger than in Ossa (2014), who does not consider environmental concerns.

As a fourth scenario, we consider that the EU adopts a WTO-consistent CBAM scenario, as proposed by Staiger (2022), because of the risk of retaliation. GATT Article 28 describes the procedure for tariff renegotiations (Guzman and Pauwelyn 2009; Cottier et al. 2014) and a procedure that is consistent with Article 28 does not violate the WTO rule. We adopt the Staiger (2022) procedure: 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. Tariff deconsolidation as a climate policy requires compensation to preserve reciprocal and mutually advantageous trade relations (Cottier, et al. 2014). By considering the higher carbon taxes as offering compensation for the CBAM, these policy packages are consistent with the WTO rule. Thus, we analyze the effect of the introduction of a CBAM scenario in which the tariff level is adjusted to restore the market access of CBAM-imposing countries. If the EU imposes a WTO-consistent CBAM on targeted industries, the median tariff on the targeted industries increases from 0.9 to 5.8 percent.

Finally, we consider a scenario in which the EU's WTO-consistent CBAM elevates the climate policy discussion to the global level, countries negotiate at the WTO over CBAMs, and major economies introduce CBAMs in a manner consistent with WTO guidance. As mentioned, trade negotiations at the WTO are a key feature of the multilateral trading system. It is possible that the negotiations over climate policy take place under WTO rules, and therefore, we call this the "climate talk" scenario.

Specifically, we consider that four major countries and regions, namely China, the EU, Japan, and the US, raise their own carbon taxes as the EU does and we attempt to solve the tariff rates that make those countries import at the same level as before the carbon tax increases. First, we consider a case where a WTO-consistent CBAM is introduced for carbon-intensive industries. It reduces emissions by 27 percent and dampens trade by only 4 percent. Then, if WTO-consistent CBAMs are extended to all industries, world trade decreases by 6 percent, but global emissions decline by 28 percent, suggesting that such a WTO-consistent procedure is a useful mechanism for achieving carbon reduction and avoiding climate wars.

The goal of the UNFCCC and COP is an effective 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, a WTO-consistent CBAM is 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 EU Council adopted a CBAM.[1] The US and China raised concerns that this CBAM would lead to disguised

[1]Press Release: https://www.consilium.europa.eu/en/press/press-releases/2023/04/25/fit-for-55-council-

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 effective method of reducing global emissions. Rather, coordinated emission reduction and trade policy is an important direction. That is, a CBAM scheme that is consistent with the WTO rules substantially reduces global emissions 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 the effects of global trade policy, with emissions incorporated following Copeland and Taylor (1994). In the model, the world consists of seven regions: Brazil, China, the EU, India, Japan, the US, and the rest of the world (ROW). The governments of each region can adopt trade and emission policies. The trade policy takes the form of import tariffs, while the emission policy takes the form of an emission tax.

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

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

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, μ_{js} is the expenditure share of industry s goods in country j, and e_{is} is the emission level of sector s in country i. The function Γ captures the damage from climate change. This depends on the global emission level rather than on individual regional emissions.

adopts-key-pieces-of-legislation-delivering-on-2030-climate-targets/

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, as follows:

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

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

where d_{ijs} is iceberg trade costs, θ is the share of resources devoted to abating emissions, l_{ijs} is labor inputs, ψ_{is} is a productivity parameter, e_{ijs} is the emission level from the production in country i for market j, and the parameter α_{ijs} is referred to as the pollution elasticity, which 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 method of introducing emissions into the model has been 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, due to data availability and for brevity, we consider that α_{ijs} is common to all regions: $\alpha_{ijs} = \alpha_s$. Firms in region i in sector s pay an emission tax, ϵ_{ijs}, for one unit of production for market j. For the same reason, we set $\epsilon_{ijs} = \epsilon_{is}$.

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:

$$c(x_{ijs}) = \epsilon_{is}^{\alpha_s} w_i^{1-\alpha_s} \kappa \psi_{is}^{\alpha_s-1} d_{ijs}x_{ijs}, \tag{5}$$

where $\kappa = \alpha_s^{-\alpha_s}(1-\alpha_s)^{\alpha_s-1}$.

Shephard's lemma provides us with the emission level:

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

Governments impose an ad valorem import tariff with tariff rate t_{ijs}, and let denote $\tau_{ijs} = 1 + t_{ijs}$. Consumers are assumed to maximize their utility without considering environmental damage. If there is an incentive to raise import tariffs to mitigate environmental damage, benevolent governments seek to obtain the lower bound of tariffs. Firms in region i face the following 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:

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

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

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

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

Substituting this into profits yields:

$$\pi_{is} = \frac{1}{\sigma_s} \sum_j M_{is} \tau_{ijs}^{-\sigma_s} \left(\frac{\sigma_s}{\sigma_s - 1} \frac{d_{ij} \epsilon_{is}^{\alpha_s} w_i^{1-\alpha_s} \kappa \psi_{is}^{\alpha_s - 1}}{P_{js}}\right)^{1-\sigma_s} \mu_{js} X_j. \tag{9}$$

This is a profit function, and we assume a fixed number of market entries, with the number of producers 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:

$$L_i = \sum_s M_{is} \sum_j l_{ijs} = \sum_s \sum_j (1 - \alpha_s)(\sigma - 1) \pi_{ijs} w_i^{-1}. \tag{10}$$

The trade volume is expressed by:

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

Because $\pi_{ijs} = T_{ijs}/\sigma_s$, the above labor market 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:

$$P_{js} = (\sum_i T_{ijs}\tau_{ijs}\frac{P_j}{\mu_{js}X_j})^{1/(1-\sigma_s)}. \tag{12}$$

The budget constraint is:

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

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

$$M_{is}e_{is} = \sum_j M_{is}e_{ijs} = \sum_j M_{is}\alpha_s \frac{1}{\epsilon_i}\frac{\sigma_s - 1}{\sigma_s}p_{is}d_{ijs}x_{ijs} \tag{14}$$

The equilibrium conditions are equation (9), (10), (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 average 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 a common approach when analyzing counterfactuals in quantitative general equilibrium models. That is, we analyze the ratio of the counterfactual to the original value 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:

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

For the labor market clearing condition, we obtain the following:

$$\hat{w}_i = \sum_s \hat{\pi}_{is}\frac{(1-\alpha_s)(\sigma_s-1)(1/\sigma_s)\sum_n T_{ins}}{\sum_s(1-\alpha_s)(\sigma_s-1)\sum_j(1/\sigma_s)T_{ijs}} \tag{16}$$

The price index is:

$$\hat{P}_{js} = (\sum_i \frac{T_{ijs}\tau_{ijs}}{\sum_m \tau_{mjs}T_{mjs}}\hat{\epsilon_{is}}^{\alpha_s(1-\sigma_s)}\hat{w}_i^{(1-\sigma_s)(1-\alpha_s)}\hat{\tau}_{ijs}^{1-\sigma_s})^{1/(1-\sigma_s)} \tag{17}$$

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

The second term is:

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

$$= \sum_s\sum_i \hat{t}_{ijs}\hat{\tau}_{ijs}^{-\sigma_s}(\frac{\hat{\epsilon_{is}}^{\alpha_s}\hat{w}_i^{1-\alpha_s}}{\hat{P}_{js}})^{1-\sigma_s}\hat{X}_jt_{ijs}T_{ijs}/X_j$$

The last term is:

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

Finally, because the trade volume is given by equation (11) and the emission level from region j to market i is expressed as follows,

$$e_{jis} = \alpha_s \frac{\sigma_s}{\sigma_s - 1} \frac{1}{\epsilon_{js}} \epsilon_{js}^{\alpha_s - \alpha_s \sigma_s} w_j^{(1-\alpha_s)(1-\sigma_s)} \kappa^{1-\sigma_s} \psi^{(\alpha_s - 1)(1-\sigma_s)} d_{jis}^{1-\sigma_s} \tau_{jis}^{-\sigma_s} \frac{\mu_{is} X_i}{P_i^{1-\sigma_s}}, \tag{20}$$

the Dekle et al. (2007) formula for emissions in j is:

$$\hat{e}_{js} = \sum_i \hat{\epsilon_{js}}^{\alpha_s - 1 - \alpha_s \sigma_s} \hat{w_j}^{1-\alpha_s - (1-\alpha_s)\sigma_s} \hat{\tau}_{jis}^{-\sigma_s} \frac{\hat{X}_i}{\hat{P_i}^{1-\sigma_s}} \frac{\frac{\alpha_s(\sigma_s - 1)}{\sigma_s} \frac{1}{\epsilon_{js}} T_{jis}}{\sum_i \frac{\alpha_s(\sigma_s - 1)}{\sigma_s} \frac{1}{\epsilon_{js}} T_{jis}}. \tag{21}$$

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

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

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

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

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

$$ER_{js} = \sum_i M_{js} \epsilon_{js} e_{jis}, \tag{25}$$

where ER_{js} is the emission tax revenue, which can be calculated from actual trade data using $ER_{js} = \sum_i \frac{\alpha_s(\sigma_s - 1)}{\sigma_s} T_{jis}$.

Several remarks are required. 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, $-\Gamma(\sum_i \sum_s M_{is} e_{is})$. We are concerned with the upper limit of welfare because climate change may affect welfare negatively. 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.

Third, to examine the tightening of emission regulations, we consider that the government raises its emission tax. In doing so, we do not consider the government's 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. To focus on the trade policy dimension, we consider that under such a Nash tariff-setting equilibrium, 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.

Finally, with regard to WTO-consistent CBAMs, we first introduce emission tax increases in CBAM-introducing regions. Then, we solve the above equilibrium condition with respect to tariffs with an additional constraint, which is the difference in import volume between the pre- and post-emission-tax cases. That is, in addition to the equilibrium conditions, we add the following constraints:

$$\sum_j T'_{jcs} - \sum_j T_{jcs} = 0, \text{for all } c \in C \text{ and } s \in S \tag{26}$$

where C is the set of countries introducing CBAMs, S is the set of industries, and T' is the trade volume after the CBAMs. We search for the solution by minimizing the sum of squares of the equilibrium conditions. We constrain the policy variable to be nonnegative, that is, we allow only import tariffs, not import subsidies. The solution that we report is a WTO-consistent CBAM tariff.

3. Data and Calibrated Parameters

The data and codes used here are adopted from Ossa (2014) based on the Global Trade Analysis Project (GTAP) 8 database. 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. Thus, our analysis is illustrative rather than ascertainable in terms of global trade policy in a quantitative global general equilibrium model. We also use the same industry classification and regions as in Ossa (2014); that is, there are seven regions (Brazil, China, the EU, India, Japan, the US, and the ROW) and 33 sectors (Table 2). We consider that a higher carbon tax is levied on carbon-intensive industries, which are industry numbers 23 to 28: paper, chemical, plastic, mineral, and metal products.

The GTAP 8 database includes emission level data, and we use the emissions data of each sector. There is one observation of zero emissions (plant-based fibers in Japan), for which we set the emission level to a low level, 0.01 million tons, for calculation purposes. The trade policy data are taken from Ossa (2014) based on the Market Access Map database 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 schemes. Thus, for example, there is a fine classification of the agricultural sector, but not of 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. Nevertheless, it is sufficiently detailed to account for sector differences in carbon intensity because there are separate entries for chemical and metal industries.

Because it is difficult to summarize various environmental regulations and construct emission taxes reflecting those regulatory policies, we calibrate the emission tax rates by dividing emission tax revenue by 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 levels. As we show below, the world median carbon tax rate used in this study is approximately 50 US dollars per ton.

When the EU introduces a CBAM that equates carbon prices among regions, we calculate the CBAM tariff rate using the difference between emission revenues. We normalize each region's emission revenues by the trade value: τ_{iEU} = (Emission Revenue in the EU - Emission Revenue in region i)/Trade$_{iEU}$. If this value is negative, which means higher emission revenue in other regions than in the EU, we set the tariff rate at zero. The median tariff rate is 18.279 percent, and the largest tariff rate is 170.299 percent.

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. 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. The above parameter value is similar to their values. Hence, we use the values from Shapiro and Walker (2018) for corresponding industries, which are shown in Table 2. Then, the calibrated world median emission tax is approximately 50 US dollars per ton. For the EU, it is approximately 186 US dollars per ton. Thus, when the EU raises the emission tax for all industries by 10 US dollars, it represents a 5 percent increase. For carbon-intensive industries, raising the emission tax by 40 US dollars implies a 21 percent increase.

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 adopt the relevant values from Ossa (2014), who estimates trade elasticities using the method of Feenstra (1994). 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, particularly the carbon leakage effects. This stringent carbon policy can be considered part of the EU's Fit for 55 program. We raise the EU emission tax by 10 US dollars per ton for all industries and by 40 US dollars per ton for the carbon-intensive industries. In the EU, the initial calibrated emission tax rate is 186.439 US dollars, indicating an emission tax increase of 26.82 percent for carbon-intensive industries. Tables 3 and 4 show the percent changes in each country's trade and emissions, respectively. Column 1 of Table 4 reports that production decreases in the EU, whereas outputs increase in other regions. Although the emission level decreases, as shown in column 1 of Table 3, the policy affects EU industries, and the introduction of a CBAM may therefore be justified.

The effects of the CBAM are examined by raising the EU's tariffs. In practice, a CBAM is introduced to raise import tariffs on carbon-intensive industries, such as the cement and energy sectors, and to equalize the carbon tax rate among regions (Larch and Wanner 2017). The results are reported in column 2 of Table 4. The exports of the EU's trading partners decline, and the output level of the EU is restored. As shown in column 2 of Table 3, foreign emissions decline. Thus, the purpose of the CBAM is achieved, as in Larch and Wanner (2017). To reduce foreign emissions, this policy can be regarded as involving emission content tariffs similar to the policy studied by Copeland (1996).

A possible consequence of the EU's CBAM is that other regions may introduce CBAMs as well. In particular, if the EU imposes unilaterally optimal tariffs, the other regions may introduce CBAMs motivated by retaliation or simply consider that it is necessary to impose tariffs to reduce emissions and carbon leakage. We analyze a case where the EU imposes unilaterally optimal tariffs and then all other countries introduce CBAMs, which we refer to as the "climate war." We compute a noncooperative tariff-setting Nash equilibrium and calculate the trade and emission levels. We consider the following two cases: 1) climate wars occur in targeted carbon-intensive industries only, and 2) climate wars occur in all industries. Column 1 in Table 5 reports that climate wars in targeted industries reduce global emissions by 2.2 percent and world trade by 11.8 percent. Climate wars in all industries result in high Nash tariffs: the average tariff rates are 66 percent, which is 55 percent higher than the original rates. This climate war reduces world trade by 64.4 percent, which is a costly means of achieving a reduction in global emissions. In fact, most importantly, the global emission level declines by only 0.7 percent, as shown in column 2 of Table 5. Although the EU's emissions decrease substantially because of its carbon tax and the high tariffs worldwide, the emission levels rise in other regions, such as Japan and the US. As a result, the climate war does not effectively stop the deterioration of the global climate.

An 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 to 53 percent). This creates an opportunity for China and the US to increase rice exports, and their emissions rise as a result of these export increases. However, the abolition of the high tariff on rice by the Japanese government is not a reasonable assumption under a climate war. Hence, instead of using Nash tariffs, we attempt to analyze the impact on emissions using the actual tariffs for the rice sector in Japan. Then, the increase in emissions due to the export expansion in this sector is mitigated and the global emission level decreases by 0.7 percent, as mentioned, whereas the US emission levels still increase.

Finally, our analysis shows that WTO-consistent CBAMs are effective. As Staiger (2022) argues, an MFN-type tariff increase might not violate WTO rules because it is nondiscriminatory and ensures the market access level that existed before the imposition of the carbon tax in the EU. If the EU introduces a WTO-consistent CBAM, global emissions decrease by 1.2 percent and world trade declines by only 0.004 percent (see column 3 of Table 5). We refer to the scenario in which a WTO-consistent CBAM is discussed at the WTO and implemented among four major markets, China, the EU, Japan, and the US, as "climate talks." Column 4 of Table 5 shows that under the climate talks scenario where the four major markets introduce WTO-consistent CBAMs on carbon-intensive industries, the global emission level decreases by 27 percent, whereas trade only declines by 3.7 percent. As shown in column 5 of Table 5, if the CBAM is imposed on all industries, because the median tariff rate is moderately higher (17 percent) than the initial tariff (3.9 percent), world trade decreases by 6 percent, and the level of global emissions falls by 28.3 percent. If the CBAMs are constrained by the market access principle and used as offsetting tools to restore the trade volume in a coordinated manner, they reduce global emissions considerably but dampen world trade only moderately. Thus, the negotiations over climate policy at the WTO have considerable potential to reduce global emissions while limiting the severity of the effect on trade.

As noted in the previous section, a comparison of our cases with emission concerns and the case without emission concerns, as in Ossa (2014), is important. The question is whether there is a difference in Nash tariffs between these cases. In addition, this comparison indicates how useful the WTO is in tackling global warming in a multilateral cooperative system. Figure 1 depicts the tariff rate distribution arranged from the lowest to the highest. Nash tariffs with emissions are higher than those without. With emissions, under climate wars, the median tariff rate is 66 percent. The median tariff level in Ossa (2014) is 58.1 percent, which is the Nash tariff without emission 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 increase tariffs further because governments can increase their revenues from an expansion of domestic production under tariff protection.

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, if one region's unilateral CBAM 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 raising carbon taxes and adopting WTO-consistent CBAMs. These results suggest that to solve the global warming problem without sacrificing current economic activities to a large extent, joint operation and cooperation is required under both the UNFCC–COP and WTO.

Our investigations have some limitations; in particular, we do not discuss evaluations of the damage caused by climate change. A benefit of our research is that other environmental policies can be examined using our 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 issues regarding the effectiveness of such a mechanism.

Political factors motivated by environmental concerns are likely to be crucial. The public pays attention to climate change and some political parties focus 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 both carbon taxes and import tariffs to reduce not only domestic, but also foreign emissions. Investigating such environmental lobbying effects may provide intriguing insights into climate change and international trade.

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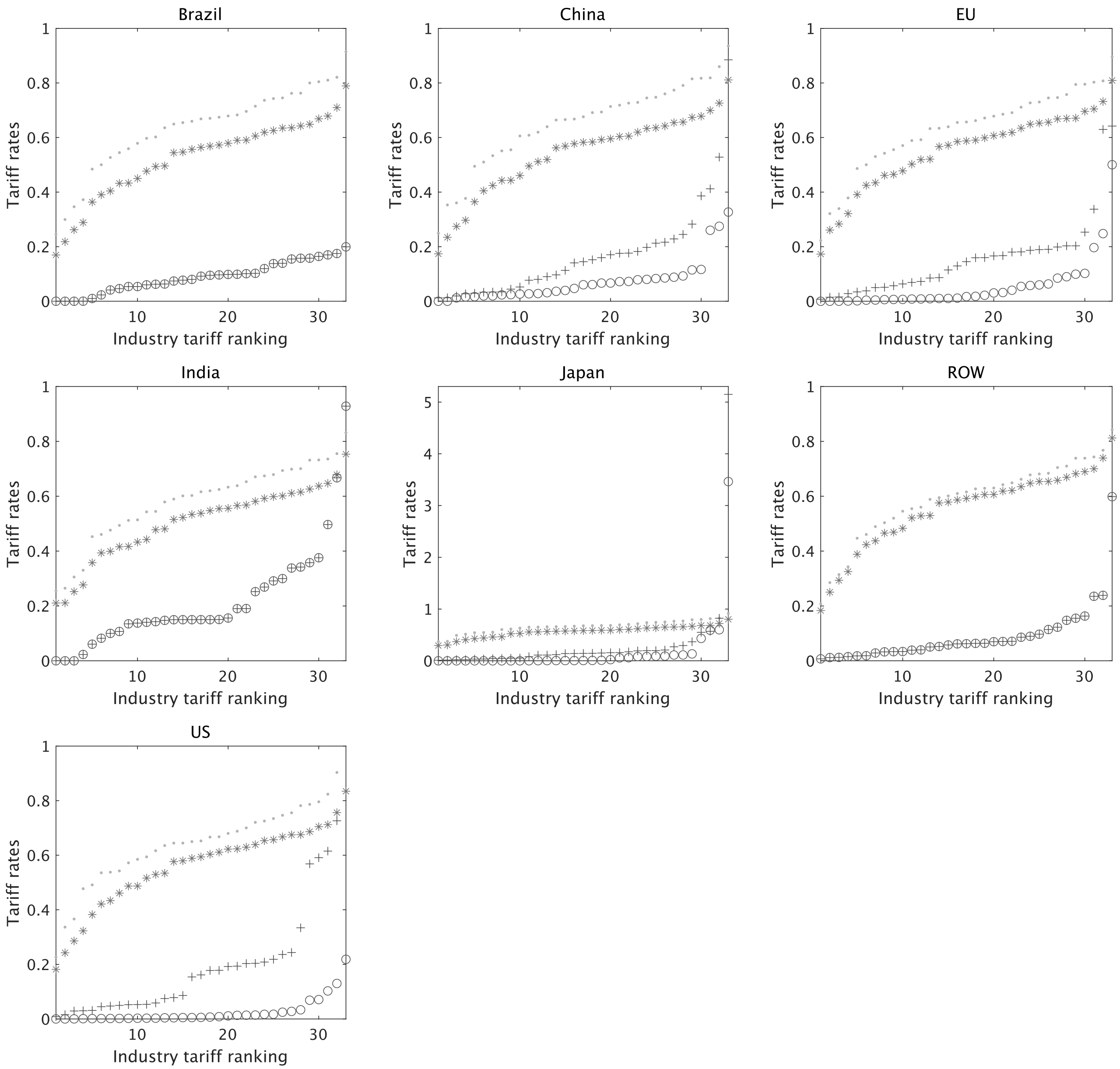

Note: The vertical axis represents median tariff rates, and the horizontal axis represents the tariff rate ranking by industry. The symbols "o," "*," "·," and "+" denote factual tariff rates, Nash tariff rates without environmental concerns, Nash tariff rates with environmental concerns, and WTO-consistent tariff rates, respectively. For Brazil, India, and the ROW, a WTO-consistent tariff does not entail retaliation, and the factual and WTO-consistent tariffs coincide.

Figure 1: Tariff Rates

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

Industries	α
Agriculture (1 to 18)	0.004
Textiles (19)	0.0022
Wearing apparel (20)	0.0022
Leather products (21)	0.0022
Wood products (22)	0.0103
Paper products, publishing (23)	0.0223
Chemical rubber plastic products (24)	0.0205
Mineral products (25)	0.0303
Ferrous metals (26)	0.0557
Metals (27)	0.0557
Metal products (28)	0.0019
Motor vehicles and parts (29)	0.0016
Transport equipment (30)	0.0019
Electronic equipment (31)	0.0005
Machinery and equipment (32)	0.0015
Manufactures nec (33)	0.0019

Table 2: Emission Intensity

The emission intensity values are from Shapiro and Walker (2016). We use the intensity value of agriculture for GTAP 8 industries 1–18, other metal for mineral products, basic metals for ferrous metals and metals, fabricated metal for metal products, and other transport for manufactures nec.

	ETS	CBAM	CBAM (Uni)	War (Tar)	War	EUWTO	WTO (Tar)	WTO
Brazil	0.038	-2.889	-1.748	-0.483	-2.886	-0.222	-2.334	-2.713
China	0.026	-0.305	-1.283	-2.157	-0.419	-0.051	-52.019	-54.403
EU	-16.295	-14.988	-10.574	-17.053	-25.023	-15.579	-14.751	-13.457
India	0.051	-3.302	-2.059	-1.387	-12.074	-0.294	-1.814	-3.389
Japan	0.026	-0.91	-1.074	0.161	1.767	-0.092	-15.474	-13.315
ROW	0.07	0.007	-3.61	-0.788	1.487	-0.571	-4.819	-4.392
US	0.036	-0.418	-1.781	0.414	6.466	-0.175	-30.656	-27.007

Table 3: Emission Level: Percent Changes

The percent changes for ETS (emission tax), CBAM (import tariff), Wars (Nash tariff), EUWTO (WTO-consistent tariff imposed by the EU), and WTO (WTO-consistent tariffs imposed by the four major markets) denote the changes under each of these scenarios compared with the purged (trade balance) case. "Uni" denotes the unilateral tariff case and "Tar" denotes the case of tariffs on targeted industries.

	ETS	CBAM	CBAM (Uni)	War (Tar)	War	EUWTO	WTO (Tar)	WTO
Brazil	0.017	-2.625	-1.254	-14.65	-60.425	-0.158	-1.83	-1.049
China	0.003	-0.296	-0.914	-7.375	-58.389	0.0002	-3.263	-1.954
EU	-0.03	-1.053	-6.376	-13.373	-63.621	-0.9	-4.346	-7.062
India	0.013	-3.596	-1.85	-17.396	-53.653	-0.293	-2.298	-5.758
Japan	0.01	-1.017	-0.879	-10.571	-61.055	-0.056	-3.861	-5.093
ROW	0.007	0.1	-2.924	-13.845	-62.189	-0.478	-4.27	-7.719
US	0.011	-0.202	-2.038	-9.555	-62.415	-0.195	-2.117	-6.774

Table 4: Trade Percent Changes

The percent changes for ETS (emission tax), CBAM (import tariff), wars (Nash tariff), EUWTO (WTO-consistent tariff imposed by the EU), and WTO (WTO-consistent tariffs imposed by the four major markets) denote the changes under each of these scenarios compared with the purged (trade balance) case. "Uni" denotes the unilateral tariff case and "Tar" denotes the case of tariffs on targeted industries.

	War (Tar)	War	EUWTO	WTO (Tar)	WTO
Emission	-2.24	-0.7	-1.23	-27.019	-28.27
Trade	-11.83	-64.4	-0.004	-3.65	-6.153

Table 5: World Level: Percent Changes

The percent changes for ETS (emission tax), CBAM (import tariff), wars (Nash tariff), EUWTO (WTO-consistent tariff by imposed by the EU), and WTO (WTO-consistent tariffs imposed by four major markets) denote the changes under each of these scenarios compared with the purged (trade balance) case. "Uni" denotes the unilateral tariff case and "Tar" denotes the case of tariffs on targeted industries.