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ORIGINAL ARTICLE

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Optimal tariffs and firm technology choice: An environmental approach

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Abstract

This paper analyzes environmental concerns by a government in a setting of rent-extracting strategic trade policy with endogenous firm investment into production technologies. The simple analysis reinforces the importance of investment incentives caused by tariffs in general and shows that the resulting implications for the optimal tariff decision can be completely different between traditional tariff considerations and an environmentally conscious government. We show that an importing country in a dynamic setting with endogenous firm technology choices prefers to impose discriminatory tariffs both ex post and ex ante when emissions matter, while—as previously found in the literature—a commitment to uniform tariffs is optimally chosen when environmental concerns do not play a role.

JEL CLASSIFICATION

F13; F18; D24; Q58

1 | INTRODUCTION

For years, countries under the umbrella of the World Trade Organization (WTO) have concurred to promote a cooperative trade outcome and to punish those that unduly try to extract rents from importing firms through trade restrictions. The most favored nation (MFN) clause to prevent discrimination between trading partners is often regarded as the fundamental pillar of the WTO and the General Agreement on Tariffs and Trade (GATT) (e.g., Bagwell & Staiger, 1999) and exhibits several potentially welfare-improving features in various contexts (see e.g., Choi, 1995; Saggi, 2004).¹ A real

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agreement over global climate policy, however, has not been achieved as of yet. While alarms about environmental damage, climate change, and the like are undoubtedly a major and rising global concern, they do not appear to be of equally high priority for all countries so far.

In the analysis presented here, we consider a model setting of rent-extracting strategic trade policy in oligopolistic competition in the spirit of Brander and Spencer (e.g., 1984a, 1984b) with endogenous firm investment into environmentally friendly production technologies. A main focus lies on the importance of providing dynamic innovation incentives to firms and considering imperfect competition à la Cournot.² The oligopolistic framework is well suited for analyzing the strategic interaction among firms and between firms and governments. Importantly, it is also able to cover homogeneous goods industries and a limited set of large dominant firms. Significant shares of world emissions are directly or indirectly generated by industries such as oil, gas and electricity, iron, steel and cement, and by the agricultural sector (e.g., Herzog, 2009), all representing highly homogeneous products.

In a simple analysis of a government additionally considering environmental damages caused in the production process of foreign exporters, we will show that the results of traditional tariff considerations dealing with standard production costs need not necessarily apply any longer. The result of Choi (1995) that a commitment to uniform tariffs by a MFN clause provides higher incentives for foreign firms to invest into cost-saving technologies is turned around in the environmental setting presented here. We will show that discriminatory tariffs are optimal for the tariff-setting government both in the short and in the long-run view with respect to foreign firms' emission reduction incentives.

Section 2 of this paper starts off with a brief literature review and continues in Section 3 by introducing the general framework and recollecting the standard marginal cost results for comparative purposes. Then, we adjust this model to fit into the environmental context and results are derived and compared. The environmental model is finally extended by adding a third firm from the home market. Concluding remarks follow.

2 | LITERATURE REVIEW

In spirit, we follow in the footsteps of the strategic trade policy literature initiated by Brander & Spencer and the discriminatory taxes literature. For example, Long and Soubeyran (1997, 1999) provided important insights on the interplay of domestic and foreign industry concentration, potentially firm-specific tariffs and trade policies. However, in the current paper, we abstract from such complexities and use a simplistic market structure in order to focus on the dynamic innovation incentive channel, combined here with environmental concerns of the tariff-setting home government.

While this paper is mainly concerned with the comparison of discriminatory and uniform tariffs under environmental concerns with respect to their induced technology choice, there has been a growing literature on various aspects of carbon emissions and environmental policies. Veel (2009) posits that any meaningful discourse on carbon tariffs must incorporate both political and legal constraints, and seeks to contribute to this discourse by identifying the relevant constraints and exploring certain policy options which could satisfy those constraints. Moore (2011) again mentions the legal and practical problems of implementing unilateral carbon trade policies, such as the mentioned need to concur with WTO guidelines and difficulties in actually measuring the emissions caused by a certain product, etc.

Even within OECD countries, for instance, stark differences in terms of the extent of environmental policies are still present (Botta & Koźluk, 2014) and even more so for less integrated countries. Countries that *have* decided on a need to impose carbon reduction mechanisms are nonetheless concerned about the competitiveness of local firms and about the possibility of “carbon leakage” (cf.

Babiker, 2005) when other countries do not implement similar policies. If production simply moves to jurisdictions where no environmental measures such as a carbon reduction program are in place, potential reductions in the home country can be nullified or even surpassed.

As nicely summarized by Long (2015), the carbon leakage effect is one possible manifestation of “Green Paradox” outcomes. These can arise when policies aimed to improve environmental outcomes in the first-order actually have second-order negative effects on the environment, dampening, or even dominating the desired goals.

To compensate for arising problems like these, in contrast to years of politicians and scholars promoting trade liberalization, some are suggesting the increased use of differentiating measures again (e.g., Ismer & Neuhoﬀ, 2007; Stiglitz, 2006); one of these being tariffs based on imports' carbon emissions as a relatively eﬀective measure with the least prospect of legal and practical barriers (cf. Böhringer et al., 2014).

Similar in flavor to our paper, Long and Soubeyran (2005) find that firm-specific “selective penalization” via taxes in an oligopoly market can provide an eﬃcient second-best solution. However, contrary to our model, they partly focus on firm asymmetries and do not consider firms' abatement possibilities and costs.

Eyland and Zaccour (2014) also consider a Cournot framework and find that in a limited two-country-two-government setting, border tax adjustments (BTAs) by one country can in principal work quite well to achieve similar results as would emerge from cooperative policy decisions. Balistreri et al. (2019) try to determine optimal border policy while considering the legal context in terms of compliance with GATT. They compare the relation between a domestic carbon price and a border tariff and explicitly consider a possible leakage effect on unregulated regions.

However, Long (2015) shows that, even with BTAs, leakage and other green paradox outcomes may still arise when considering more complex market structures, interest rates, and overall intertemporal substitution.

Following that vein, our paper cannot and does not claim to solve the overall cooperation and enforcement problems of this important topic with the unilateral instrument analyzed here. Still, the—in the context of tariff policies—hitherto somewhat neglected investment channel seems to be worth considering as one small additional piece of the puzzle.

3 | CARBON TARIFF MODEL

We consider a three-stage game played between a government in a home country and two foreign firms located in two different foreign countries. All sales and consumption can only occur in the home country. Firms are symmetric *ex ante*, and we consider the case of linear demand $P = a - bQ$ where $Q = q_1 + q_2$.

In the first stage of the game, firms can choose their technology determining its respective (emission) costs e_1 and e_2 . Spending a higher (and marginally increasing) sunk fixed cost achieves lower marginal costs in this technology investment stage. This relationship is represented by the function $F = \Phi(e)$ and we assume $\Phi' < 0$ and $\Phi'' > 0$ to capture the mentioned trade-off. In the second stage, the home government decides on the import tariffs t it imposes on the foreign firms. In the last stage, given that technologies and tariffs are in place, the firms compete à la Cournot and the Nash equilibrium is determined.

We consider two different possible ways of setting tariffs. Under a uniform setting, the government sets the same tariff to all countries and firms, while tariffs may vary between different countries under

a discriminatory (or preferential) regime. Initially, assume that the government can freely choose between the two.

3.1 | A standard tariff model

The setup used here builds on the model introduced by Choi (1995). We briefly recapture his results in order to directly compare the environmental outcomes and highlight the arising differences.

In the non-environmental setup by Choi, at the stage of technology investment with $F = \Phi(c)$, a higher fixed cost achieves lower marginal standard production costs c_1 or c_2 .

Solving by backward induction, maximizing both firms' profits, we get intermediate equilibrium quantities of

$$q_i(\mathbf{c}; \mathbf{t}) = \frac{a - 2c_i - 2t_i + c_j + t_j}{3b}, \quad i = 1, 2, \quad i \neq j \quad (1)$$

with c_i and t_i being a firm's own cost and tariff to be faced and c_j and t_j representing the competitor's cost and tariff. The government then considers the following welfare function by anticipation of firms' behavior

$$W(\mathbf{t}; \mathbf{c}) = CS + t_1 q_1(\mathbf{t}, \mathbf{c}) + t_2 q_2(\mathbf{t}, \mathbf{c}). \quad (2)$$

Optimal tariffs are then given for the preferential (t^*) and uniform tariff (t^{**}) regimes by

$$t_i^*(\mathbf{c}) = \frac{2a - 3c_i + c_j}{8}, \quad i = 1, 2; \quad i \neq j \quad (3)$$

$$t^{**}(\mathbf{c}) = \frac{2a - c_i - c_j}{8}. \quad (4)$$

We can see that a government which would observe one low-cost and one high-cost firm, would have an incentive to raise the low-cost firm's tariffs and lower the high-cost firm's tariffs compared to a uniform tariff. Given such an ex post cost structure across firms, it can be shown that it would be welfare maximizing for a government to set discriminating tariffs in this way and the effective cost-differential of production costs plus tariffs between a low-cost producer and a high-production-cost firm is reduced by the optimal tariffs.

To see the basic intuition behind this result, we can draw an analogy of the home government as an intermediate supplier to the foreign firms, with the intermediary good being “the right to sell in the home country.” A firm with low production costs wants to sell more, therefore, has a higher demand c.p. for this right to sell and will exhibit a lower elasticity of demand because of it. This low elasticity can be exploited by the government by charging a discriminating high price, that is, by setting higher tariffs.

We then consider the first-order conditions from the technology choice stage and compare them for the discriminatory (c^*) and the uniform (c^{**}) regime:

$$\Phi'(c^*) = -\frac{3(a - c^*)}{16b} \quad (5)$$

$$\Phi_I(c^{**}) = -\frac{5(a - c^{**})}{16b} \quad (6)$$

It follows that $c^{**} < c^*$ in equilibrium. To see this, note that the marginal profit (RHS) of further lowering cost is always higher under the uniform regime at any *given* level of c . This means that firms have stronger incentives to decrease their cost and in the end choose a lower-cost technologies when they face uniform tariffs.

This creates a dilemma for the government. It wants to charge discriminating high tariffs to low-cost firms, but in equilibrium both firms choose the same cost level after all, because any firm incentive to unilaterally decrease costs is negated by the expected discriminatory tariff. Therefore, no additional tariff income can be gained compared to uniform tariffs in the static sense. Additionally, because of the investment dynamics, there is a further welfare loss due to firms investing too little in cost reductions when they have to anticipate the possibility of discriminatory tariffs, which results in higher prices for the home consumers. Because tariffs will be de facto uniform in any equilibrium and the mere possibility for the government to opt for preferential tariffs leads to less investment and higher production costs for firms, the government is better-off by restricting itself ex ante from using them.

Here, voluntarily subscribing to a MFN clause and thereby credibly restricting oneself to uniform tariffs, is working as a commitment device to overcome the time-inconsistency problem of ex ante versus ex post government tariff incentives.

3.2 | The environmental model

We now further consider the situation of a government that also pays attention to the environmental damage caused in production. As a first step of changing the model by Choi, we use the environmental emission cost e in addition to classic marginal unit costs. Firms can only decrease their emission level e instead of their raw cost level c . That is, we hold the raw production cost constant at $c = \bar{c}$.³ For this, consider a situation in which production is already operating at the border of technology in the sense that no further cost improvements in terms of real production costs can be made. However, assume that this current means of production still exhibits an emission cost which can be reduced by investing into, for example, filter vents or recycling techniques of varying qualities. For simplicity, we also normalize to $\bar{c} = 0$ w.l.o.g.

The model is solved by backward induction. In the third stage, firms maximize their profits *given* technologies and tariffs. The home country can demand import tariffs from the foreign firms and tariffs are collected in the form of $T = \sum t_i q_i$. Profits of the foreign firms are then given by

$$\pi_i = (a - b(q_1 + q_2) - t_i) q_i, i = 1, 2 \quad (7)$$

It is important to note that marginal environmental costs e_i do not enter the profit function directly at this point. This nicely represents the externality character of the issue, as firms do not have an inherent incentive to reduce these costs in the absence of external intervention. We will see that the analyzed tariffs set by the importing country's government will force firms to consider the environmental emission costs they are producing. Here, tariffs are working in an indirect way, providing a potential instrument, for example, when direct governmental regulation is not possible.

Resulting from optimization of Equation (7), we get the outputs resulting from the third-stage Cournot–Nash game with $t = (t_1, t_2)$ as

$$q_i(\mathbf{t}) = \frac{a - 2t_i + t_j}{3b}, i = 1, 2, i \neq j. \quad (8)$$

In the second stage, the home government sets tariffs to maximize

$$W(\mathbf{t}) = (1 - u) [CS + t_1 q_1(\mathbf{t}) + t_2 q_2(\mathbf{t}) [-u] e_1 q_1(\mathbf{t}) + e_2 q_2(\mathbf{t})], u \in [0, 1]. \quad (9)$$

On the one hand, it considers the consumer surplus CS in the home country and the tariff revenues it collects from the foreign firms. These “classic” considerations are weighted here by $(1-u)$. The interesting addition here is the latter term that depicts environmental costs like carbon emissions and enters the welfare function negatively. The parameter u , therefore, measures how much weight the government wants to put on the environmental considerations compared to the classic objectives.

Again, we analyze the potential tariff choices of the home government. Now, under a discriminatory tariff system, welfare maximization and the ensuing first-order conditions yield the following *optimal discriminatory tariffs* denoted by t^* , taking as given the firms' technologies $\mathbf{e} = e_1, e_2$

$$t_i^*(\mathbf{e}) = \frac{2a(1-u) + 5e_i u + e_j u}{8(1-u)}, i = 1, 2, i \neq j. \quad (10)$$

Comparing to Equation (3) from the non-environmental setting nicely shows an important difference: the sign for the own costs e_i is now positive.

In the setting without the environment, the optimal discriminatory tariffs set by the government would decrease the effective cost differential between a high- and a low-cost producer by imposing higher tariffs on the low-cost producer. Thereby, the incentive to invest into cost-reducing research is lowered for all producers.⁴ However, when we now look at the tariffs in the environmental model, we can see that a low-cost/low-emission producer will benefit through lower import tariffs, reinstating the incentive to invest into R&D. Note that the competing importing firm j will also slightly benefit from a reduction of i 's emission cost, which can be seen from the positive sign on competitor's emissions e_j in Equation (3). This can decrease the incentive to invest to some extent by also allowing a partial free-riding effect. Nevertheless, the positive sign on the competitor's technology is a result that carries over from the non-environmental analysis, but here, the positive effect on being able to reduce the own tariff to be faced clearly outweighs this factor.

Solving for the optimal nondiscriminatory tariff t^{**} is straightforward, again from the maximization of welfare with the additional restriction that $t_1 = t_2$ has to hold:

$$t^{**}(\mathbf{e}) = \frac{2a(1-u) + 3e_1 u + 3e_2 u}{8(1-u)}. \quad (11)$$

Looking at the signs for emission costs \mathbf{e} in comparison to the respective cost counterpart \mathbf{c} in Equation (4) of the initial setting, we see that they are also flipped. This means that lowering one's emissions now has a benefit for a firm in the sense of lowering the tariff to be faced. However, due to the uniform tariff, the effect of lowering the emission cost also benefits the competing importer in the same magnitude. In the non-environmental results, while the effects go in the opposite direction, they are the same for the own firm and the import competitor as well. Considering only the point of view of competition with the other foreign firm, tariffs under a MFN regime play no further role for the firms' considerations on costs, neither in the environmental case nor with traditional production costs.

Still, in both setups, firms will have an incentive to lower their own costs, stemming from different channels in the different cases. In the model with classic marginal costs, firms have a general incentive to lower their costs for standard competitive reasons in strategic interaction. Introducing an MFN tariff reduces this incentive by demanding higher tariffs on imports with lower costs, but then equally so for both firms. Under the discriminatory regime, in response to a fall in the cost c_i , tariff t_i is raised even more drastically while t_j on the other firm is actually *decreased*, which dampens investment incentives further as explained in the previous section.

In the environmental case, firms have no inherent incentive to lower their emission costs at all. Introducing tariffs on these emissions can now work to establish this incentive in such a setting. In this case, a MFN tariff will be set in such a way that it already gives some incentive to the importers to lower their costs. While the other importer can actually free-ride and partake in an equal amount on the cost-savings and benefits of the cost-reducing firm, both benefit from lower tariffs.

Here, the optimal tariffs set by a discriminatory regime can lead to even better results in terms of investment incentives by letting the cost-saving firm enjoy a higher benefit in the form of a lower tariff than the competitor. As stated before w.r.t. Equation (10), the other firm is also allowed a somewhat lower tariff, but the now increasing effective cost differential, which is given here by the tariff differential only, would still allow a single cost-saving firm to expand its output relatively more while forcing the importing competitor to lower its output, as can be seen in the following equation.⁵

$$q_i^*(\mathbf{e}) = \frac{2a(1-u) - 3e_i u + e_j u}{8(1-u)b}, i = 1, 2, i \neq j. \quad (12)$$

This already points towards the result that innovation incentives will be higher in the preferential setting here.

Finally, we look at the first stage of the game, where technology choices are made. In the timing of the game, we implicitly assume that firms can set their technologies anticipating the resulting trade policies by the government. At least in the short and medium-run, we believe this to be a plausible assumption. A commitment to discriminatory or uniform tariffs would usually be given by public international contracts and policies, with political processes presumably being more rigid than firms' technology decisions. A country's stance on environmental considerations—represented in the model by term u —will also likely be public common knowledge, at least by tendency, derived from public political statements, etc.

We compare the first-order conditions to now show analytically that in the environmental setup introduced in this paper, indeed lower emissions will be chosen under the discriminatory regime, as it has been already claimed intuitively from the comparison of the two setups.

Proposition 1 *Let e^* and e^{**} be the symmetric Nash equilibrium technology choices under the discriminatory tariffs and an MFN clause on carbon tariffs, respectively. Then, under linear demand and a reasonably low environmental weight $u \leq \frac{a}{a+c}$,⁶ we get $e^* < e^{**}$. That is, a less*

carbon emitting and, therefore, environmentally beneficial technology is chosen by firms in the discriminatory regime.

Proof At the technology decision stage, the firms maximize

$$\Pi_i[\mathbf{e}; \mathbf{t}(\mathbf{e})] = \pi_i[\mathbf{e}; \mathbf{t}(\mathbf{e})] - \Phi(e_i) \quad (13)$$

which yields from $\frac{\partial \Pi_i}{\partial e_i} = 0$ and $\Phi_I(e_i) = \frac{\partial}{\partial e_i} \pi_i[\mathbf{e}; \mathbf{t}(\mathbf{e})]$ the conditions under the discriminatory tariff regime (e^*) and the MFN regime (e^{**}), respectively:

$$\Phi_I(e^*) = \pi_I(e^*) = -\frac{3}{16} \frac{u}{(u-1)^2} \frac{a(1-u) - e^*u}{b} \quad (14)$$

$$\Phi_I(e^{**}) = \pi_I(e^{**}) = -\frac{2}{16} \frac{u}{(u-1)^2} \frac{a(1-u) - e^{**}u}{b}. \quad (15)$$

On the one hand, it must hold that $\Phi_I(e) < 0$ (the fixed innovation cost is lower for higher emissions) which also implies here that *operating* profits π_i naturally rise with falling tariffs (through falling emissions). If u is sufficiently low, that is, in the generally feasible range, the term $a(1-u) - e^*u$ becomes positive and $\Phi_I(e) < 0$ is fulfilled. For a given level of e , marginal additional profits from lowering costs are always higher in the discriminatory case. Therefore, marginal profits will surpass the marginal cost from investing in cost reduction for a lower range of e and a lower cost level, here in terms of emission costs, is chosen in the discriminatory equilibrium. In other words, at the level of e where $\Phi_I(e^{**}) = \pi_I(e^{**})$ is just fulfilled, e can still be profitably further decreased in the e^* -regime only. Thus, from $\Phi_I(e^*) < \Phi_I(e^{**})$ for any given e it can be deduced that $e^* < e^{**}$ once we assume a decreasing marginal return of innovation investment.⁷

This is in contrast to the case without emissions, where the result was $c^{**} < c^*$.

Next, we evaluate the respectively achieved welfare levels. In equilibrium, the ex ante symmetry of firms carries over and both firms choose a common cost level, resulting in the following Home welfare:

$$W(e) = \frac{a^2(u-1)^2 + 2aeu^2 + e^2u^2 - 2aeu}{4(1-u)b}. \quad (16)$$

Apart from a lower total environmental cost, lower emissions lead to a higher consumer surplus and lower tariff income through lower tariffs. Overall, the effect of lower emissions on equilibrium welfare is strictly positive in the feasible parameter range, as we show in the appendix.

Even though it can also be shown that the sum of welfare in the Home country and *operating profits* of the two foreign firms is also increasing with lower emissions costs for the feasible range, we cannot make a definitive statement on final world welfare. Further analytical assumptions about the exact nature of the technology investment function would need to be made on top of the issue that we assume completely different welfare standpoints in terms of the valuation of environmental issues, and therefore, a clean comparison of an agreed upon world welfare would be difficult to draw.

In the same vein, results would be ambiguous if we would allow for a negative relationship of cleaner goods and normal marginal costs. Which of the two effects would dominate, naturally depends, on the one hand, on the environmental weight u and on the exact magnitude of the trade-off between environmental and standard production costs.

3.3 | Home firm extension

As a robustness check, we now additionally consider a third firm that is located in the home market. This fits the notion of a country that is interested in reducing emissions and can do so, on the one hand, by introducing a mechanism to guide the emissions by its local firm, but, on the other hand, has no

political reach over the foreign firms except for the border tariffs that it can set on imports. Naturally, the welfare function will consider an additional term stemming from the producer rents of the home firm.

Again, we solve by backward induction and start by looking at the third stage first. There, firms maximize their profits given technologies and set tariffs. Demand is still given by $P = a - bQ$, where now $Q = q_h + q_1 + q_2$.

Profits of the home firm h take the form of

$$\pi_h = (a - b(q_1 + q_2 + q_h) - \bar{e}) q_h \quad (17)$$

where \bar{e} represents an at this point exogenously given rate to be paid for emissions by the home firm. One interpretation here is that this rate is assumed to be what emerges from an efficient and well-functioning emission market that is in place in the *hom* region, but cannot be employed for *foreign* firms, for example, due to a lack of political agreements with foreign countries. For simplicity, we also normalize this rate to $\bar{e} = 0$. While we do not explicitly allow for aspects such as carbon leakage, firm-delocation, etc. in the model, the considered stylized setting is rather applicable to a situation where delocation might have already occurred. The firms considered here as foreign firms can also be viewed as previous home firms that moved away or offshored their production in response to the local pollution measures.

As in the previous section, the home country can demand (potentially discriminatory) import tariffs from the foreign firms. Profits of the foreign firms are then given by

$$\pi_i = (a - b(q_1 + q_2 + q_h) - t_i) q_i, i = 1, 2 \quad (18)$$

In the second stage, the home government sets tariffs to now maximize.

$$W(\mathbf{t}) = (1 - u) [CS + \pi_h(\mathbf{t}) + t_1 q_1(\mathbf{t}) + t_2 q_2(\mathbf{t})] - u [e_1 q_1(\mathbf{t}) + e_2 q_2(\mathbf{t})], u \in [0, 1). \quad (19)$$

The first-order conditions solve for the following optimal discriminatory tariffs denoted by t^* and uniform tariffs t^{**} , respectively, again taking as given the firms' emission technologies $\mathbf{e} = e_1, e_2$

$$t_i^*(\mathbf{e}) = \frac{6a(1 - u) + 13e_i u + 3e_j u}{20(1 - u)}, i = 1, 2, i \neq j. \quad (20)$$

$$t^{**}(\mathbf{e}) = \frac{6a(1 - u) + 8e_1 u + 8e_2 u}{20(1 - u)}. \quad (21)$$

Tariffs overall are set more aggressively in this setting, which is to be expected. Raising the foreign competitors' costs by the tariffs now has the added advantage of increasing the home firm's profits. In addition, the creation of consumer rent is not solely dependent on foreign firms anymore. Both of these channels tend to increase the foreign tariffs set by the home government.

We can check that the greater investment incentive, and therefore, lower emissions chosen by the firms are still given by discriminatory tariffs in this extended setting. The first-order conditions at the technology stage are given for the discriminatory tariff regime (e^*) and the MFN regime (e^{**}), respectively, by

$$\Phi'(e^*) = -\frac{9}{100} \frac{u}{(u - 1)^2} \frac{a(1 - u) - 4e^* u}{b} \quad (22)$$

$$\Phi'(e^{**}) = -\frac{4}{100} \frac{u}{(u-1)^2} \frac{a(1-u) - 4e^{**}u}{b} \quad (23)$$

The relative dominance of investment incentives under the preferential regime is even amplified now that the home firm is taken into account.

4 | CONCLUDING REMARKS

The simple analysis of a government considering environmental damages caused in the production process of foreign exporters has shown that traditional tariff considerations facing standard production costs need not apply in this case. The result of Choi that an MFN clause provides higher incentives for foreign firms to invest into cost-saving technologies is turned around in the model presented here. Now, discriminatory tariffs are optimal for the tariff-setting government both in the short- and in the long-run view by incentivizing firms' investments into green technologies.

In the setting of investments into a reduction in standard production costs, tariffs overall actually dampened the incentive to engage in R&D that has both a global social benefit as well as a private benefit to the foreign exporters. The mere prospect of the home government potentially charging differentiating tariffs creates a commitment problem in addition, without any *ex post* benefit. The environmental setting represents a different issue with the foreign firms having no inherent incentive to achieve a reduction in emission costs and creating a negative externality on the home region. Here, tariffs work as an instrument to create an investment incentive for foreign firms in the first place and discriminatory tariffs provide the stronger incentive to reduce emissions even further.

The model implies the suggestion for environmentally conscious governments to drop MFN clauses altogether as an extreme case. There is an ongoing discussion if and in how far discrimination based on environmental aspects indeed might or should be reconciled with WTO guidelines (e.g., Balistreri et al., 2019; Ismer & Neuhoﬀ, 2007). Even potentially risking WTO violation punishments and trade retaliation in the absence of a common agreement and to weigh such a potential backlash against possible benefits of decreasing emissions are considered as an extreme option (cf. Fouré et al., 2016).

In any case, the potential effects that can be caused by the investment incentive channel highlighted in the model presented here need to be taken into consideration when countries decide on both tariff and environmental policy measures. While we believe that the model in its current stylized form can already provide an important benchmark for a variety of particularly relevant real-world circumstances, future work can expand these insights in detail to a more general framework in terms of demand and technology functions, differentiated goods industries and more.

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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ENDNOTES

- ¹ Also cf. Horn and Mavroidis (2001) for a broad survey covering more legal aspects as well.
- ² Following Kreps and Scheinkman (1983), we assume that the results hold under Bertrand competition as well when taking into account a preceding capacity buildup before price competition takes place. In a trade context, this sequence appears particularly plausible.
- ³ Another natural assumption would be a negative relationship between cost level and emission rate, that is, $c'(e) < 0$. While this would provide a somewhat countervailing effect to the following results, both in the investment stage as well as for tariff setting, we abstract from this for the sake of brevity here and focus on the channel caused by environmental investments.
- ⁴ DeGraba (1990) already highlighted this insight analogously for the setting of an input supplier who price discriminates between downstream producers based on their production costs.
- ⁵ The arising technical analytical limitations are briefly discussed in the appendix. However, these do not affect the analysis of results for plausible parameter values.
- ⁶ The low weight u is only needed to generally stay in the range of analytically feasible solutions, see the appendix for the derivation of the condition.
- ⁷ To be more precise, the innovation function ϕ must be more convex than π for the SOC of Equation (13) to be satisfied. However, given that $\pi''(e^{**})$ and $\pi''(e^*)$ result in constant values—depending on the assumed value of u most likely below 1—this will be fulfilled for a very large range of convex innovation functions.
- ⁸ See Choi (1995, p. 154) where the assumption $(a - c) = 100$ is made.

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APPENDIX

FEASIBILITY RESTRICTION ON U

Let us consider again the equilibrium firm quantities, given the respective optimal tariffs

$$q_i^*(\mathbf{e}) = \frac{2a(1-u) - 3e_i u + e_j u}{8(1-u)b}, i = 1, 2, i \neq j. \quad (\text{A1})$$

$$q_i^{**}(\mathbf{e}) = \frac{2a(1-u) - e_i u - e_j u}{8(1-u)b}, i = 1, 2, i \neq j. \quad (\text{A2})$$

For values of u approaching 1, the numerators would take on negative values, which is not feasible. The intuition is the following: the more and more a government cares for the environment, the more it will aim to restrict the emission causing production by the importers completely. Therefore, as can be also seen in Equations (10) and (11), optimal tariffs for u moving toward 1 would approach ∞ . In reality, it would suffice for a government to set prohibitively high *finite* tariffs in order to foreclose production and thereby avoid any emissions. More generally, to stay in the relevant range, it needs to hold that

$$q(\mathbf{e}) \geq 0, \quad (\text{A3})$$

as negative quantities are not feasible. Here, we impose symmetry of costs w.l.o.g. Due to the ex ante symmetry of importing firms, they will also symmetrically choose their optimal level of costs. This leads to the following condition:

$$\begin{aligned}
 2a(1-u) - 2eu &\geq 0 \\
 \Leftrightarrow u &\leq \frac{a}{a+e}
 \end{aligned}
 \tag{A4}$$

No definite prediction can be made here, but given that a is likely to be quite larger than e , this condition is likely to hold.⁸ Any values of $0.5 < u < 1$ would actually mean that a government puts *more* weight on the environmental considerations than on its traditional objectives, that is, consumer and producer surplus and tax income, which is needed to fulfill its governmental tasks. This is, at least for the moment, very unlikely, so the analysis is very likely to hold under realistic values of a relatively small u .

EMISSIONS AND WELFARE

As we argue in Section 2.2, welfare is rising with lower emission costs.

Equilibrium welfare is given by:

$$W(e) = \frac{a^2(u-1)^2 + 2aeu^2 + e^2u^2 - 2aeu}{4(1-u)b}. \tag{A5}$$

It needs to hold that

$$\begin{aligned}
 W(e) &< 0 \\
 2au^2 + 2eu^2 - 2au &< 0 \\
 u &< \frac{a}{a+e}.
 \end{aligned}
 \tag{A6}$$

This is the same restriction already imposed in (A4), therefore, lower emissions will always lead to a higher Home welfare in the feasible parameter range.