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Optimal Tariffs and Firm Technology Choice: An Environmental Approach

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Optimal Tariffs and Firm Technology Choice: An Environmental Approach

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Abstract

This paper introduces the additional dimension of environmental concerns by a government into a setting of rent-extracting strategic trade policy with endogenous firm investment into production technologies. It considers the presence of imperfect competition, namely Cournot competition. The simple analysis highlights the importance of investment incentives caused by tariffs. Furthermore, the implications from traditional tariff considerations can be completely different to the ones derived with an environmentally conscious government. It is shown that an importing country now prefers to impose discriminatory instead of uniform tariffs in a dynamic setting with endogenous technology choices, in order to induce the exporting firms to choose a technology that exhibits lower costs in terms of emissions.

Keywords: Climate policy; Carbon tariffs; Technology choice; Discriminatory tariffs.

JEL Classification Numbers: F13, F18, D24, Q58.

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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 try to extract rents from importing firms through trade restrictions. An 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 are not of equally high priority for all countries. 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 to impose carbon reduction mechanisms are concerned about keeping their firms competitive and about the possibility of carbon leakage when other countries do not implement similar policies. If production simply moves to jurisdictions where no carbon reduction program is in place, the reductions in the home country can be nullified or even surpassed. This is why, despite years of politicians and scholars promoting trade liberalization, some are promoting the increased use of tariffs again, now based on imports' carbon emissions.

I will show in a simple analysis of a government considering environmental damages caused in the production process of foreign exporters that traditional tariff considerations dealing with standard production costs need not apply in this case. The result of Choi (1995) that a commitment to uniform tariffs under a most-favored nation (MFN) clause provides higher incentives for foreign firms to invest into cost-saving technologies is turned around in the model presented here. I will show that discriminatory tariffs are optimal for the tariff-setting government both in the short and in the long-run view. A main focus lies on the importance of providing dynamic innovation incentives and considering imperfect competition à la Cournot.

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

Section 2 of this paper starts by re-collecting Choi's results for the linear case for comparative purposes. Then, this model is adjusted to fit into the environmental context and results are derived and compared. Concluding remarks follow.

2 Carbon Tariff Model

2.1 The Model by Choi (1995)

The setup used later builds on the model introduced by Choi (1995), which we briefly compare here in order to directly compare the results and highlight the arising differences.

We consider a three-stage game played between a government in a home country and two foreign firms located in different countries. All sales and consumption can only occur in the home country. Firms are completely 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 non-environmental game, firms can choose their technology deter-

mining its costs. Lower marginal costs can only be achieved by spending higher sunk costs. This relationship is represented by $F = \Phi(c)$ and it is assumed that $\Phi' < 0$ to represent the mentioned trade-off. In the second stage, the home government decides on the import tariffs 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 will be determined.

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

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

The government then considers the following welfare function by anticipation of firms' behavior

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

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 differ for different countries under a discriminatory (or preferential) regime. Initially, assume that the government can freely choose between the two. Optimal tariffs are 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. 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 such a way that the effective cost-differential of production costs and tariffs of a low-cost producer compared to

a high-production-cost firm is completely negated 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:

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

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

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 technology 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 incentive to unilaterally decrease costs is negated by the expected discriminatory tariff and 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 to restrict itself ex ante from using them.

Here, voluntarily subscribing to an 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* vs. *ex post* government tariff incentives.

2.2 Environment

We now consider the situation of a government that also pays attention to the environmental damage caused in production.

Demand is still given by $P = a - bQ$. As a first step of changing the initial model, we now consider an environmental emission cost e *instead* of classic marginal unit costs, that is, we normalize the raw production cost to $c = 0$ for now. There is again a technology, i.e. cost decision stage with the same assumptions as before, only now firms can decrease their emission level e instead of their raw cost level c by investing. It is not unrealistic to think of technologies that might exhibit a trade-off between physical production costs and the resulting emissions. However, this discussion is postponed to a later point and we first focus on the simple case here where the cost c remains constant.

Again, we solve the model by backwards induction and start by looking at the third and last stage first. There, firms maximize their profits *given* technologies and tariffs. The home country can again 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

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

Also note that marginal environmental costs e_i do not enter the profit function directly at this point. This represents well the externality character of the issue, as firms do not have an inherent incentive to reduce these costs in the absence of external intervention. In this paper, we will see that the considered tariffs set by the importing country's government will act as an indirect way to force firms to consider the environmental emission costs they are

producing. Other possibilities include direct governmental regulation.

Resulting from optimization of Equ. (7), we get the outputs resulting from the third-stage Cournot-Nash game with $\mathbf{t} = (t_1, t_2)$ as

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

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

$$W(\mathbf{t}) = (1 - u)[CS + t_1q_1(\mathbf{t}) + t_2q_2(\mathbf{t})] - u[e_1q_1(\mathbf{t}) + e_2q_2(\mathbf{t})], \quad u \in [0, 1]. \quad (9)$$

On 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 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. At $u = 0$, we are basically back in the non-environmental model, while moving towards $u = 1$ would signify a government that cares more and more about the environmental damage.

Now, under a discriminatory tariff system, welfare maximization yields the first-order conditions

$$\frac{\partial W}{\partial t_i} = 0, \quad i = 1, 2, \quad (10)$$

that solve for the following *optimal discriminatory tariffs* denoted by t^* , taking as given the firms’ technologies $\mathbf{e} = e_1, e_2$

$$t_i^*(\mathbf{e}) = \frac{2a(1 - u) + 5e_iu + e_ju}{8(1 - u)}, \quad i = 1, 2, \quad i \neq j. \quad (11)$$

Comparing to Eq. (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 producers¹. However, when we now look at the situation of a government that cares for environmental costs caused by emission, we can see that firms will be rewarded for lower emissions 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 the own costs of i , which can be seen from the positive sign on competitor's costs e_j . This can decrease the incentive to invest to some extent. Nevertheless, the positive effect on being able to reduce the own tariff to be faced clearly outweighs this here, and the positive sign on e_j is a result that carries over from the non-environmental analysis.

Solving for the optimal non-discriminatory tariff t^{**} (henceforth: MFN (most favored nation) tariff) is straightforward, again from the maximization of welfare with the additional restriction that $t_1 = t_2$ has to hold:

$$t^{**}(\mathbf{e}) = \frac{2a(1-u) + 3e_1u + 3e_2u}{8(1-u)}. \quad (12)$$

Looking at the signs for costs \mathbf{e} in comparison to the respective cost counterpart \mathbf{c} in Equ. (4) of the initial setting, we see that they are flipped. This means that lowering one's cost 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 cost is exactly the same on the competing importer. 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. From the point of view of competition with the other foreign firm, tariffs under the MFN regime play no role for the firms' considerations on costs in neither case. Still, in both cases, firms will have an

¹DeGraba (1990) already highlighted this insight analogously for the setting of an input supplier who price discriminates between downstream producers based on their production costs.

incentive to lower their own costs, stemming from different channels in the different cases.

In the standard marginal cost model, firms have a general incentive to lower their costs because lower costs let them increase their own output and lower the competitor's output and thereby make higher profits. Introducing an MFN tariff reduces this incentive by demanding higher tariffs on imports with lower costs, but 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*. This basically sums up again the main mechanisms in place that lead to the non-environmental results of finding the low cost-reduction incentive in the discriminatory case.

In the “environment 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, an 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 low-cost incentives by letting the cost-saving firm enjoy a higher benefit in terms of a lower tariff. As stated before, the other firm is also allowed a somewhat lower tariff, but the effective cost differential, which is given here by the tariff differential only, would still allow a single cost-saving firm to expand its output while forcing the importing competitor to lower its output, as can be seen in the following equation.

$$q_i^*(\mathbf{e}) = \frac{2a(1-u) - 3e_i u + e_j u}{8(1-u)b}, \quad i = 1, 2, \quad i \neq j. \quad (13)$$

Therefore, innovation incentives will be higher. However, a limitation of the analysis becomes evident at this point. For values of u approaching 1, the numerator will 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 seen in Eqs. (11) and (12), optimal tariffs

for u moving towards 1 would approach ∞ . Realistically, tariffs will be set at a prohibitively high level which is reached at finite levels of t already. To stay in the relevant range, it needs to hold that

$$q_i^{e^*}(\mathbf{e}) \geq 0, \quad (14)$$

as negative quantities are not feasible. This leads to the following condition²

$$\begin{aligned} 2a(1-u) - 2eu &\geq 0 \\ \Leftrightarrow \quad \frac{a}{a+e} &\geq u \end{aligned} \quad (15)$$

No definite prediction can be made here, but given that a is likely to be quite larger than e , this condition is likely to hold³. Any values of $0.5 < u < 1$ would actually mean that a government puts *more* weight on the environmental considerations than on its traditional duties, that is consumer and producer surplus and tax income, which is needed to fulfill its governmental tasks. This is, at the moment, very unlikely, so that the analysis is likely to hold under realistic values of a relatively small u .

Finally, we now look at the first stage of the game, where technology choices are made. We compare the first-order conditions to now show analytically that in the environmental setup introduced in this paper, we see that indeed lower costs 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 , $e^* < e^{**}$. That is, a less carbon emitting and therefore environmentally beneficial technology is chosen by firms under the discriminatory regime.*

²Here, symmetry of costs is already imposed w.l.o.g. Due to the ex ante symmetry of importing firms, they will also symmetrically choose their optimal level of costs.

³See Choi (1995,p.154) where the assumption $(a-c) = 100$ is made.

Proof. At the technology decision stage, the firms maximize

$$\Pi_i[\mathbf{e}; \mathbf{t}(\mathbf{e})] = \pi_i[\mathbf{e}; \mathbf{t}(\mathbf{e})] - \Phi(e_i) \quad (16)$$

which yields from $\frac{\partial \Pi_i}{\partial e_i} = 0$ and $\Phi'(e_i) = \frac{\partial}{\partial e_i} \pi_i[\mathbf{e}; \mathbf{t}(\mathbf{e})]$ the conditions under the discriminatory tariff regime (e^*) and the MFN regime (e^{**}) respectively

$$\Phi'(e^*) = -\frac{3}{16} \frac{u}{(u-1)^2} \frac{a(1-u) - e^*u}{b} \quad (17)$$

$$\Phi'(e^{**}) = -\frac{2}{16} \frac{u}{(u-1)^2} \frac{a(1-u) - e^{**}u}{b} \quad (18)$$

It must hold that $\Phi'(e) < 0$ which also implies here that operating profits π_i naturally rise with falling costs. It is straightforward to see that this condition is also fulfilled when the condition that is already imposed in Equ.(15) holds. If u is sufficiently low, the term $a(1-u) - e^*u$ becomes positive and $\Phi'(c) < 0$ is fulfilled. From $\Phi'(c^{e^*}) < \Phi'(e^{**})$ for any given e it can be deduced that $e^* < e^{**}$. 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 c and a lower cost level, here in terms of emission costs, is chosen in the discriminatory equilibrium. This is in contrast to the case without emissions, where the result is $c^{**} < c^*$.

■

2.3 Home Firm

As a next difference to the original setting, we now consider a third firm that is located in the home market. This better fits the notion of a country that is interested in reducing emissions and can do so on one hand by introducing some kind of mechanism to guide the emissions by its local firm, but 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 backwards induction and start by looking at the third and last stage first. There, firms maximize their profits given technologies and set tariffs. Again, demand is given by $P = a - bQ$, where now $Q = q_h + q_1 + q_2$,

Profits of the home firm h take the form of

$$\pi_h = (a - b(q_1 + q_2 + q_h) - \bar{e})q_h \quad (19)$$

where \bar{e} represents an at this point exogenously given rate to be paid for emissions by the home firm. The connection to reality 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 *home* region, but cannot be employed for *foreign* firms, e.g. due to a lack of political agreements with foreign countries. For now, we also normalize this rate to $\bar{e} = 0$.⁴

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

$$\pi_i = (a - b(q_1 + q_2 + q_h) - t_i)q_i, \quad i = 1, 2 \quad (20)$$

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

$$W(\mathbf{t}) = (1 - u)[CS + \pi_h(\mathbf{t}) + t_1q_1(\mathbf{t}) + t_2q_2(\mathbf{t})] - u[e_1q_1(\mathbf{t}) + e_2q_2(\mathbf{t})], \quad u \in [0, 1]. \quad (21)$$

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

$\mathbf{e} = e_1, e_2$

$$t_i^*(\mathbf{e}) = \frac{6a(1 - u) + 13e_iu + 3e_ju}{20(1 - u)}, \quad i = 1, 2, \quad i \neq j. \quad (22)$$

⁴In a planned extension of this paper, we want to endogenize this rate and analyze possible trade-offs between internal and external environmental instruments.

$$t^{**}(\mathbf{e}) = \frac{6a(1-u) + 8e_1u + 8e_2u}{20(1-u)}. \quad (23)$$

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

$$\Phi'(e^*) = -\frac{9}{100} \frac{u}{(u-1)^2} \frac{a(1-u) - 4e^*u}{b} \quad (24)$$

$$\Phi'(e^{**}) = -\frac{4}{100} \frac{u}{(u-1)^2} \frac{a(1-u) - 4e^{**}u}{b} \quad (25)$$

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

3 Concluding Remarks

This 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.

Taken at face value and ignoring all other economic and political considerations, the

model implies the suggestion to environmentally conscious governments to drop MFN clauses altogether. This obviously seems drastic and unlikely in reality. Nevertheless, potentially risking WTO violation punishments and trade retaliation and to weigh these against possible benefits of decreasing emissions does not seem to be out of the question (Fouré et al., 2016). In any case, the effects that can be caused by the investment incentive channel highlighted here need to be taken into account when countries decide on both tariff and environmental policy measures.

While deliberately so at this point, the model might still be too simplistic in its current form. There is a myriad of ways in how the model could be refined to better describe a realistic situation. Carbon emissions of the home country and how they are dealt with could be endogenized. This raises the question of how other countries deal respectively with these emissions and requires multiple or a common world market. Do the other countries care about the environment equally or do they differ, e.g. in their valuation u concerning the environment. Some countries might be inherently more prone to dangers of environmental changes, for example countries that are situated near coastal lines. Countries facing severe economic problems and poverty might have different priorities.

In terms of the model, looking at a situation that combines traditional marginal costs with emission costs would be interesting. Is there a relationship between the two? Can lower emissions only be realized at the cost of higher normal costs? This might not be too unrealistic to think of. How a government would react that can only use one tariff instrument to deal with both kinds of costs, is an interesting question to pose.

In a world that considers various governments and markets, the desired effects of a single country imposing carbon tariffs might evaporate when exporters engage in other avoidance measures. When sales are simply diverted to a different country, production is continuing as it was and no emission savings can be realized. Therefore, a country acting on its own would need to present a very large and relevant market to achieve an effect. Otherwise, multiple countries need to come together to agree on a harmonized policy. However, coming back

to possible differences in valuation and priorities, it can be difficult to agree on commonly agreed upon measures.

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