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Comercio Administrado y Política Medioambiental bajo Competencia Imperfecta

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Resumen

El objetivo de este artículo es profundizar sobre la relación teórica entre el comercio internacional y el medio ambiente. Mediante un modelo duopolístico, una empresa doméstica y otra extranjera compiten en el mercado doméstico produciendo un bien homogéneo con tecnologías de producción diferenciadas. En este contexto, examino el efecto de la protección administrada sobre la decisión de la empresa doméstica por adoptar o no una tecnología medioambientalmente limpia. La autoridad comercial elige el nivel de protección mediante un arancel específico antes de que la empresa doméstica decida su nivel de producción, pero después de que ésta opta por la adopción. Al ser una política de segundo mejor, la protección administrada genera pérdida de bienestar. Pese a esta distorsión, con la adopción, la disminución en la externalidad compensa el costo de adoptar la tecnología más limpia. Para la autoridad comercial, el conservar la credibilidad de la protección administrada, evita efectos negativos que exacerban procesos de apertura comercial sobre el medio ambiente: una política de libre comercio podría ser nociva para la empresa doméstica, ya que los incentivos para adoptar, son nulos.
JEL Classification: F18.
Key Words: Cournot Competition, Managed Trade and Pollution.

Managed Trade and Environmental Policy under Imperfect Competition

Abstract

This paper aims to deepen the theoretical relationship between international trade and the environment. I design a duopolistic competition model where a domestic and a foreign firm compete in the domestic market with homogeneous products and differentiated production technologies. In this context, I examine the effect that managed trade has on the domestic firm's choice to adopt or not an environmental-friendly technology. The commercial authority decides the level of protection applying a specific trade tax before the domestic firm determines its production level, but after the domestic firm makes its choice to adopt or not the cleaner technology. This second-best policy leads to welfare losses. Nevertheless, the decrease in the monopolistic distortion and the production externality, compensates for the costs associated with the adoption of the cleaner technology. For the policy maker, to remain credible regarding the managed trade protection, avoids negative effects that may exacerbate opening trade processes upon the environment: a free-trade policy could be counterproductive for the domestic firm to adopt, since the incentives to adopt are null.
Clasificación JEL: F18.
Palabras clave: Competencia Cournot, Comercio administrado y Contaminación.

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1. Introduction

Two significant trends in the international trade arena and some outstanding strategic trade reforms followed by several advanced and emerging countries have shaped nowadays international trade's architecture and its dynamism.

On the one hand, since the end of the Second World War, countries have engaged in major global trade negotiations that in subsequent trade rounds have resumed under the Doha Round, promoting under the most favored nation principle (MFN), a number of multilateral taxes and subsidies reductions.

On the other hand, episodes of high volatility observed in the international financial markets associated with an unfavorable evolution of financial and economic conjunctural indicators, have had significant spillover effects on the pace of expansion of international trade. To compensate for fluctuations in trade flows, policy makers have managed trade protection granting in some cases, even more safety, than otherwise it would have been observed, if strategic protection could have been acknowledged as a result of a non-cooperative equilibrium among trade partners.

In this context, however, it is not sufficiently clear if the extra protection granted based on less dynamic international trade flows is more distortionary than that awarded in episodes of a significant pace of expansion of the global economic activity. The former argument calls for a counter-cyclical protectionism, while the latter argument, calls for a pro-cyclical protectionism, both forms being well known by their welfare-loss consequences[2].

The effects of protectionism on welfare must be analyzed in the light of the number of strategic trade reforms we have witnessed during the last two decades that in general have taken two broad approaches: i) unilateral, bilateral or multilateral reforms, some of them yet to be implemented; and ii) second and even third best reforms to partially correct trade distortions or some other externalities in production and consumption in specific sectors.

In this paper, I present a duopolistic competition model where a domestic and a foreign firm compete in the domestic market with homogeneous products and differentiated production technologies. The domestic firm has a pollutant technology, while the foreign firm is assumed to have an environmental-friendly technology. In this context, I design a mechanism that provides incentives for the domestic firm to adopt a cleaner technology with the aim to reduce domestic pollution. In doing so, I investigate if administered protection, as a trade policy, partially corrects the production externality in a second-best fashion, where the domestic government has a limited commitment to provide the proposed administered protection, and if domestic firms are willing to adopt the cleaner technology in the absence of an explicit environmental policy designed with a first best approach. I analyze this assumption finding that there is an optimal trade tax that credibly provides the incentives for domestic firms to adopt the cleaner technology of production. Though the administered protection clearly generates some welfare losses, the expected reduction of the production externality compensates these losses via welfare gains[3].

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[2] For an empirical analysis of counter and pro-cyclical protectionism see Bagwell and Staiger (2003).

[3] For a recent and detailed survey on trade-related environmental issues, see De Melo (2014) and Frankel (2009).

In this context, I examine the theoretical relationship between administered trade through a trade tax and an environmental policy designed to adopt a cleaner technology in a polluted open economy with endogenous pollution levels, assuming that the government actually has a very limited commitment credibility. In so doing, I propose a three-stage game: i) during the first stage, the domestic firm decides whether to adopt or not the cleaner technology, ii) in the second stage the domestic government chooses the degree of administered trade protection, and iii) in the third stage domestic and foreign firms compete à la Cournot in the domestic market.

The basic insight of the model relies upon the fact that unless the government credibly threatens granting administered protection, the domestic firm would not adopt the cleaner technology. Therefore, the objective is twofold: on the one hand, the domestic government has a clear incentive to protect a cleaner firm, than to protect a pollutant one; and on the other hand, the firm would adopt the cleaner technology if it has enough confidence about the government's commitment. In this context, a free trade policy would be unfavorable because it would provide no elements to make credible the government's threat, whereas an autarky situation will not contribute to switch on the mechanism linking pollution and trade.

Following Regibeau and Gallegos (2004), Brander and Spencer (1985), Eaton and Grossman (1986), Dixit (1983) and Spencer and Brander (1983), this paper considers a duopolistic competition between firms combined with strategic interaction between domestic and foreign governments in imposing optimal trade and environmental policies. The distinction between the previous works on strategic interaction is that the model developed here, considers that the production of the final tradeable good generates certain amount of pollution, which is assumed to be proportional to the output levels; and it only harms consumers, not neighboring firms or countries. Therefore, no transboundary pollution is considered. In that sense, environmental authorities design strategically an optimal environmental policy to deal only with domestic pollution.

Ludema and Takeno (2007), propose a model where unilateral tariffs are designed to induce foreign firms to adopt more environmental-friendly technologies assuming there is a negative cross-border externality on production coming from the foreign country. Despite the non-environmental purpose of several international examples of this type of policy intervention, the implication is that unilateral tariffs can be partially effective environmental policies[4].

This basic insight is analyzed formally in a two-country partial equilibrium model. The emphasis is on the domestic market of one of the two countries. This market can be served by n domestic firms and m foreign firms. Initially, I will take these numbers as exogenously determined, starting with n=1=m. Later on, I will endogenize them. Domestic production creates an amount of pollution proportional to domestic output: the cleaner the technology, the lower these pollution levels will be. As foreign firms serve the market through exports, they do not generate any local pollution.

However, unlike Spencer and Brander (1983), Brander and Spencer (1985) and Eaton and Grossman (1986), to analyze the strategic interaction between a credible threat and possible

[4]Ludema and Takeno (2007), provides some examples of such instruments, for instance to induce the adoption of fishing devices with the aim to avoid dolphins or turtle mortality. The Tuna-Dolphin WTO Case, is the best example of how those restrictions have been discriminatory and have provided disguised trade protection to the US.

improvements in social welfare through commitments granted by the government, the timing of the granted protection is crucial. In this paper, I assume that the domestic government has a limited commitment. In so doing, I suppose that firms choose their output levels in the third stage as is usual, i.e., just after the government chooses its trade policy. The main difference is that I allow the domestic firm to choose the kind of technology before trade policies are set up.

In a three-stage model with no transboundary pollution, Xing (2006) examines the strategic effects that lenient environmental policies on exporting countries have on the design of environmental policies in importing countries, and finds that the strategic behavior of the exporting country leads to the application of optimal environmental tariffs on imports from countries with lax environmental regulations[5]. Iida and Takeuchi (2011) propose a four-stage model to influence a domestic-polluting firm to adopt a cleaner technology of production from the foreign, depending on the concern the domestic country has on the environmental damage if the domestic firm does not use the cleaner technology. Iida and Takeuchi (2011) propose that if the country cares about the environmental damage, a policy of free trade is better compared to a tariff policy with the aim to achieve the technological transfer: the cost of free trade is that there would be no tariff revenue, but the gain is a lower license fee to use the cleaner technology.

The plan of the paper is the following. In the second section I develop a duopolistic model with two firms competing in the domestic market with a homogeneous product. The domestic country faces domestic pollution and chooses the mechanism to credible threaten its limited commitment to protect cleaner production technologies. In the third section, the model is extended to include n domestic and m foreign firms to determine endogenously the optimal number of adopting firms. In the fourth section I present the main conclusions and some comments on further research.

2. The Model

The framework for the analysis I build consists on a domestic country assumed to be a small open economy and a net importer of the final homogenous good initially produced by two firms competing each other in a Cournot-Nash fashion only in the domestic country. The domestic firm produces the homogeneous good with a pollutant technology whereas the foreign firm already produces it with an environment-friendly technology. Because the domestic country faces domestic pollution, only the domestic government is assumed to choose the mechanism to credibly threaten its commitment to protect cleaner production technologies. This is done by maximizing a social welfare function that accounts for the effects of the trade tax on the consumer surplus, the benefits of the domestic firms, plus the tax revenue net of pollution costs.

The domestic country is assumed to consume the final good and initially, is modelled using a general specification for the inverse demand function $P(Q)$, where $Q=q_1+q_2$. I also assume

[5]In its three-stage model Xing (2006) explains that the optimal environmental tax strategically affects the environmental-lax exporting country, conditioning its environmental policies. In this context, Xing (2006) justifies the implementation of environmental taxes when exporting countries have an artificial comparative advantage due to the poor environmental regulation.

symmetric cost structures and constant marginal costs equal to zero between firms (c=0), to eliminate the strategic-trade associated effects[6].

The foreign firm's export-oriented production, constitutes the domestic country's imports. Trade policy takes the form of a specific trade tax (t). The home country is the only one with an active trade policy. The case for one domestic firm competing with one foreign firm will show some of the basic insights of this model. Later on, a more general case where n domestic and m foreign firms interact each other, will be shown. The home firm is indexed as firm 1, while the foreign firm is indexed as firm 2. The foreign firm does not pollute in the domestic country, because no transboundary pollution is considered. In this context, the "polluting" technology generates local pollution, while the "clean" technology does not.

A continuum of technology adoption decisions is available, so that I index the adoption choice. A technology adoption choice θ is associated with each point on the interval [0,1]. Two benchmark cases can be characterized: a firm that does not adopt the cleaner technology, and a firm that does adopt the cleaner technology[7]. Therefore, the social welfare cost of pollution is directly proportional to local output in the domestic country. In this context, the credible threat that the government makes, influences the decision the domestic firm takes to fully or partially adopt the cleaner technology, or not adopt at all.

As previously mentioned, the parameter θ belongs to the interval [0,1]. If the domestic firm fully adopts the cleaner technology $\theta=0$, and pollution emissions are $\theta q_1=0$. This means that if the cleaner technology is totally adopted, it will actually eliminate all pollution[8]. If the home firm partially adopts the cleaner technology $\theta\in(0,1)$ and $\theta q_1\in(0,q_1)$. Finally, if the domestic firm does not adopt the cleaner technology, $\theta=1$ and $\theta q_1=q_1$.

I also assume that the home firm is initially endowed with the pollutant technology but it can adopt the cleaner technology at a fixed cost F. Likewise, I assume that the choice of technology does not affect the marginal costs of production[9].

In this context, the home country's government is free to set its tariff at any level it wishes whereas the domestic firm must decide whether to keep its current polluting technology or to adopt the new cleaner one at a cost F, in the first stage. In the second stage the domestic government decides the level of protection to grant through a specific trade tax t. In the third stage firms simultaneously choose their output levels in a Cournot-Nash fashion. Once the game is set up, it is solved for its unique sub-game perfect equilibrium[10].

2.1 Third stage: firms compete à la Cournot

[6]If the choice of technology affected the marginal costs, policies aimed at reducing would also affect the "aggressiveness" of the domestic firms.
[7] These benchmark cases reflect that firms can fully, partially or do not adopt at all the cleaner technology.
[8] This eliminates the traditional "scale" effect associated with trade.
[9] With this I avoid strategic trade-like effects.
[10] The proposed sequence assumes that in general, firms and governments pursue their self-interest looking ahead by themselves. See Brander and Spencer (1987).

It is well known that under Cournot conjectures, each firm believes that its counterpart will hold its output fixed while the output level of that firm changes[11]. In this context, profit functions for each of the firms take the following form:

$$\pi_1(q_1,q_2)=P(Q)q_1-F \qquad (1)$$

$$\pi_2(q_1,q_2,t)=P(Q)q_2-tq_2 \quad (2)$$

for the foreign firm[12].

Where F stands for the fixed cost of adopting the cleaner technology, and t is the specific trade tax. Reaction functions are obtained directly from: $\partial\pi_i/\partial q_i=\pi_{qi}=0$, for any i=1,2.

$$\pi_{q_1}(q_1,q_2)=P(Q)+q_1P'(Q)=0 \qquad (3)$$

$$\pi_{q_2}(q_1,q_2,t)=P(Q)+q_2P'(Q)-t=0 \quad (4)$$

With second order conditions $\partial/\partial q_i[\partial\pi_i/\partial q_i]=\pi_{qiqi}<0$,for any i=1,2, and$\partial/\partial q_i[\partial\pi_i/\partial q_j]=\pi_{qiqj}<0$, for any $i\neq j$

$$\pi_{q_1q_1}=2P'(Q)+q_1P''(Q)<0 \qquad (5)$$

$$\pi_{q_2q_2}=2P'(Q)+q_2P''(Q)<0 \ (6)$$

In order to know the effect of the trade tax t on the production levels q_1 and q_2, I totally differentiate eqs. (3) and (4) to obtain the signs for dq_1/dt and dq_2/dt:

$$\pi_{q_1q_1}dq_1+\pi_{q_1q_2}dq_2+\pi_{q_1t}dt=0 \qquad (7)$$

$$\pi_{q_2q_1}dq_1+\pi_{q_2q_2}dq_2+\pi_{q_2t}dt=0 \qquad (8)$$

Since $\pi_{q_1t}=0$ and $\pi_{q_2t}=-1$, the system can be solved simultaneously to obtain:

$$dq_1/dt=-\pi_{q_1q_2})/\Delta>0 \quad (9)$$

$$dq_2/dt=\pi_{q_1q_1}/\Delta<0 \qquad (10)$$

where $\Delta=\pi_{q_1q_1}\pi_{q_2q_2}-\pi_{q_2q_1}\pi_{q_1q_2}>0$[13]. Provided the Routh-Hurwitz condition for reaction function stability is in place, eqs. (9) and (10) clearly show that an increase in the trade tax t, leads to a domestic output increase, and to a foreign output decrease.

2.2 Second stage: choosing the optimal trade tax

At this point that the home government is the only policy active, to choose the optimal trade tax, it maximizes the following social welfare function:

$$W(t,\theta)=CS+PS+TR-PC \qquad (11)$$

[11]This means that $dq_i/dq_j=0$, for any $i\neq j$.
[12] Foreign firm exports to the domestic country which has an import tariff in place.
[13] Worth noting is that "cross effects" are weaker than "own effects" on the decline of the marginal revenue, i.e., $\pi_{qiqi}<\pi_{qiqj}$,for any $i\neq j$.

where CS stands for consumer surplus, PS for producer surplus, TR for tariff revenue and PC for pollution costs. In other words, the social welfare function takes the next explicit form:

$$W(t,\theta)=\int_o^Q P(Q)dQ-P(Q)Q+\pi_1(q_1,q_2)+tq_2-\theta q_1 \quad (12)$$

As is usual, eq. (12) considers consumer and producer surpluses and tariff revenues net of social costs of pollution ($tq_2-\theta q_1$).

For a given level of the technological parameter, the domestic government performs $dW(t,\theta)/dt=0$[14].As I expected, the trade tax has the very well-known negative effect on the consumer surplus:

$$d/dt[\int_o^Q P(Q)dQ-P(Q)Q]=-QP'[\pi_{q_1q_1}-\pi_{q_1q_2}/\Delta]<0 \quad (13)$$

a positive effect on the producer surplus[15].

$$d\pi_1(q_1,q_2)/dt=q_1P'\pi_{q_1q_1}/\Delta>0(14)$$

and a positive effect on the tariff revenue net of pollution costs as well:

$$d[tq_2-\theta q_1]/dt=t\pi_{q_1q_1}/\Delta+q_2-q_1(d\theta/dt)>0 \quad (15)$$

as long as $d\theta/dt<0$, the effect of the trade tax on the tariff revenue net of pollution costs is positive as well, and if the government's commitment is credible and the trade tax provides the sufficient incentives to fully adopt the cleaner technology $d\theta/dt=0$[16].

With these inputs, the government's tax choice affects the balance between these positive and negative effects: should positive effects more than compensate the negative effect on the consumer surplus, the effect of the managed trade using a trade tax on the social welfare would clearly be positive[17].

In any case, the optimal tax will be a function of the indexed parameter θ, i.e.,$t^{opt}=t(\theta)$ where $\theta\in[0,1]$.

In this freely managed trade regime, the protection will be stronger, the lower the parameter θ is. Therefore, for each technological choice within the interval [0,1] there is an optimal trade tax,

[14] Since:$dQ_1/dt=dq_1/dt+dq_2/dt=\pi_{q_1q_1}-\pi_{q_1q_2}/\Delta<0$ because $Q_1=q_1+q_2$, and $\pi_{q_1q_1}<\pi_{q_1q_2}$
$\partial\pi_1/\partial q_1=0$ by (3)
$\partial\pi_1/\partial q_2=q_1P'(Q_1)$ by (1)
$\partial\pi_1/\partial t=0$ because t is an optimal trade tax on imports,
$dq_2/dt=\pi_{q_1q_1}/\Delta<0$ by (10)
$dq_1/dt=-\pi_{q_1q_2}/\Delta>0$ by (9).

[15] Notice that $d\pi_1(q_1,q_2)/dt=(\partial\pi_1/\partial q_1)(dq_1/dt)+(\partial\pi_1/\partial q_2)(dq_2/dt)$, if $\partial\pi_1/\partial q_1=0$, then $d\pi_1(q_1,q_2)/dt=(\partial\pi_1/\partial q_2)(dq_2/dt)$. With Cournot conjectures also remember that $dq_1/dq_2=0$.

[16] Equation (15) shows a positive effect on the tariff revenue net of pollution costs, considering that the level of the optimal trade tax is not prohibitive.

[17] A strong negative effect coming from the consumer surplus would be counterproductive, just as it would be a policy of free trade in the sense that the mechanism that triggers the adoption of the cleaner technology is the credible threat that the government could protect the firm which is adopting the cleaner technology granting some administered trade protection.

which according to the assumptions made, it will grant its highest protection when $\theta=0$, therefore, the optimal trade tax, will be in the range: $t^{opt} \in \max[t(\theta=1),t(\theta=0)]$.

In the general case,we have:

$dW(t,\theta)/dt=0 \Rightarrow$

$$t^{opt}=QP'[\pi_{q_1q_1}-\pi_{q_1q_2}]-[q_1P'+q_2\Delta/\pi_{q_1q_1}]-\theta\pi_{q_1q_2}/\pi_{q_1q_1}\geq 0 \qquad (16)$$

which clearly is positive when $\theta=0$, i.e., when the domestic firm has fully adopted the cleaner technology.

2.3 First stage: adopting the technology

Adopting the environment-friendly technology has naturally to be assessed in two ways: from the firm's perspective and from a social-welfare point of view. Firstly, the net gain of adopting the cleaner technology must be non-negative:

$$\pi_1(q_1,q_2;\theta=0)-\pi_1(q_1,q_2;\theta=1)\geq F \qquad (17)$$

Equation (17) compares the net gain of adopting the environment-friendly technology: the greater the granted managed trade protection through a higher trade tax associated with a low pollution parameter θ, the higher the possibility that it would lead to an adoption choice for a given sunk cost F, provided the net gain function be non-negative.

Secondly, if the technology adoption parameter is indexed and $\theta \in [0,1]$, the trade tax would be zero if the domestic firm does not adopt the clean technology. Therefore, as Regibeau and Gallegos (2004) pointed out, a free-trade policy would be harmful for the environment as long as there would be no incentives for the domestic firm to adopt the cleaner technology.

Naturally, at this point I will look for the level of the optimal trade tax and the resultant tariff revenue that compensates for the welfare loss on the consumer surplus due to the application of the trade tax. The answer to this question is strongly linked with the value the pollution parameter θ takes, and the level of imports from the foreign country q_2. Strategically, if the credible threat of granting managed trade protection is taken for acknowledged by the domestic firm and it fully adopts the cleaner technology, the trade tax chosen by the government, is expected to provide the highest protection[18].

In the context of the managed trade protection proposed here, the combination of these two effects, points to a result where an optimal trade tax must be higher than that obtained from a non-cooperative game solution where the domestic firm does not necessarily adopt the cleaner technology. The explanation is straightforward: if the mechanism linking pollution and trade does not provide the incentive to adopt the cleaner technology through the credible threat, there is no

[18] This does not mean that trade revenues will be at their highest level as well, because whereas t is a decreasing function of θ, q_2 is an increasing function of θ, so that the higher the pollution parameter is, the greater the level of imports will be, but the lower the tariff revenue will result as well. On the other hand, being q_1 and q_2 perfect substitutes, their levels depend on the parameter θ. If the domestic firm adopts, $\theta=0$ and $q_1$is expected to be higher than q_2. If the domestic firm does not adopt, $\theta=1$ and q_1 is expected to be equal to q_2, because t would be zero.

reason to adopt it[19]. The limited commitment of the government to provide protection is acknowledged by the domestic firm when trade protection is administered to finally adopt the cleaner technology, but not when the local government does not have such a mechanism. In that case, it might be unfavorable to adopt the cleaner technology at the sunk cost F, because there would be insufficient incentives to adopt it. In other words, the optimal trade tax between the managed trade regime and the non-cooperative solution is in the range:

$$t^{opt}(\theta)\in\max\{t(\theta=1),t(\theta=0)\} \text{ for } \theta\in[0,1] \qquad (18)$$

where $t(\theta=1)$ is the optimal tax when the domestic firm does not adopt (non-cooperative solution), whereas $t(\theta=0)$ is the level of trade tax that emerges from the adoption. In the first case $t=0$, whereas in the second case t is at its highest level[20].

Proposition 1: In this model, managed trade provides the strongest ex-post protection. The non-cooperative solution including any possible trade liberalization lowers the domestic firm's incentives to adopt the cleaner technology.

Proof:

i) For the small open economy case, the non-cooperative solution for an optimal trade tax is: $t^{opt}=0$,

ii) Any free trade policy would set $t=0$, and

iii) Any trade liberalization will not provide more incentives for the domestic firm to adopt than the freely managed trade regime.

At this point, the question that naturally arises is if tariff revenues net of pollution costs do really compensate for the welfare loss associated with the negative effect of the trade tax on the consumer surplus. To answer to this question, the appropriate measure to compare is the change in tariff revenue net of pollution costs plus the change in producer surplus vis-à-vis the change in consumer surplus, i.e.,

$$\Delta\{PS+TR-PC\}\geq\Delta CS \qquad (19)$$

as long as the change in the left-hand side of the eq. (19), more than compensates the change in the right-hand side, the tariff revenue net of pollution costs plays its role.

Proposition 2: Managed trade protection increases the domestic price and the domestic profit, reduces the foreign profit, maximizes the trade tax, and increases tariff revenues net of pollution costs after adoption.

[19] This is also true, whether I use a framework of a small or a big open economy.

[20] Notice that in the model the domestic country is a small open economy where by definition $t^{opt}=0$. If the domestic country were a big open economy, therefore having some market power to fix international reference relative prices, the optimal tax would be $t^{opt}=1/\varepsilon^*$, being ε^* the very well-known price elasticity of the foreign offer curve. In this case: $t^{opt}(\theta)\in\max\{t(\theta=1),t(\theta=0)\}$ for $\theta\in[0,1]$ should be strictly greater than $t^{opt}=1/\varepsilon^*$. Failing to do so in the managed trade protection regime, firms would not adopt the cleaner technology, because an optimal level of protection is already given.

Proof:

i) The increase in the price is given by the following expression:

$dP/dt=P'(dq_1/dt+dq_2/dt)=P'(\pi_{q_1q_1}-\pi_{q_1q_2}/\Delta)>0;$

ii) The increase in the domestic profit follows from:

$d\pi_1/dt=(\partial\pi_1/\partial q_1)(dq_1/dt)+(\partial\pi_1/\partial q_2)(dq_2/dt)=q_1P'\pi_{q_1q_1}/\Delta)>0;$

iii) The reduction in the foreign profit from:

$d\pi_2/dt=q_2P'dq_1/dt-q_2=-q_2(1+P'\pi_{q_1q_2}/\Delta)<0;$

iv) The maximization of the trade tax from adopting or not the cleaner technology, where:

$t^{opt}(\theta)\in\max\{t(\theta=1),t(\theta=0)\}$ for each $\theta\in[0,1]$.

v) The increase in tariff revenues net of pollution costs:

$d[tq_2-\theta q_1]/dt=t\pi_{q_1q_1}/\Delta+q_2-q_1d\theta/dt>0.$

2.4 Private vs. social incentives

Analyzing the firm's incentive to adopt the cleaner technology and the social incentives to adopt it naturally leads us to ask if there is a threshold where the negative effect of the administered protection on the consumer surplus could more than compensate for the remaining positive effects considering there is a sunk cost of adoption as well. As I have already mentioned, the incentive domestic private firms have to adopt the environmental-friendly technology can be obtained by simply comparing the firm's benefits against the sunk cost F.

$$\Phi_1=\pi_1(\theta=0)-\pi_1(\theta=1)\geq F \qquad (20)$$

In this way, the private incentive for the domestic firm, i.e., the difference between the benefits of adopting and not adopting, should be no less than the sunk cost F.

I will assume that this is the case, and then I will compare the change in the social welfare of adopting the cleaner technology net of the private incentives. Therefore, the change in the social welfare net of the private incentives becomes:

$$\Delta W-(\Phi_1-F)=\Delta CS+\Delta(TR-PC) \qquad (21)$$

The first term on the right-hand side of eq. (21) is the change in the consumer surplus. This term is clearly negative since adopting the cleaner technology means to face higher domestic prices reflecting the administered protection given by the government. The second term on the right-hand side is the change in the tariff revenue net of pollution costs. This term has two elements: one that not always is an increasing function of θ, i.e., the tariff revenue ΔTR, because it depends on the value the pollution parameter θ takes[21].The second one is the change in the cost associated

[21] The pollution parameter is a continuous variable taking values between 0 and 1, tariff revenues would take a maximum and then would decline to zero as long as θ approaches to 1.Therefore, for "high" values of θ, adoption clearly increases tariff revenues, whereas for "low" values of θ, adoption naturally decreases tariff revenues.

with the pollution externality, ΔPC. The change in this latter term is always positive, because $d\theta/dt \leq 0$ and the full adoption makes the pollution parameter equal to zero, i.e., $\theta=0 \Rightarrow PC=0$.

Notice that the change in social welfare will be positive if the change in the tariff revenue net of pollution costs more than compensate for the negative effect of managed protection on the consumer surplus. However, in that case, private incentives to adopt the cleaner technology could be insufficient from the social welfare point of view. This means that eq. (21) is positive for the values the indexed θ can take, but there are some values for the sunk cost F at which adoption, though desirable, does not necessarily take place[22].

2.5 Endogenous number of domestic adopting firms

In this section I will examine the main effects of changing the number of domestic and foreign firms, upon the optimal trade tariff, the private incentives and the social welfare of adopting the cleaner technology. Moreover, I will consider a subcase in which I am determining endogenously the number of home adopting firms. For that purpose, I will have δ domestic firms adopting the high technology and n-δ not adopting it. These n domestic firms will compete in the third stage with m foreign firms in the domestic market. The timing of the game is like the general case. I will analyze the subgame perfect equilibrium in each of the three stages.

3. Third Stage: firms compete à la Cournot

Like in the general case, I assume that all domestic firms are symmetric and the choice of technology does not affect marginal costs. In fact, without loss of generality, I will assume that the marginal costs are constant and equal to zero for the sake of simplicity. Additionally, I will assume a specific inverse demand function of the linear type where $P(Q)=a-bQ$, where $a=1=b$. Then, the profit functions of every representative firm take the following form:

Domestic representative adopting firm:

$$\pi_i=P(Q)q_i-F, \text{ for any } i=1,2,...,\delta. \quad (22)$$

$$\pi_j=P(Q)q_j, \text{for any } \delta+1,...,n. \quad (23)$$

Foreign representative firm:

$$\pi_k=P(Q)q_k-tq_k, \text{ for any } k=1,...,m. \quad (24)$$

where the specific inverse demand function is:

$$P(Q)=1-(\textstyle\sum_{i=1}^{\delta}q_i+\sum_{j=\delta+1}^{n}q_j+\sum_{k=1}^{m}q_k) \quad (25)$$

Again, at this stage of the game, conjectures are of the Cournot type. In order to get the reaction functions, I solve for the first order conditions considering that domestic and foreign firms are

[22] See the graph of the last proposition.

symmetric[23].Then for the non-pollutant domestic firms and after solving simultaneously the reaction functions I obtain the output levels in equilibrium for each type of firm:

$$q_d^H=(1+mt)/(1+m+n) \quad (26)$$

$$q_d^L=(1+mt)/(1+m+n) \quad (27)$$

$$q_f=(1-t(n+1))/(1+m+n) \quad (28)$$

It is clear from eqs. (26), (27) and (28) that the effect of the trade tax in each of the output levels affects positively the output of domestic firms and negatively the output of the foreign firm[24]. With this information we obtain:

$$P=(1+tm)/(1+ m+n) \quad (29)$$

$$Q=(n+m(1-t))/(1+ m+n) \quad (30)$$

Similarly, substituting those output values in each profit function we have for the non-pollutant domestic firm:

$$\pi_i=(1+mt/1+ m+n)^2\text{-F, for any } i=1,2,...,\delta. \quad (31)$$

for the pollutant domestic firm:

$$\pi_j=(1+mt/(1+ m+n)^2\text{, for any } j=\delta+1,...,n. \quad (32)$$

and for the foreign representative firm:

$$\pi_k=(1+tm)(1-t[n+1])/[1+ m+n]^2\text{, for any } k=1,2,...,m. \quad (33)$$

3.1 Second stage: optimal trade tax

At this stage of the game, government chooses the optimal trade tax maximizing a social welfare function that includes, as is usual, the consumer surplus, profits of the domestic firms, the trade tax revenue and the costs associated with pollution emissions. It is important to recall that if domestic firms adopt the cleaner technology, it has been assumed that pollution emissions are reduced to zero, i.e., $\theta q_i=0$ for any $i=1,...,\delta$. Then the social welfare function takes the following functional form:

$$W(t,\theta)=\int_o^Q P(Q)dQ-P(Q)Q+\delta\pi_i(0)+(n-\delta)\pi_j(\theta)+tmq_f-\theta(n-\delta)q_d^L \quad (34)$$

After totally differentiating eq. (34) with respect to t for a given θ, i.e., $dW(t,\theta)/dt=0$, we obtain:

$$t^{opt}=((1+2n)-\theta(n-\delta)(1+ m+n))/(2(1+n)^2+m) \quad (35)$$

Aiming at having an interior solution the degree of adoption must take the value$\theta<(1+2n)/(n-\delta)(1+ m+n)$, which naturally occurs because $\theta\in[0,1]$. Therefore, the optimal tax is clearly positive.

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[23] Because firms are symmetric: $\sum_{i=1}^{\delta}q_i=\delta q_d^H$, $\sum_{j=\delta+1}^{n}q_j=(n-\delta)q_d^L$ and $\sum_{k=1}^{m}q_k=mq_f$, where d and f stands for domestic and foreign production or firms; respectively, and H stands for "high" or clean technology, whereas L for "low" or dirty technology.

[24] Notice that superscripts H and L stand for "high technology" and "low technology", in other words, for adopting and not adopting firms.

Proposition 3: The larger the number of adopting firms δ, the higher the level of the optimal trade tax will be.

Proof: By taking the partial derivative of the optimal trade tax with respect to parameter δ:

$\partial t^{opt}/\partial\delta=\theta(1+m+n)/[2(1+n)^2+m]>0$.

Proposition 4: The larger the number of not adopting firms (n-δ), the lower the level of the optimal trade tax will be.

Proof: By taking the partial derivative of the optimal trade tax with respect to parameter (n-δ):

$\partial t^{opt}/\partial(n-\delta)=-\theta(1+m+n)/[2(1+n)^2+m]<0$.

On the other hand, comparing the domestic firm's incentives to invest in the non-polluting technology, any single domestic firm compares the net benefit of full adoption versus not adopting at all the cleaner technology:

$$\Phi_i\equiv\pi_i(\theta=0)-\pi_i(\theta=1)\geq F\text{, for any } i=1,...,n. \quad (36)$$

Therefore, when comparing this private benefit with the sunk cost F, there is a threshold for adoption: the lower the sunk cost F is, the higher the degree of adoption the domestic firm will take. Naturally, the i-th firm will invest in the cleaner technology if and only if $F<\Phi_i$.

Comparing the change in the domestic welfare net of the net producer surplus from adopting versus not adopting the cleaner technology:

$$\Delta W-(\Phi_1-F)=\Delta CS+\Delta(TR-PC) \qquad (37)$$

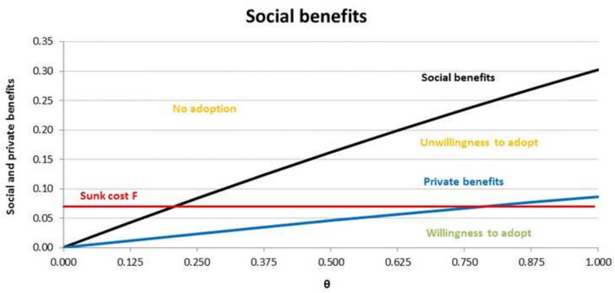
Equation (37) for the specific case where n=1=m allows us to see the expected result:

$$\Delta W-(\Phi_1-F)=7\theta(8-\theta)/162 \qquad (38)$$

which is no negative given that $\theta\in[0,1]$.

Proposition 5: Private incentives are insufficient to adopt the cleaner technology from the point of view of the domestic welfare, specifically when the sunk cost of adoption F lies in the range (Φ_i,ΔW)

for a given ϑ.



Finally, assuming free entry to get the endogenous number of adopting firms, I analyze the benefits of any adopting firm net of sunk costs for a given indexed value of θ, when benefits for this firm are equal to zero to get the maximum number of adopting firms, i.e.,

$$\pi_i=(2(1+n)^2+m+m[(1+2n)-\theta(n-\delta)(1+ m+n)])/(2(1+n)^2+m)(1+ m+n))^2-F=0, \text{ for any } i=1,2,\ldots,\delta. \quad (38)$$

which implies that the number of adopting firms obtained is:

$$\delta=[2(1+n)^2+m]\{(1+ m+n)\sqrt{F}-1\}-m(1+2n-\theta n(1+ m+n))/\theta m(1+ m+n), \text{ for any } \theta\in(0,1]. \quad (39).$$

4. Conclusion

The mechanism that allows domestic firms to adopt the cleaner technology, is strongly linked with the credibility that the limited commitment the domestic government sets up. The managed trade regime grants protection aiming at abating pollution from the production externality. In this context, liberalizing international trade could be counterproductive since a minimum rate of protection is needed to make that threat credible for the domestic producer to adopt, in certain degree, the cleaner technology, as long as the sunk cost F does not exceed the producer surplus.

Notably, even though the model can be thought of for a small open economy -as in this paper-, the tariff that is obtained from the managed trade protection regime in the presence of production externalities is different from zero, as is usual when modelling small open economies in a context of imperfect competition. Precisely, the government's threat to be credible, requires a positive level of protection, otherwise, it would not be credible and the alleged managed protection will not have the expected adoption results. However, even in the case of a big open economy, the level of protection must be higher than that obtained from a non-cooperative solution as long as the domestic government needs to keep its limited commitment to grant extra protection to adopt the cleaner technology.

The domestic welfare behaves as expected when the domestic pollution parameter takes some values to favor interior solutions for the output levels and the specific trade tax. In those cases, it is clear that even though the effects of the managed protection are well known as distortionary, those are clearly compensated as long as the sunk costs do not exceed the gross benefits from adopting the cleaner technology. For the policy maker, to maintain credibility on the level of protection granted, is crucial to avoid negative effects that may exacerbate opening trade processes upon the environment: a free-trade policy could be counterproductive for the domestic firm to adopt, since the incentives to adopt are null.

This model clearly can be extended if I allow pollutant technologies of production in the foreign country, so that governments play a subgame simultaneously choosing the levels of protection, while firms play à la Cournot, being at the same time, followers whether adopting or not the cleaner technology through the protection granted in the second stage.

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