OPTIMAL TRADE AND ENVIRONMENTAL POLICIES IN A POLLUTED SMALL OPEN ECONOMY

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Resumen: Este trabajo investiga la relación teórica que existe entre las políticas óptimas de comercio y medio ambiente, y sus efectos sobre el bienestar de una economía pequeña, contaminada y abierta, que enfrenta distorsiones comerciales y externalidades en la producción. La contaminación afecta a los consumidores, pero no la productividad de las unidades de producción vecinas, y se genera por el propio proceso de producción a través del uso industrial de un insumo intermedio. El bien final no numerario y el insumo intermedio son producidos con una tecnología que exhibe rendimientos constantes a escala, donde los factores primarios de producción son considerados como no comercializables y son ofrecidos inelásticamente. En este marco teórico se consideran tres instrumentos: un arancel a un bien final, un impuesto a la contaminación y un arancel a las importaciones del insumo intermedio que genera contaminación.

Abstract: Using a pollution-trade general equilibrium model I investigate the theoretical relationship between trade and environmental policies and their welfare effects in a perfectly competitive small open economy, facing trade and pollution distortions. Pollution does harm consumers but does not affect the productivity of neighboring firms and is generated as a by-product of the production process through the industrial use of a pure intermediate input. The final tradable good and the intermediate input are produced with a constant returns to scale technology where non-tradable primary factors of production are offered inelastically. In this framework there are three instruments considered: a tariff on a final good, a pollution tax and a tariff on the imports of the pollution-creating intermediate input.

Clasificación JEL: F18

Palabras clave: optimal policies, intermediate pollutant input, welfare, small open economy, políticas óptimas, insumo intermedio contaminante, bienestar, economía pequeña y abierta.

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1. Introduction

Since the implementation of the General Agreement on Tariffs and Trade (GATT 47) policy-makers have had to understand and explain the linkages between trade and environmental policies and their effects on the environment, trade and welfare of open economies due to further world trade liberalisations.

While environmentalists maintain that free trade may harm the environment and could adversely affect welfare, free traders argue that freer trade is likely to improve them. The former are particularly concerned about free trade's long-term effects upon the use of environmental resources, arguing that further trade liberalisation will eventually expand the extent of the preexisting externalities and the market failures that create them. Thus their main concern lies in the fact that long-term losses due to the depletion of natural resources could offset the short-term welfare gains, resulting in the non-sustainability of the liberalisation policy, unless appropriate environmental and trade policies are designed and put in place.

This paper is concerned with the theoretical relationship between trade and environmental policies and their effects on welfare in a polluted small open economy. Unlike Turunen-Red and Woodland (1999), however, I propose a number of comparative static exercises to determine the optimal trade and environmental policies under different second-best scenarios, rather than proposing piecemeal trade and environmental reforms in a multilateral setting. I study the nexus between trade and environmental policies and how direct and indirect effects of changes in trade and environmental taxes affect domestic welfare.

Most of the literature[1] has focused on two particular issues: the way pollution is modelled, and how to correct production externalities in open economies with second-best trade policies. Copeland and Taylor (2001) and Turunen-Red and Woodland (2001) propose a standard framework to assess trade liberalisations under the scale, composition and technique effects of trade on the environment. In Copeland (1994) and Copeland and Taylor (2003), local pollution is modelled as a by-product of the production process and an emissions tax is imposed by the government. Copeland (1994) carried out a number of comparative static cases where direct and indirect (spill over) effects of trade policies on the environment are considered. He

[1] See Baumol and Oates (1988), Cropper and Oates (1992) among others for a general discussion on this matter.

concludes that piecemeal trade and environmental reforms should be coordinated. On the other hand, he provides a number of cases where the use of quotas, as a control for pollution emissions, does not provide a possible second best justification for trade restrictions on the production of the remainder of the productive sectors.[2]

The current paper also addresses the relationship between trade and endogenous pollution levels. However, the main focus is quite different from the previous literature. It departs from the standard approach in the sense that, although pollution is similarly generated as a by-product of the production process, it occurs through the use of an intermediate pollutant input.[3] In so doing, this paper emphasises explicitly the incorporation of an intermediate input which can or cannot be produced domestically. Special attention is given to the treatment of an intermediate input in the context of the dual approach and the concepts of net and gross output revenue. This theoretical departure seems to be more realistic in the sense that potentially every final good can be thought of as an intermediate input and its consumption can generate any kind of pollution.

On the other hand, the model incorporates the issue of pollution intensiveness in the final goods' production. With that fundamental change, I provide a justification for the policy-maker to use trade policy instruments to deal, in a second best fashion, with production externalities.[4] The perfectly competitive small open economy faces exogenous international prices and has three policy instruments available, a per-unit tax on the non-numeraire good, a per-unit tax on the intermediate input and a pollution tax. Firms in the two relevant sectors of the economy are profit maximisers and the non-numeraire sector uses the intermediate input intensively, so it can be considered as the pollutant. The main feature of the model adds realism to the results obtained from the comparative statics carried out, because through trade policy, spillover effects actually reduce or exacerbate

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[2] See Corden and Falvey (1985).

[3] Pollution generated in this way can be interpreted as being produced through industrial consumption, rather than by the production process itself.

[4] This way of modelling pollution avoids the complexity that arises when pollution is modelled as a result of the production process like in the joint-production approach. Additionally, it provides the same framework as in the Heckscher-Ohlin model where factors are materialised in final goods, so that we can think of exports as being exports of factors of production. It also provides us a mechanism where, via prices, direct and indirect effects of trade and environmental policies influence the reallocation of resources when prices of final goods go up or down as a result of trade and environmental reforms.

the negative effects of the use of the intermediate input. In that sense, the results presented in this model can be considered as an argument that justifies including some environmental standards in trade negotiations.

The plan of the paper is as follows. In section 2, the theoretical aspects of the model are thoroughly explained. I will develop the production and consumption sides with a number of theoretical concepts that will allow us to examine the effects of marginal changes in a distorted equilibrium. The perfectly competitive framework and the dual approach will simplify this analysis. In section 3, the case of a small open economy is treated and several comparative static exercises are performed in order to find the optimal environmental and trade policies under different second-best settings. Finally, in section 4 some conclusions are outlined.

2. The Model

I start by considering a standard model of a perfectly competitive small open economy that faces fixed world prices. Two final goods are produced by two subsectors which differ in the intensity of the use of the intermediate input which is produced by a third sector, and tradeable in the international market, as the final goods.

Pollution is generated as a by product of the production process. The first final good is the numeraire so that its price will, as is usual, be considered as $p_1 = 1$; the second final good will be the non-numeraire, so that its price p_2 will be the relative price of the non-numeraire good in terms of the numeraire, and the third product, an intermediate input, will have its price q in terms of the numeraire as well. I will suppose the intermediate input is a nitrogenous fertiliser.

The economy is assumed to be endowed with three primary factors of production which are offered inelastically and are non-tradeable in international markets, namely: labour, capital and urea. The economy has three industries, each one producing only one product. Sector one and two produce the numeraire and non-numeraire respectively, with two of the following primary factors each: capital, labour and fertiliser as intermediate inputs. Sector three produces the intermediate input with three primary factors of production: capital, labour and urea.

To keep things simple, I have assumed that pollution does harm consumers but does not affect productivity in neighbouring firms. On the other hand, pollution generated through consumption activities is not considered.[5] The two final goods and the intermediate input are produced with a constant returns to scale technology. The proposed model is a standard one of a perfectly competitive small open economy with trade and pollution taxes: t and τ, as trade instruments and s playing a role as a pollution tax.[6]

To characterise the production side of this small open economy I will use the gross GDP or revenue function:[7]

$R(p, q+s, V) = \max_{\{g, g^F\}} \{pg \mid (x, V) \in T\}$.[8] By the envelope theorem (Hotelling's Lemma): $R_p = g$ is the gross supply of the non-

[5] Copeland and Taylor (1995) consider a model where pollution is generated in the consumption sector.

[6] Unlike Copeland (1994), where the model explicitly incorporates a vector of pollutants generated by the production process, in this model there is not a function that relates the amount of product to the amount of pollution generated. Instead it is assumed to be produced by the use (industrial consumption) of the intermediate input.

[7] The main differences in a context of the Heckscher-Ohlin framework are firstly, that the introduction of an intermediate input makes necessary the introduction of the gross and net output concepts, both at an industry level, and at a sectorial level. The latter is the relevant variable for the purposes of this model. The net (sector) product is defined as the gross product of commodity j minus the input of commodity j used in all industries (including the one that produces that commodity). If as a result of the above calculation the net product is zero, it means that commodity j has been produced only to serve as an input in the production of other final goods.

Secondly, considering that the intermediate input is produced with the same primary factors as the final goods, it is necessary to make further assumptions regarding the dimension of the model. Accordingly, in the traditional two by two case (two factors-two products), the introduction of the intermediate input carries out several other theoretical implications. Batra and Casas (1973), pointed out that the Heckscher-Ohlin theorem depends on the validity of the Stolper-Samuelson and Rybczynski theorems. However, when three goods are produced, the pattern of trade turns out to be indeterminate.

To solve this, either the intermediate input or one of the final goods should be considered as non-tradeable. Alternatively, another solution would be to consider that world prices are such that the production of one of the goods is unprofitable. In such a case, we would have the classical two by two case again, but the solution would be unattractive. So, this model preserves the attraction of the two-by-two case in its n-by-n generalization in the sense that the definition of factor intensity involves only the technology and not the factor endowments. The uniqueness of the determination of the factor market prices by the goods' prices holds in this three-by-three model (factor price equalisation theorem).

[8] The revenue function is convex in prices and concave in factor endowments,

numeraire product; $R_q = g^F$ is the gross supply of the intermediate input; $R_v = w$ is the vector of primary factor prices, and $R_F = q + s$ is the industrial consumer's price of fertiliser.

Because the revenue function is convex in prices, output supplies are upward-sloping, then: $R_{pp} \geq 0$ and $R_{qq} \geq 0$. On the other hand, the sign of the fertiliser's cross price effect on the non-numeraire good's supply, i.e., $R_{pq} \leq 0$, whether the non-numeraire good uses intensively the intermediate input $(R_{pq} < 0)$, or not $(R_{pq} = 0)$.[9]

Being concave in the factor market prices, the second derivatives of the revenue function are: $R_{vv} \leq 0$ and $\frac{\partial R_F}{\partial F} = R_{FF} \leq 0$,[10] i.e., the inverse demands for all factors are downward-sloping. On the other hand, the Rybczynski coefficients are: $R_{pv} = R_{vp}$, and $R_{pF} = R_{Fp} >$ or < 0, depending on whether the non-numeraire good uses the intermediate input intensively $(R_{pF} > 0)$, or not $(R_{pF} < 0)$, respectively.

The demand side will be modelled using the dual of the indirect utility function. The expenditure function will now include the amount of fertiliser used by the agricultural sector. It emerges from the following maximisation program: $E(p, U, F) = \min_{\{c\}}\{pc : U \geq U_0, c \geq 0\}$.[11]

Application of the envelope theorem (Shephard's lemma) leads

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and linearly homogeneous in each set of parameters.

[9] An alternative way to look at it is that if the intermediate input is used intensively in the production of the non-numeraire good, an exogenous increase in the price of the non-numeraire good, p_2, would cause an increase in the production of this final good, consequently, that would increase the demand for the intermediate input. However, due to the reallocation of productive resources, the excess demand for the intermediate input would put pressure on the industrial's consumer price, therefore increasing $(q+s)$ and then decreasing the production of the final non-numeraire good. By Young's theorem $R_{pq}=R_{qp}\leq 0$.

[10] According to the concavity of the revenue function. It answers the question about how the producer's price of fertiliser changes when the supply of fertiliser changes.

[11] The utility function is additively separable in goods and pollution, i.e., $U(c,F)=\phi(c)+\varphi(F)$, since pollution adversely affects consumers' utility we have $\varphi'(F)<0$. Besides, in the utility function, consumption of goods is a choice variable for the consumer, but pollution generated through the industrial consumption of fertiliser F is not controlled by the representative consumer. Equivalently, consumer preferences may be represented by the expenditure function $E(p,U,F)$ which is concave in p, and increasing in U and F. An increase in the level of F is assumed to harm consumers, so that the minimum cost of attaining a given utility level increases with F.

us to get: E_p the Hicksian demand function, E_U the reciprocal of the marginal utility of income, and E_F the marginal damage. Moreover, due to the concavity of the expenditure function on p, the second derivatives of the expenditure function are $E_{pp} \leq 0$, which is the slope of the compensated demand function.[12] Likewise, $E_{pU} > 0$ with prices given, the increase in utility leads to an increase in the level of consumption. Furthermore, $E_{pF} \geq 0$ so that the increase in the level of pollution affects the compensated demand for final goods.[13]

2.1. *Equilibrium*

The equilibrium for this economy will be represented by the following trade expenditure functions for the domestic and foreign countries, respectively, and the market clearing conditions on the non-numeraire and the intermediate inputs:

$$E(1, p+t, U, F) = R(1, p+t, q+\tau, V, F) - R_F F + sF + tm + \tau m^F \quad (1)$$

$$E^*(1, p, U^*, F^*) = R^*(1, p, q, V^*, F^*) - R^*_F F \quad (2)$$

$$m + m^* \neq 0 \quad (3)$$

$$m^F + m^{F*} \neq 0 \quad (4)$$

In general from equations (1) to (4) it is necessary to determine four unknowns, i.e., two relative prices p and q, and two utility levels U and U^* with four equations. Where:

$$m^F = F - R_q \quad (5)$$

$$m = E_p - R_p \quad (6)$$

$$R_F = q + s + \tau \quad (7)$$

[12] For normal goods the substitution effect will be negative.

[13] To preserve the same level of utility it is necessary to compensate by increasing the amount of the non-numeraire good. However, if compensation is derived from the numeraire good, this derivative is equal to zero.

$$p^d = p + t \tag{8}$$

$$q^d = q + \tau \tag{9}$$

are the imports of the intermediate input (5), the imports of the non-numeraire good (6), the industrial consumer price of the intermediate input (7), the one to one relationship between domestic and international prices of the non-numeraire good (8), and the one to one relationship between the domestic and international prices of the intermediate input (9). Moreover, F is the amount of fertiliser used as an intermediate input by the final goods' sector, t is a trade tax on the non-numeraire good, τ is a trade tax on the intermediate input, and s is a tax on the use of the intermediate input. Equations (1) and (2) represent the general equilibrium trade expenditure functions for the representative consumer in the domestic and foreign countries, whereas equations (3) and (4) capture the market clearing conditions for the non-numeraire and intermediate inputs respectively.[14]

As usual, the representative consumer spends all his income (Wal ras'law): in order to achieve the level U of utility, the representative consumer will spend as much as the gross revenue less the value of the gross intermediate product, plus the revenue collected by the government in the form of a tax on the use of the intermediate input, a trade tax on the imports of the non-numeraire and a trade tax on the imports of the intermediate input. One key assumption made here is that the revenue collected by the government is distributed to the representative agents by mean of lump-sum transfers. The same reasoning would apply to the foreign country.

3. Welfare Effects and Optimal Policies

The model presented involves a small open economy where the foreign country has no active role in the channels by which the domestic welfare is affected.[15] The methodology consists in totally differentiating

[14] Notice that equation (2) does not involve the use of trade and environmental instruments for the foreign country. Besides, equations (3) and (4) held with equality mean that both, domestic and foreign countries, determine international prices for all tradeable commodities. By Walras' law, the market clearing condition for the numeraire good does hold.

[15] Implicitly, the rest of the world is playing a role in the determination of international prices and therefore, in the fulfillment of the market clearing conditions for the intermediate and the non-numeraire good.

the trade expenditure and the market clearing conditions, to establish how the equilibrium can be marginally changed, and how that change affects domestic welfare in order to further examine which channels of transmission are acting.

Totally differentiating (1) and using (5) to (9), taking into account that from (8) and (9) $dp = dt$ and $dq = d\tau$, I get an expression that measures the welfare as a function of the targets: consumption of the intermediate input and imports of the non-numeraire good and intermediate input, rather than the policy instruments:

$$E_U dU = (s - E_F)dF + \tau dm^F + tdm \tag{10}$$

As is known, $E_U > 0$ is the inverse of the marginal utility of income, thus $E_U dU$ measures the change in welfare of the representative consumer and has, according to (10), three components: the change in the consumption of the intermediate input (dF), the effect of the trade distortion on the intermediate input $\left(dm^F\right)$, and the effect of the trade distortion on the non-numeraire good (dm).[16]

Totally differentiating (5), (6) and (7) to get an expression that measures the change in welfare in terms of the changes in the instruments, i.e., the pollution tax and the trade taxes, rather than the targets as in eq. (10), we have,

$$\begin{aligned} E_U dU(1 - tC_y) = &-\alpha A ds - \left[t(R_{pp} - E_{pp}) + \tau R_{qp} - \alpha R_{Fp} A\right] dt \\ &- \left[tR_{pq} + \tau R_{qq} + \alpha(1 - R_{Fq})A\right] d\tau \end{aligned} \tag{11}$$

Equation (11) combines the direct and indirect effects of marginal changes in the policy instruments on domestic welfare. From (7), (8) and (9) marginal changes in the policy instruments directly affect commodities' prices. These potential marginal changes in domestic prices affect the allocation of productive resources among the three different sectors and then on the levels of industrial production, which in turn affects the demand for the intermediate input and then the pollution emissions' level.

As pointed out by Copeland (1994) in the presence of trade taxes (t and τ), an increase in pollution has a direct effect on consumers E_F and indirect effects on trade distortions represented with the term

$$-\tau(1 - R_{qF}) - t(E_{pF} - R_{pF}).$$

[16] The trade distortions are the import tariffs on the non-numeraire good and on the intermediate input.

Then, the A term in equation (11),

$$A = [E_F - s - \tau(1 - R_{qF}) - t(E_{pF} - R_{pF})]$$

represents the measure of the marginal external damage to consumers from pollution (involving direct and indirect effects) and the pollution tax s that compensates the externality.

Accordingly, the term αds represents the direct effect of the change in the tax s on the use of intermediate input F. Similarly, the term $t\,(R_{pp} - E_{pp})\,dt$ captures the direct effect of the change in the trade tax on the net output of the traded non-numeraire good. On the other hand, $\tau R_{qq} d\tau$ represents the direct effect of the change in the trade tax on the intermediate input, on the net output of traded intermediate input. Similarly, the terms $\tau R_{qp} dt$ and $t R_{pq} d\tau$ captures cross effects of marginal changes in trade distortions.

Additionally, the indirect effects of marginal changes in the trade distortions on the demand for the intermediate input (pollution) are represented by the terms: $-\alpha R_{Fp} dt$ for the non-numeraire and, $\alpha(1 - R_{Fq}) d\tau$ for the intermediate sectors, respectively. Likewise, the term $(1 - tC_y) > 0$ is known as the tariff multiplier and is assumed to be positive for normal goods.[17] To find the optimal policies, I will show the next subcases by means of some comparative statics.

3.1. *First Best Cases: One Policy Instrument, One Distortion*

I consider three first best cases where the policy maker or a central planner has just one instrument available to deal with one distortion at a time. I present three sub-cases depending on the type of policy instrument available. Case A shows the optimal level of the pollution tax when trade taxes are at their free trade levels. Cases B and C show the optimal trade taxes for the non-numeraire and the intermediate, respectively, taking into account that the pollution tax is at its optimal level and unalterable.

3.1.1. Case A

The domestic small open economy optimally chooses the pollution tax. Trade taxes corresponding with the non-numeraire good and

[17] The tariff multiplier is known as the Hatta condition and its derivation is fully explained in Hatta (1977).

intermediate input are at their free trade level, i.e., $t = \tau = 0$, which implies $dt = d\tau = 0$.

Equation (11) becomes:

$$E_U dU(1 - tC_y) = -\alpha\,[E_F - s]\,ds \tag{12}$$

Equation (12) measures the change in domestic welfare that depends on the difference between the marginal damage E_F and the pollution tax s, and the direction of the marginal change in the pollution tax (ds). If the pollution tax increases ($ds > 0$), it has two effects on domestic welfare, depending on the difference between the marginal damage and the level of the pollution tax. If the marginal damage is greater (lower) than the pollution tax, i.e., $E_F > s$ ($E_F < s$), an increase in the pollution tax would positively (negatively) affect the domestic welfare.[18]

From (12) we can get the first order condition that maximises domestic welfare to find the optimal pollution tax:

$$\frac{dU}{ds} = 0 \Longrightarrow s^* = E_F \tag{13}$$

The optimal pollution tax is defined by (13) and exactly equal to the marginal damage. It is best known as the Pigouvian tax. Intuitively, the optimal Pigouvian tax results when trade taxes are at their optimal free trade level. This guarantees the relation between the production externality and the level of the pollution tax.

3.1.2. Case B

The domestic small open economy optimally chooses the trade tax on the non-numeraire good. Trade tax corresponding to the intermediate input is at its free trade level, i.e., $\tau = 0$, which implies $d\tau = 0$, while the pollution tax is at the Pigouvian level but unalterable, therefore $ds = 0$.

Equation (11) becomes:

$$E_U dU(1 - tC_y) = -t\,[(R_{pp} - E_{pp}) + \alpha R_{Fp}(E_{pF} - R_{pF})]\,dt \tag{14}$$

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[18] If we had a pollution tax reform, the direction of such a reform would be dependant on the difference between E_F and the level of the pollution tax s.

From (14) we can determine the optimal trade tax that maximises the welfare of the small open economy. The first order condition is then the following:

$$\frac{dU}{dt} = 0 \Longrightarrow t^{*} = 0 \tag{15}$$

The optimal trade tax on the non-numeraire is defined by (15) , and corresponds with its free trade level.[19]

3.1.3. Case C

The domestic small open economy optimally chooses the trade tax on the intermediate input. Trade tax corresponding with the non-numeraire good is at its free trade level, i.e., $t = 0$, which implies $dt = 0$, while the pollution tax is at the Pigouvian level but unalterable, therefore $ds = 0$. In this case (11) becomes:

$$E_U dU(1 - tC_y) = -\tau \left[R_{qq} - \alpha(1 - R_{Fq})(1 - R_{qF})\right] d\tau \tag{16}$$

From (16) we can find the optimal trade tax such that maximises the small open economy's welfare with the first order condition:

$$\frac{dU}{d\tau} = 0 \Longrightarrow \tau^{*} = 0 \tag{17}$$

The optimal trade tax on the intermediate input is defined by (17), and corresponds with its free trade level.[20]

3.2. *Second Best Cases: One Policy Instrument, Two Distortions*

I consider two sub-cases depending on the type of policy instrument available. In case D, I am assuming that the pre-existent policy-induced distortion through the trade tax on the intermediate input

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[19] This means that when the trade tax on the intermediate input is at its free trade level, i.e., τ^{*}=0, and the pollution tax is the Pigouvian tax, i.e., s^{*}=E_F (unalterable), the first best optimal trade tax on the non-numeraire good is the optimal free trade tax, i.e., t^{*}=0.

[20] This means that when the pollution tax is at its optimal level, i.e., s^{*}=E_F, and unalterable, and the trade tax of the non-numeraire good is at its free trade level, i.e., t^{*}=0, the first best optimal trade tax for the intermediate input is the optimal free trade tax.

is not present because the it is at its optimal level $\tau^* = 0$. Furthermore, I assume that the pollution tax is at a suboptimal level ($s = 0$), although the production externality is still present.

3.2.1. Case D

The domestic small open economy optimally chooses the trade tax on the non-numeraire good. $\tau = s = 0$ which implies $d\tau = ds = 0$.

Then (11) becomes:

$$E_U dU(1 - tC_y) = \qquad (18)$$

$$-(t(R_{pp} - E_{pp}) - \alpha R_{Fp}[E_F - t(E_{pF} - R_{pF})])dt$$

Equation (18) measures the change in welfare only in terms of the change in the trade tax. It can be seen that (18) has a mix of direct and indirect effects that affect its sign. For instance, an increase in the trade tax on the non-numeraire good ($dt > 0$) has two effects: the direct effect $-t(R_{pp} - E_{pp})dt$ that measures the difference of two pure substitution effects, and the indirect effect of the change in the trade tax, via the price of the non-numeraire, on the demand for the intermediate good, i.e., $-\alpha R_{Fp}\,[E_F - t(E_{pF} - R_{pF})]\,dt$.[21]

The optimal trade tax comes from the first order condition: $\frac{dU}{dt} = 0 \Rightarrow$

$$t^* = \frac{\alpha R_{Fp}}{[R_{pp} - E_{pp} + \alpha R_{Fp}(E_{pF} - R_{pF})]} E_F \qquad (19)$$

To determine the sign of the optimal trade tax in (19), assume the non-numeraire sector is using the intermediate input intensively, i.e., $R_{pF} > 0$.[22] Besides, suppose that compensation to consumers comes from the numeraire good, i.e., $E_{pF} = 0$.[23] In such a case, the

[21] If we had a trade reform, the sign of the indirect effect would be crucial to determine the total welfare effect if $dt<0$.

[22] If the non-numeraire sector is not using the intermediate input intensively $R_{pF}<0$.

[23] If compensation comes from the non-numeraire good $E_{pF}>0$. Turunen-Red and Woodland (2001) argue that if the utility function is additively separable in goods and pollution, i.e., $U(c,F)=\phi(c)+\varphi(F)$, as long as pollution adversely affects consumer's utility we know $\varphi'(F)<0$. This implies that $E_{pF}=0$.

optimal trade tax given by (19) would be a negative one, i.e., $t^* < 0$, which means that it would correspond to a subsidy on the imports of the non-numeraire good.

The intuition is that in the absence of a pollution tax correcting the production externality ($s = 0$), a small open economy trading with the rest of the world and acting as a price taker will subsidise its imports of the non-numeraire good,[24] aiming to displace the domestic production of the non-numeraire pollutant good, taking into account both, the production externality and the trade policy-induced distortion, according to the assumptions made.[25]

3.2.2. Case E

The domestic small open economy optimally chooses the trade tax on the intermediate input. $t = s = 0$ which implies $dt = ds = 0$.

In this case, the policy maker has neither the trade tax on the non-numeraire good, nor the pollution tax. Only the trade tax on the intermediate input is available to the policy maker, but the production externality is still present.

Thus the trade balance equation (11) now measures the change in welfare in terms of the change in the trade tax on the intermediate input:

$$E_U dU = -\left(\tau R_{qq} + \alpha(1 - R_{Fq})\left[E_F - \tau(1 - R_{qF})\right]\right) d\tau \tag{20}$$

Equation (20) measures the change in domestic welfare in terms of the marginal change of the trade tax on the intermediate input. Its coefficient has, as in the previous case, a mix of direct and indirect effects upon welfare transmitted via the price of the intermediate input q. For instance, an increase in the trade tax of the intermediate input ($d\tau > 0$) has two effects: $-\tau R_{qq} d\tau$ as a pure substitution (direct) effect. The indirect effect is measured by the term $-\alpha(1 - R_{Fq})\left[E_F - \tau(1 - R_{qF})\right] d\tau$. The term $\left[E_F - \tau(1 - R_{qF})\right]$ is, in this case, the relevant measure of the marginal external damage.

To determine the optimal trade tax on the intermediate input, we look for the first order condition of (20):

[24] Notice that we are not considering transboundary pollution.

[25] From (19) it can be inferred that if the non-numeraire good is not intensive in the use of the intermediate input, i.e., $R_{Fp}<0$, the resulting optimal trade tax on the non-numeraire good would be positive, i.e., $t^*>0$, and greater than the marginal damage E_F.

$\frac{dU}{d\tau} = 0 \Rightarrow$

$$\tau^* = \frac{1}{\left[(1 - R_{qF}) - \frac{R_{qq}}{\alpha(1-R_{Fq})}\right]} E_F \tag{21}$$

Equation (21) is the optimal trade tax that maximises domestic welfare. To find out its sign assume the economy is a net importer of the intermediate input, i.e., $m^F > 0$, then this implies that $(1 - R_{qF}) > 0$ or $\frac{\partial m^F}{\partial F} > 0$.[26] Accordingly, the optimum trade tax on the intermediate input (21) would be positive, i.e., $\tau^*>0$.

The rationale for this result has to do with the fact that imposing a trade tax on the imports of the intermediate input, would cause its price to become greater, decreasing the demand for F and improving indirectly the domestic welfare by reducing pollution emissions.

3.3. *First Best Cases: Two Policy Instruments, Two Distortions*

Next, I examine the case in which the policy maker decides on the level of the instruments available, now two at a time, with two distortions present. I consider two sub-cases: each of the trade taxes in combination with a pollution tax. In so doing, I consider the remainding trade tax as being at its optimal free trade level.

3.3.1. Case F

The domestic small open economy optimally chooses both the trade tax on the use of the intermediate input and the optimal level of the pollution tax. $t = 0$ which implies $dt = 0$.

In this case, the small open economy does not have trade distortions on the non-numeraire good. Equation (11) becomes:

$$\begin{aligned} E_U dU = & -\alpha \left[E_F - s - \tau(1 - R_{qF})\right] ds \\ & - \left[\tau R_{qq} + \alpha(1 - R_{Fq}) \left[E_F - s - \tau(1 - R_{qF})\right]\right] d\tau \end{aligned} \tag{22}$$

[26] The fact that $0<R_{qF}<1$, can be thought of as a consequence of the fact that the domestic country is a net importer of the intermediate input, so that if the rate at which the supply of fertiliser changes R_q relative to changes in the demand for fertiliser R_{qF}, is lower than one, then the domestic country needs to import this input, due to the sluggish adjustment of its domestic supply.

As in the previous cases, from (22) the marginal changes on the levels of the pollution tax (ds) and the trade tax on the intermediate input ($d\tau$) do affect the domestic welfare through direct and indirect effects. If trade tax τ increases ($d\tau > 0$), the direct effect is captured by $-\tau R_{qq} d\tau$, and corresponds to the effect of the marginal change in the trade tax on the supply of the intermediate input. On the other hand, the term $-\alpha(1 - R_{Fq})\left[E_F - s - \tau(1 - R_{qF})\right] d\tau$ measures the indirect effect of the change in the trade tax and then on pollution generation. Since $R_{qq} > 0$, the direct effect of a change in the trade tax τ on the production of the intermediate input will always be positive: the more protection, the higher the level of domestic output will be. Conversely, a reduction in the level of protection will decrease the level of domestic intermediate input produced.[27]

Solving the simultaneous equation system derived from the first order conditions: $\frac{dU}{ds}|\bar{\tau} = 0$ and $\frac{dU}{d\tau}|\bar{s} = 0$, from (22):

$\frac{dU}{ds}|\bar{\tau} = 0$

$\Rightarrow$

$$s = E_F - \tau(1 - R_{qF}) \tag{23}$$

and,

$\frac{dU}{d\tau}|\bar{s} = 0$

$\Rightarrow$

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[27] To determine the sign of the indirect effect we need to define whether the home country is a net importer of the intermediate input. In such a case, as explained above, the sign of the expression $(1-R_{qF})$, would be positive, where R_{qF} involves the indirect effect of the change in the trade tax on the demand for the intermediate input and the generation of pollution. Its sign will also depend on whether the relevant measure of the marginal damage is positive or negative, i.e., the term $[E_F-s-\tau(1-R_{qF})]$.

Further examination of the coefficient premultiplying the marginal change in the pollution tax allows us to establish that the total marginal damage to consumers is given by the expression $\alpha[E_F-\tau(1-R_{qF})]$, where the direct effect is captured by the marginal damage E_F and the indirect effect by $\tau(1-R_{qF})$. Using a similar setting, Turunen-Red and Woodland (2002) modelled the effects of pollution on welfare with an index of environmental damage, which measures the environment's quality as a function of the amount of pollution emissions considering, abatement activities. This characteristic, leads to a different set of policy implications.

$$\tau = \frac{\alpha(1 - R_{Fq})\,(s - E_F)}{(R_{qq} - \alpha(1 - R_{Fq})(1 - R_{qF}))} \tag{24}$$

Now solving simultaneously the equation system (23) and (24), we get:

$$s^* = E_F \tag{25}$$

$\Rightarrow$

$$\tau^* = 0 \tag{26}$$

Equations (25) and (26) show the first best level of trade and pollution taxes. While (25) measures the optimal Pigouvian tax, (26) is the free trade level for the tax on the intermediate input. This result is consistent with a trade tax on the non-numeraire good being at its free trade level, i.e., $t^* = 0$.

3.3.2. Case G

The domestic small open economy optimally chooses the trade tax on the non-numeraire good and the optimal level of the pollution tax. $\tau = 0$, which implies $d\tau = 0$.

In this case the small open economy does not have a trade distortion on the intermediate input. Equation (11) then becomes:

$$E_U dU(1 - tC_y) = -\alpha\,[E_F - s - t(E_{pF} - R_{pF})]\,ds \tag{27}$$
$$- [t(R_{pp} - E_{pp}) - \alpha R_{Fp}\,[E_F - s - t(E_{pF} - R_{pF})]]\,dt$$

As in the previous case, we need to solve the simultaneous equation system from the first order conditions, i.e., $\frac{dU}{ds}|\bar{t} = 0$ and $\frac{dU}{dt}|\bar{s} = 0$, simultaneously. So, from (27):
$\frac{dU}{ds}|\bar{t} = 0$

$\Rightarrow$

$$s = E_F - t(E_{pF} - R_{pF}) \tag{28}$$

Now from
$\frac{dU}{dt}|\bar{s} = 0$

$\Rightarrow$

$$t = \frac{\alpha R_{Fp}\,(E_F - s)}{((R_{pp} - E_{pp}) + \alpha R_{Fp}(E_{pF} - R_{pF}))} \tag{29}$$

Solving simultaneously (28) and (29), we then get:

$$s^* = E_F \tag{30}$$

$\Rightarrow$

$$t^* = 0 \tag{31}$$

If the trade tax on the intermediate good is at its free trade level, i.e., $\tau^* = 0$, the optimal first-best policy for intervention is a Pigouvian tax on the use of the intermediate input, i.e., $s^* = E_F$, and a trade tax on the non-numeraire good at its free trade level, i.e., $t^* = 0$, as (30) and (31) define. Unlike the results shown in Turunen-Red and Woodland (2002),[28] in this model the optimal trade policy is the free trade level for the trade policy instrument while the optimal environmental policy remains the Pigouvian tax. The theoretical context is similar to Copeland (1994) in the sense that if pollutants that are lightly taxed are generated when highly protected goods are produced, then there is a welfare gain if protection is reduced, which means that the direct effect of a reduction in the trade tax acts in the same direction of the indirect effect of the trade tax on the pollution emissions: both effects contribute to improve domestic welfare.[29]

[28] Turunen-Red and Woodland (2002), found a dependence between the free trade level and the level of the environmental tax, namely, "free trade is optimal in our small open economy only when environmental tax distortions have been removed or if production activities have no pollution effects". See note no. 10 in Turunen-Red and Woodland (2002).

[29] Assuming that compensation to the representative consumer comes from the numeraire good and that production of the non-numeraire is intensive in the use of the intermediate input, $(E_{pF} - R_{pF}) < 0$, then the whole associated indirect effect in (27), i.e., $\alpha R_{Fp}[E_F - s - t(E_{pF} - R_{pF})]dt > 0$, would be positive, as long as we had the optimal Pigouvian tax, i.e., $s^* = E_F$. In other words, an increase in the level of protection would exacerbate the pollution distortion because production of the pollution-intensive non-numeraire good increases at the expense of trade protection, therefore generating more pollution.

Similarly, an increase in the pollution tax would decrease industrial consumption of the intermediate pollutant input, therefore the marginal damage would decrease as well. On the other hand the spill-over effect can be expressed

3.4. *Second Best Cases: Two Policy Instruments, Three Distortions*

In this subsection I present three subcases where the policy maker does have the possibility to change two policy instruments at a time in the presence of all distortions. In each of the cases, one of the unavailable instruments is supposed to be at a suboptimal level and unalterable.

3.4.1. Case H

The domestic small open economy optimally chooses the trade tax on the non-numeraire good t and the pollution tax s in the presence of all potential distortions, with the trade tax on the intermediate input at a suboptimal level and unalterable this implies that $d\tau = 0$.

Equation (11) becomes:

$$E_U dU(1-tC_y) = -\alpha A ds - (t(R_{pp} - E_{pp}) + \tau R_{qp} - \alpha R_{Fp}A)\, dt \quad (32)$$

From (32) we solve two first order conditions that generate a system of simultaneous equations:
$\frac{dU}{dt}|\bar{s}, \bar{\tau} = 0$

$\Longrightarrow$

$$t = \frac{\alpha R_{Fp}\,(E_F - s) - \tau\,[R_{qp} + \alpha R_{Fp}(1 - R_{qF})]}{[(R_{pp} - E_{pp}) + \alpha R_{Fp}(E_{pF} - R_{pF})]} \quad (33)$$

and
$\frac{dU}{ds}|\bar{t}, \bar{\tau} = 0$

$\Longrightarrow$

$$s = E_F - \tau(1 - R_{qF}) - t(E_{pF} - R_{pF}) \quad (34)$$

Solving the system (33) and (34) we have:

as $t(E_{pF} - R_{pF})ds$, which in combination with the difference between the pollution tax and the marginal damage, gives us the total effect of the change in the pollution emissions tax on the reduction in the use of the intermediate input and the related effect on the utility and the production of the intermediate input.

$$t^* = -\frac{\tau R_{qp}}{(R_{pp} - E_{pp})} \tag{35}$$

and

$$s^* = E_F + \tau \left(\frac{R_{qp}(E_{pF} - R_{pF}) - (R_{pp} - E_{pp})(1 - R_{qF})}{(R_{pp} - E_{pp})} \right) \tag{36}$$

Looking at (35) and (36) ,it is clear that the sign of the optimal trade tax on the non-numeraire good depends on the sign of the trade tax τ imposed to the intermediate input, provided that the following factor is positive:

$$\left(\frac{-R_{qp}}{R_{pp} - E_{pp}} \right) > 0$$

as it is, by the assumptions made. Thus, the sign of the optimal trade instrument will be positive or negative, i.e., $t^* >$ or < 0, as long as the suboptimal tax on the intermediate input is positive or negative as well, i.e., $\tau >$ or < 0.

Analogously, the optimal pollution tax would be positive, negative or equal to the marginal damage, i.e., $s^* \gtreqless E_F$, depending on the sign of the term $R_{qp}(E_{pF} - R_{pF}) \gtreqless (R_{pp} - E_{pp})(1 - R_{qF})$, and the sign of the preexistent trade tax on the intermediate input, i.e., $\tau \gtreqless 0$. The relevance of this result is appreciated clearly if we compare the second best optimal pollution tax from (36) to the first best optimal one that comes from (30).

In this second best scenario the potential policy-induced distortion caused by a suboptimal τ is partially compensated by the second-best optimal pollution tax s^*, and the second best optimal trade tax t^* . While the first best scenario brought about an optimal pollution tax equal to the marginal damage, in this second best case, the optimal pollution tax is either higher or lower than the marginal damage, as it was expected. In fact, if the marginal damage is not too high, eventually the optimal trade tax t could lead to a subsidy rather than a tax.[30]

[30] This possibility could arise if the production of the non-numerarie good was not intensive on the use of the intermediate input, i.e., R_{pF}<0. In that case the sign of the second element of the optimal pollution tax would be positive or negative:

3.4.2. Case I

The domestic small open economy optimally chooses the trade tax on the intermediate input τ and the pollution tax s in the presence of all potential distortions, with the trade tax on the non-numeraire good at a suboptimal level and unalterable, this implies $dt = 0$.

From (11) we have the equation that measures the change in welfare depending on the adjustments in the policy instruments:

$$E_U dU(1 - tC_y) = -\alpha A ds - [tR_{pq} + \tau R_{qq} + \alpha(1 - R_{Fq})A]\, d\tau \quad (37)$$

Solving the system of simultaneous equations coming from the first order conditions we have:
$\frac{dU}{d\tau}|\bar{s}, \bar{t} = 0 \Longrightarrow$

$$\tau = \frac{-\{\alpha(1-R_{Fq})(E_F - s) + t[R_{pq} - \alpha(1-R_{Fq})(E_{pF} - R_{pF})]\}}{[R_{qq} - \alpha(1-R_{Fq})(1-R_{qF})]} \quad (38)$$

$\frac{dU}{ds}|\bar{\tau}, \bar{t} = 0 \Longrightarrow$

$$s = E_F - \tau(1 - R_{qF}) - t(E_{pF} - R_{pF}) \quad (39)$$

Therefore we have:

$$\tau^* = -\frac{tR_{pq}}{R_{qq}} \quad (40)$$

and,

$\tau\left(\frac{R_{qp}(E_{pF} - R_{pF}) - (R_{pp} - E_{pp})(1 - R_{qF})}{(R_{pp} - E_{pp})}\right) >$ or <0, as long as $\tau <$ or >0. Considering the case in which $\tau > 0$, $R_{pF} < 0$ and assuming that the marginal damage is relatively small,

$E_F < \tau\left(\frac{R_{qp}(E_{pF} - R_{pF}) - (R_{pp} - E_{pp})(1 - R_{qF})}{(R_{pp} - E_{pp})}\right) \Longrightarrow s^* < 0$, i.e., a subsidy to the use of the intermediate input. The rationale behind this result is that if the non-numeraire sector is not pollution intensive and the suboptimal trade tax on the intermediate input is positive, for the domestic policy-maker the spillover effect may come from the unalterable trade tax on the intermediate product, rather than from the pollution intensiveness by itself.

$$s^{*} = E_F + t\left[\frac{R_{pq}(1 - R_{qF}) - R_{qq}(E_{pF} - R_{pF})}{R_{qq}}\right] \qquad (41)$$

Equations (40) and (41) are the second-best optimal policies. Both compensate the policy induced distortion caused by the trade tax on the non-numeraire good being at a suboptimal level, and the production externality. From (40) the sign of the optimal trade tax τ^{*}depends on the sign of the pre-existent trade tax on the non-numeraire good t because $\left(-\frac{R_{pq}}{R_{qq}}\right) > 0$, on the assumptions about pollution intensiveness, and on the pattern of trade on the intermediate input. This means that $\tau^{*} \gtrless 0 \iff t \gtrless 0$

From (41) we can argue that the sign of the optimal pollution tax will depend on the sign of two components: $R_{pq}(1-R_{qF})-R_{qq}(E_{pF}-R_{pF})$ and t. Under the assumption of pollution intensiveness for the non-numeraire good and a small open economy being a net importer of the intermediate input, the first element has a positive sign. If the trade tax is positive as well, from (40) it can be seen that the second best optimal pollution tax would be higher than the marginal damage, i.e., $s^{*} > E_F$. The clear implication is that when a pollution-intensive non-numeraire sector is protected by a tariff $(t > 0)$, then domestic welfare can only be compensated with a tariff on the use of the intermediate input, i.e., $\tau^{*} > 0$, and with a pollution tax strictly higher than the optimal one, i.e., $s^{*} > E_F$. The result is understandable if we consider that a protected pollution-intensive sector has to be regulated by a pollution tax designed to lessen the excess of pollution generated.

3.4.3. Case J

The domestic small open economy optimally chooses the trade tax on the non-numeraire good t and the trade tax on the intermediate input τ in the presence of all potential distortions, with the pollution tax at a suboptimal level and unalterable, this implies $ds = 0$.

Equation (11) then becomes:

$$E_U dU(1 - tC_y) = -\left(t(R_{pp} - E_{pp}) + \tau R_{qp} - \alpha R_{Fp}A\right)dt \qquad (42)$$

$$-\left(tR_{pq} + \tau R_{qq} + \alpha(1 - R_{Fq})A\right)d\tau$$

From (42) we need to solve two first order conditions having as a result a simultaneous equation system: $\frac{dU}{dt}|\bar{s},\bar{\tau} = 0$

$\Longrightarrow$

$$t = \frac{\alpha R_{Fp}\left(E_F - s\right) - \tau\left[R_{qp} + \alpha R_{Fp}(1 - R_{qF})\right]}{\left[(R_{pp} - E_{pp}) + \alpha R_{Fp}(E_{pF} - R_{pF})\right]} \tag{43}$$

$\frac{dU}{d\tau}|\bar{s}, \bar{t} = 0$

$\Longrightarrow$

$$\tau = \frac{-\{\alpha(1-R_{Fq})(E_F - s) + t[R_{pq} - \alpha(1-R_{Fq})(E_{pF} - R_{pF})]\}}{[R_{qq} - \alpha(1-R_{Fq})(1-R_{qF})]} \tag{44}$$

Solving the system we have:

$$t^* = \alpha\left(E_F - s\right)\left\{\frac{R_{Fp}R_{qq} + R_{qp}(1 - R_{Fq})}{\Omega}\right\} \tag{45}$$

and,

$$\tau^* = -\alpha\left(E_F - s\right)\left[\frac{(R_{pp} - E_{pp})(1 - R_{Fq}) + R_{Fp}R_{pq}}{\Omega}\right] \tag{46}$$

where:

$$\begin{aligned}\Omega = {} & (R_{pp} - E_{pp})\left[R_{qq} - \alpha(1 - R_{Fq})(1 - R_{qF})\right] \\ & + \alpha(E_{pF} - R_{pF})\left[R_{Fp}R_{qq} + (1 - R_{Fq})R_{pq}\right] \\ & - R_{qp}\left[R_{pq} + \alpha(1 - R_{Fq})R_{pF})\right]\end{aligned}$$

Equations (45) and (46) are the second-best optimal trade taxes for the intermediate input and the non-numeraire good.[31] If we assume that the production of the non-numeraire good is not pollution-intensive ($R_{pF} < 0$), but that the home country is still a net importer of the intermediate input ($[1 - R_{Fq}] > 0$), factors post multiplying the optimal trade taxes would be negative if the following term held with strict inequality, $\alpha(1 - R_{Fq})R_{pF} > R_{pq}$. This means that the

[31] The small open economy case is made for optimal trade taxes if we had a Pigouvian tax, i.e., $s^* = E_F$, then $t^* = \tau^* = 0$. However, in this particular case, in which the pollution tax is at a sub-optimal level and unalterable, the sign of both trade instruments depends on the interaction between the different direct and indirect effects of changes in prices of both commodities.

direct effect of an increase in the amount of intermediate input required in its own productive sector multiplied by the indirect effect of an increase in the amount of intermediate input required in the non-numeraire sector (considering the domestic country is a net importer of the intermediate input), must be greater than the effect of an increase in the producer's price of intermediate input on the production of the non-numeraire good. With this condition the whole term in brackets in (45) would be negative, i.e., $\{\cdot\} < 0$ and the term in brackets in (46) would be positive, i.e., $[\cdot] > 0$. Therefore, the sign of the optimal policy would be determined by the sign of the difference between the marginal damage and the pollution tax $(E_F - s)$. In other words, $t^* \gtreqless 0$ if and only if $(E_F - s) \gtreqless 0$. On the other hand, if $(E_F - s) \gtreqless 0$ for the optimal trade tax on the intermediate input we would have $\tau^* \gtreqless 0$.[32]

4. Conclusion

The purpose of this paper has been to determine the optimal policies in a country that faces policy imposed distortions in the form of trade taxes on the non-numeraire good, and on the intermediate tradeable input. Furthermore it faces a production externality generated as a by-product of the production process, through the industrial consumption of an intermediate pollutant input.

The main insight comes from the fact that we are modelling pollution generation through a mechanism where we assume a certain degree of intensity in the use of a pollutant productive factor. Then, instead of using a vector of pollutants and calculating the optimal amount of pollutions emissions as a function of the vector of pollution taxes, as the majority of the trade-pollution models in the literature does, we use only one pollutant factor considering that through its

[32] For instance, if the difference between the marginal damage and the suboptimal pollution tax were positive, the optimal trade policies would be trade taxes for both sectors. The rational behind this result is that with a sub-optimal pollution tax $(E_F - s) > 0$, part of the production externality not covered by the pollution tax has to be compensated with the trade policy instruments, being both trade taxes. A second-best positive trade tax would protect the non-pollution-intensive non-numeraire sector from being displaced by pollution-intensive imports, generating a positive spillover effect on the environment(if pollution intensiveness is assumed in the imports of similar products). By the same token, a protected intermediate sector gives as a result a lower consumption of the intermediate pollutant input by the industrial consumers, therefore generating less pollution.

industrial consumption pollution is generated. The more the intensity of use of that pollutant factor, the more the amount of pollution generated by that sector. Therefore we can differentiate between highly pollutant sectors and those with production techniques which use non-pollutant productive factors intensively.

For all first best cases, for the trade tax on the non-numeraire good, the pattern of optimal policies does depend on the pollution-intensiveness. In such a case, the optimal trade tax is positive when the non-numeraire sector is not pollution-intensive. Only in that case, a tariff protected sector will not exacerbate, through spillover effects, the production externalities generated through the use of the intermediate pollutant input. The opposite makes sense when a pollution-intensive non-numeraire sector must have a subsidy on imports in order to displace domestic pollutant production with cleaner products from abroad. The spillover effect to the environment would be positive. However, the optimal pollution tax and the optimal trade tax on the intermediate pollutant input do not depend directly on the pollution-intensiveness of the non-numeraire sector, but indirectly through the marginal damage E_F. In view of these results, if we take into account the pollution-intensiveness of the imported goods, we have to further consider the degree of pollution-intensiveness of the domestic produced good. If both are pollution-intensive, a call for an optimal subsidy on the imports of the intermediate input would result in a higher pollution tax, offsetting the increase in domestic pollution. As a consequence, from the policy-making point of view, trade taxes should be determined along with pollution taxes to compensate, from a first best perspective, negative spillover effects that arise from production externalities, either in consumption or production.

Second best cases have an analogous interpretation. Even though a pattern of second best cases would be desirable, optimal policies do depend on a number of assumptions like pollution-intensiveness, the sign of the pre-existent policy instruments, and the pattern of trade of both the intermediate and the non-numeraire good. Nevertheless, for any of them, the nature of the transmission mechanism is the same: spillover effects coming from trade policies may exacerbate the pre-existent production externalities through the prices of both commodities which affect directly and indirectly the allocation of resources and then the sign of the optimal instruments.

The results presented in this paper provide a theoretical justification to propose the design of optimal trade policies linked to environmental policies in order to ensure that production externalities and the spillover effects from trade tariffs are taken into consideration and compensated with adequate policy instruments like pollution taxes. Otherwise, the use of second best policies even though theoretically supported, does not provide a second best justification for a free trade policy in the remainder of the productive sectors, not even the intermediate pollutant sector. This analysis could be extended to include a variety of instruments for environmental protection and study its effects on welfare when interacting with trade policies, then comparing which ones best fit according to the externality modelled.

References

Batra, R. N., and F. R. Casas (1973). Intermediate Products and the Pure Theory of International Trade: A Neo-Heckscher-Ohlin Framework, *The American Economic Review*, 63, 3, 297-311.

Baumol, William J., and W. E. Oates (1988). *The Theory of Environmental Policy*, Cambridge University Press.

Beghin, John, D. Roland-Host, and D. van der Mensbrugghe (1997). Trade and Pollution Linkages: Piecemeal Reform and Optimal Intervention, *Canadian Journal of Economics*, XXX, 2, 443-455.

Bhagwati, Jagdish (1971). The Generalised Theory of Distortions and Welfare, in Jagdish Bhagwati, *et al.* (eds.), *Trade, Balance of Payments and Growth*, North-Holland Publishing.

Chang, Winston W., and Wolfgang Mayer (1973). Intermediate Goods in a General Equilibrium Trade Model, *International Economic Review*, 14, 2, 447-459.

Chichilnsky, Graciela (1994). North-South Trade and the Global Environment, *The American Economic Review*, 84, 4, 851-874.

Conrad, Klaus (1993). Taxes and Subsidies for Pollution-Intensive Industries As Trade Policy, *Journal of Environmental Economics and Management*, 25, 121-135.

Copeland, Brian R. (1996). Pollution Content Tariffs, Environmental Rent Shifting, and the Control of Cross-Border Pollution, *Journal of International Economics*, 40, 459-476.

—— (1994). International Trade and the Environment: Policy Reform in a Polluted Small Open Economy, *Journal of Environmental Economics and Management*, 26, 44-65.

Copeland, Brian R., and M. Scott Taylor (2003). *Trade and Environment*, Princeton University Press.

—— (2001). *International Trade and Environment: A Framework for Analysis*, NBER Working Paper no. 8540.

—— (1995). Trade and Environment: A Partial Synthesis, *American Journal of Agricultural Economics*, 77, 765-771.

—— (1994). North-South Trade and the Environment, *Quarterly Journal of Economics*, 109, 755-787.

Corden, W. Max, and R. E. Falvey (1985). Quotas and the Second Best, *Economic Letters*, 18, 67-70.

Cropper, Maureen L., and W. E. Oates (1992). Environmental Economics: A Survey, *Journal of Economic Literature*, XXX, 675-740.

—— (1985). Tax Policy in Open Economies, in A. J. Auerbach and M. Feldstein (eds.), *Handbook of Public Economics*, vol. 1, Elsevier.

Dixit, Avinash, and V. Norman (1980). *Theory of International Trade*, Cambridge University Press.

Gallegos, A. (2004). *International Trade and Environmental Protection*, PhD Thesis, University of Essex.

Hatta, Tatsuo, and Takashi Fukushima (1979). The Welfare Effect of Tariff Rate Reductions in a Many Country World, *Journal of International Economics*, 9, 503-511.

Hatta, Tatsuo (1977). A Theory of Piecemeal Policy Recommendations, *Review of Economic Studies*, 44, 1-21.

Hoekman, Bernard, and Kym Anderson (1999). *Developing Country Agriculture and The New Trade Agenda*, World Bank Policy Research Working Paper no. 2125.

Jones, Ronald W. (1965). The Structure of the Simple General Equilibrium Models, *Journal of Political Economy*, LXXIII, 6, 557-572.

Kennedy, Peter W. (1994). Equilibrium Pollution Taxes in Open Economies With Imperfect Competition, *Journal of Environmental Economics and Management*, 27, 49-63.

Krutilla, Kerry (1991). Environmental Regulation in an Open Economy, *Journal of Environmental Economics and Management*, 20, 127-142.

Lahiri, Sajal, and P. Raimondos-Moller (1996). Correcting Trade Distortions in a Small Open Economy, *Review of International Economics*, 4, 3, 287-299.

—— (1975). International Externalities and Optimal Tax Structures, *Journal of International Economics*, 5, 15-29.

Turunen-Red, Arja, and Alan D. Woodland (2002). Unilateral Reforms of Trade and Environmental Policy, in Alan D. Woodland (ed.), *Economic Theory and International Trade: Essays in Honour of Murray C. Kemp*, Edward Elgar.

—— (2001). The Anatomy of Multilateral Trade Policy Reform, in S. Lahiri (ed.), *Regionalism and Globalization: Theory and Practice*, Routledge.

—— (2000). Multilateral Policy Reforms and Quality Restrictions on Trade, *Journal of International Economics*, 52, 153-168.

—— (1999). *Multilateral Reforms of Trade and Environmental Policy*, University of New Orleans, (mimeo).

—— (1991). Strict Pareto Improvement Multilateral Reforms of Tariffs, *Econometrica*, 59, 4, 1127-1152.

Woodland, Alan D. (1982). *International Trade and Resource Allocation. Advanced Textbooks in Economics*, 19, The Netherlands: North-Holland.

—— (1977). Joint Outputs, Intermediate Inputs and International Trade Theory, *International Economic Review*, 18, 3, 517-533.

Appendix

Second Best Cases: One Policy Instrument, Three Potential Distortions

Case 1

The domestic small open economy optimally chooses the trade tax on the non-numeraire good t in the presence of all potential distortions, with the trade tax on the intermediate input and the pollution tax both at a suboptimal level and unalterable, this implies that $d\tau = ds = 0$.

In this case (11) then becomes:

$$E_U dU(1 - tC_y) = -\left[t(R_{pp} - E_{pp}) + \tau R_{qp} - \alpha R_{Fp} A\right] dt \qquad \text{(A1)}$$

From equation (A1) the first order condition $\frac{dU}{dt}|_{\overline{\tau},\overline{s}} = 0$ $\Longrightarrow$

$$t^* = \frac{\alpha R_{Fp}\left(E_F - s\right) - \tau\left[R_{qp} + \alpha R_{Fp}(1 - R_{qF})\right]}{\left[(R_{pp} - E_{pp}) + \alpha R_{Fp}(E_{pF} - R_{pF})\right]} \qquad \text{(A2)}$$

To determine the sign of (A2) assume $R_{Fp} > 0$ and $(1 - R_{qF}) > 0$, then $t^* >$ or < 0, if $\tau >$ or < 0, and the magnitude of the marginal damage E_F, needs to be relatively high, i.e., $(Ef > s)$.

Case 2

The domestic small open economy optimally chooses the trade tax on the intermediate input τ in the presence of all potential distortions, with the trade tax on the non-numeraire good and the pollution tax both at a suboptimal level and unalterable, this implies that $dt = ds = 0$.

Equation (11) becomes:

$$E_U dU(1 - tC_y) = -[tR_{pq} + \tau R_{qq} + \alpha(1 - R_{Fq})A]\, d\tau \qquad \text{(A3)}$$

The first order condition $\frac{dU}{d\tau}|_{\overline{t},\overline{s}} = 0$
$\Longrightarrow$

$$\tau^* = -\frac{\{\alpha(1-R_{Fq})(E_F - s) + t[R_{pq} - \alpha(1-R_{Fq})(E_{pF} - R_{pF})]\}}{[R_{qq} - \alpha(1-R_{Fq})(1-R_{qF})]} \qquad \text{(A4)}$$

The sign of (A4) depends on the sign of the difference between the pollution tax and the marginal damage, i.e., $(E_F - s) >$ or $<$ 0, and the sign of the suboptimal and unalterable trade tax on the non-numeraire good, i.e., $t >$ or < 0. Suppose $R_{pF} > 0$, and $(1 - R_{Fq}) > 0$, then the optimal trade tax would be $\tau^* >$ or < 0.

Case 3

The domestic small open economy optimally chooses the pollution tax on the non-numeraire good s in the presence of all potential distortions, with trade taxes on the non-numeraire good and the intermediate input both at a suboptimal level and unalterable, this implies that $\Longrightarrow dt = d\tau = 0$.

Equation (11) then becomes:

$$E_U dU(1 - tC_y) = \qquad \text{(A5)}$$

$$-\alpha\left(E_F - s - \tau(1 - R_{qF}) - t(E_{pF} - R_{pF})\right) ds$$

The first order condition $\frac{dU}{ds}|_{\overline{t},\overline{\tau}} = 0$
$\Longrightarrow$

$$s^* = E_F - \tau(1 - R_{qF}) - t(E_{pF} - R_{pF}) \qquad \text{(A6)}$$

As a result of the suboptimal trade taxes, (A6) shows that the optimal pollution tax is different from the optimal Pigouvian tax. Suppose $R_{pF} > 0$, and $(1 - R_{Fq}) > 0$, then the sign of the optimal pollution tax would depend on the sign of both trade taxes, i.e., $s^* >$ or < 0, if $t >$ or < 0, and $\tau <$ or > 0.