ENVIRONMENTAL POLICIES AND TRADE UNDER NON-COMPETITIVE MARKETS
(directions for developing economies)

1. Introduction

Environmental policy is increasingly becoming an integral part of economic and industrial policy. Since traditional instruments like exchange rate revaluation, tariffs, subsidies, or policies to improve the economic structure have come to be governed by EC directives or GATT rules, national governments have had to look for other instruments and policy fields to shift rents. In order to maintain international competitiveness and achieve full employment, environmental policy has become industrial policy, and even trade policy.

Although the majority of theoretical research in environmental economics is based on a closed economy, the open economy context has received increasing attention. In particular, several authors have considered optimal trade and environmental policies in an open economy, which can influence its terms of trade. As is well known from the literature on distortions (e.g., Bhagwati (1971)), the first-best policy requires two instruments: a trade tax to improve the terms of trade and pollution tax to offset the externality. Much of the interest has centered on second-best policies for the case where only one instrument is available. If trade policy is the only instrument, Baumol and Oates (1988) and Markusen (1975) show that in the presence of pollution, the optimal tariff may be higher or lower than that which would maximize rent extraction from foreigners, since the policymaker must also consider the effect of the tariff on pollution levels. Similarly, if tariff levels are exogenous, Markusen (1975) and Krutilla (1991) show that optimal-second best pollution taxes will be either higher or lower than those, which would fully internalize the externality, since terms of trade effects must be considered.

This paper examines a different aspect of this problem. Its purpose is to analyze the welfare effects of strategic pollution tax (subsidy) in a distorted small open economy. The model employed describes a situation of partial equilibrium, characterized by imperfect competition among domestic producers in a pollution-intensive industry, which is import substitute, and trade distortion generated by the...
existence of ad-valorem tariff in the imported commodity. In a second extension to the literature, we analyze the policy issues associated with trade and their effects on pollution tax.

The structure of the paper is as follow: Section 2 describes the core model and establishes the optimal pollution policy that maximizes the social welfare. Section 3 examines the effects of international trade and provides an analysis of the impact of a tariff on pollution optimal policy. Finally, section 4 contains the conclusions.

2. The model

The market structure used analyzes a situation of partial equilibrium, where there is not interaction with others sectors of the economy or impact in the factor market. According to Dixit (1988a), the domestic and imported products are considered imperfect substitutes; domestic firms produce a homogeneous good. The condition of small country is assumed, leaving aside, therefore, the possibility to influence the terms of trade, it is considered that the foreign good is offered under perfect competition and does not exist the possibility of exporting the domestic good due to transportation costs, external tariffs, etc. Before proceeding some general comments are in order: First: the paper is concerned with the effects of specific pollution tax (subsidy) on production in a static (i.e., single period) context, in which market structure, cost conditions, entry barriers are given. Second: the focus of attention is on industries in which domestic firms sell on domestic markets but do not export the product. Finally, despite the use of specific functional forms, much of the analysis can be readily generalized, as discussed in the last section.

2.1. Demand

Domestic consumers consume three goods, x, y and z. Goods x and y are close but imperfect substitutes for one another. Good z represents the consumption of all other goods in the economy; setting its price to unity it is used as numeraire. Assuming that pollution damage on consumers’ utility is a function of the level of emissions, e, generated by the domestic industry, we can express the preferences of the consumers by an aggregated quasi-linear utility function of the form

\[ U(x, y, z, e) = U(x, y) + z - g(e), \]

with:
- x: domestic good
- y: imported good
- z: numeraire good
- g(e): pollution damage.

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1 The positive effect of a small tariff on social welfare of developing countries has already been shown in the issues of optimal trade policy under imperfect competition [cf. Levy and Nolan (1992), Saez (1988), and Sampaolesi (1994)].
The separability in (1) implies that the environmental damage from pollution does not affect the relative attractiveness of the goods. For convenience, the implicit form for \( U(x, y) \) takes the functional form:

\[
U(x, y) = a_i x - (b_i / 2) x^2 + a_y y - (b_y / 2) y^2 - k x y,
\]

where: \( a_i, b_i, k > 0; \ b_i \geq k \) (for \( i = x, y \)).

Utility maximization, subject to the budget constraint yields inverse demand functions for \( x \) and \( y \) of the form

\[
(3a) \quad P_x = a_x - b_x x - k y
\]

\[
(3b) \quad P_y = a_y - b_y y - k x
\]

where: \( P_y = P_y^* E (1 + t_y) \)

and: \( P_y^* \): international price of \( y \)

\( E \): nominal exchange rate

\( t_y \): ad-valorem tariff.

The demand system has some useful properties. First, the income elasticities of demand for both \( x \) and \( y \) are zero; hence, the traditional measure of consumer surplus ('the area above the price and below the demand curve') is an exact measure of the gain to consumers from purchasing a product at a given price. Second, the aggregate surplus accruing to consumers from consuming \( x \) and \( y \) at price \( P_x \) and \( P_y \) can be written as

\[
(4) \quad CS = U(x, y) - P_x x - P_y y,
\]

changes in (4) provide an exact measure of the change in consumer welfare resulting from changes in \( P_x \) or \( P_y \). Finally, the parameter \( k \) provides an indicator of the degree of substitutability between \( x \) and \( y \); a higher value for \( k \) (given \( a_i, a_y \) and \( b_i \)) denotes a closer degree of substitutability between the two products.

2.2. Supply

The good \( x \) is produced under monopolistic conditions. The domestic firm produces under conditions of constant average and marginal costs, with \( c \) denoting the marginal cost. Associated with the production of \( x \) is a pollutant. However, the domestic firm has a technology available to abate the pollutant. We chose units such that emissions are the difference between output level \( x \) and abatement effort level \( a \), i.e., \( e = x - a \). Total abatement costs are quadratic in effort levels of the form \((1/2) a^2\). Then, if \( \tau \) denotes the pollution tax (subsidy) on emissions for the industry, the domestic firm chooses \( x \) and \( a \) in order to maximize its profit function given by:

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\( \text{Note that even though the analysis is easily extensible to other forms of imperfect competition, this is not the target of the paper.} \)
(5) \[ \Pi(x, a) = P_x x - (c x + \tau (x - a) + (1/2) a^2) \]
which leads to first-order conditions

(6a) \[ x = \left( P_x - (c + \tau) \right) / b_x \]

(6b) \[ \tau = a, \]

where (6a) is the usual condition that profit-maximization for the monopolist involves producing at a point where price exceeds the modified marginal cost. In addition, (6b) requires that the firm abates pollution to the point where the marginal abatement cost equals the pollution tax.

2.3. Equilibrium

Using the system of equations formed by (3a), (3b), and (6) we can express the equilibrium output combination and the equilibrium price for the domestic market as

(7a) \[ x = \frac{1}{\Delta} \left[ b_x (a_x - (c_x + \tau)) - k (a_y - P_y) \right] \]

(7b) \[ y = \frac{1}{\Delta} \left[ 2 b_x (a_y - P_y) - k (a_x - (c_x + \tau)) \right] \]

(7c) \[ P_x = \frac{1}{\Delta} \left[ b_x (b_y a_x - k (a_y - P_y)) + (b_x b_y - k^2) (c_x + \tau) \right], \]

where \( \Delta = (2 b_y b_x - k^2) > 0. \)

From (7a) and (7b), a necessary condition for the existence of equilibrium is that \( a_y \geq (c_x + \tau), \) a firm’s costs cannot exceed the maximum price that consumers are willing to pay for its product, and \( a_y \geq P_y, \) a very high price for \( y \) rules out the possibility of import it. Letting \( \tau^{\text{MAX}} (\tau^{\text{MIN}}) \) denote the upper (lower) bound on \( \tau, \) equalizing (7a) and (7b) to zero yields:

(8a) \[ \tau^{\text{MAX}} = [(a_x - c_x) - (k/b_y) (a_y - P_y)] > 0 \]

(8b) \[ \tau^{\text{MIN}} = [-2b_x/k] (a_y - P_y) + (a_x - c_x)] >= 0, \]

where \( \tau^{\text{MIN}} < 0 \) implies the possibility of a pollution subsidy for the domestic industry.

2.4. Comparative static

We now examine the response of outputs and domestic price to a change in \( \tau. \) From (7) we obtain:
Where the signs of the derivatives agree with the relation of substitution between the goods. Note also that for $k$ equal to zero (independent goods) an increase in $\tau$ does not have any effect on the amount imported of $y$.

2.5. Government

The government imposes a specific pollution tax on emissions, denoted by $\tau$ (with $\tau < 0$ implying that $e$ are subsidized), and a tariff on the imported good, denoted by $t_y$ (with $t_y < 0$ implying that $y$ is subsidized); hence, the net government revenues (losses) are described as

$$R = (P_y^* E t_y) y + \tau e.$$  

2.6. Social welfare

Since aggregate social welfare, $SW$, is the sum of: (i) consumer surplus, (ii) domestic firms profits, (iii) net government revenues, and (iv) pollution damage, we have

$$SW = CS + (P_x x - (c_x + \tau e + (1/2) a_x^2)) + ((P_y^* E t_y) y + \tau e) - g(e).$$

Hence, if environmental damage is only local and given by $g(e) = (1/2) m e^2$, $m > 0$, substituting by (4), (6b), and $e$, we can rewrite (13) as

$$SW = U(x, y) - c_x x - (1/2) \tau^2 - (P_y^* E) y - (1/2) m (x - \tau)^2.$$ 

This provides a simple interpretation of social welfare as the utility gain from consuming $x$ and $y$ less the private cost of producing $x$, the social cost of acquiring $y$ (the domestic price net of tariff), and the loss in consumer utility generated by the level of pollution.

We turn now to examine the role of pollution tax in enabling the government to maximize social welfare. From (14), the effect on $SW$ of a small change in $\tau$ is given by

$$\frac{\partial SW}{\partial \tau} = \frac{\partial U}{\partial x} \frac{\partial x}{\partial \tau} + \frac{\partial U}{\partial y} \frac{\partial y}{\partial \tau} - (c_x + m(x - \tau)) \frac{\partial x}{\partial \tau}$$

$$- \tau - P_y^* E \frac{\partial y}{\partial \tau} + m (x - \tau).$$
Utility maximization ensures that $\partial U/\partial x = \lambda P_y$ and $\partial U/\partial y = \lambda P_x$, where $\lambda$ is the marginal utility of income; the functional form of the utility function assures that $\lambda = 1$. Hence (15) reduces to

$$\frac{\partial SW}{\partial \tau} = (P_x - (c_y + m(x-\tau)))\frac{\partial x}{\partial \tau} + (P_y^* E t_y)\frac{\partial y}{\partial \tau} - \tau + m(x-\tau).$$

Further differentiation yields the result that $\frac{\partial^2 SW}{\partial \tau^2} < 0$, implying that $SW(\tau)$ is concave for $\tau \in (\tau_{MIN}, \tau_{MAX})$. Simplification of (16), using (6a), (10) and (11); yields the result that $\frac{\partial SW}{\partial \tau} = 0$ when $\tau = \tau^*$, where

$$\tau^* = -\frac{(x b y b_y)}{A'} + (P_y^* E t_y) (k/A') + m(x-\tau^*),$$

where $A' = (b_y + A) > 0$.

To establish the form of $SW(\tau)$ outside $\tau \in (\tau_{MIN}, \tau_{MAX})$, note that increases in $\tau$ above $\tau_{MAX}$ leave $SW$ unchanged because the domestic industry can not compete under such cost condition. By contrast, reductions in $\tau$ below $\tau_{MIN}$, result in a decrease in $SW$; under this circumstances, the product is served only by the domestic industry, thereby decreasing the level of welfare. Since $SW(\tau_{MAX})$ can be shown to exceed $SW(\tau = 0)^3$, the relationship between social welfare and the pollution tax (subsidy) takes the form describes in the figure below.

**Relationship between social welfare and pollution policy ($\tau^* > 0$)**

\[ \text{SW} \]
\[ \text{SW} (\tau = \tau^*) \]
\[ \text{SW} (\tau = \tau_{MAX}) \]
\[ \text{SW} (\tau = \tau_{MIN}) \]

\[ \tau_{MIN} \quad 0 \quad \tau^* \quad \tau_{MAX} \]

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3 Formally, we can show that $SW(\tau_{MIN}) < SW(\tau_{MAX})$ through the expenditure function $e(P_x, P_y, U)$. Then: a) for $\tau_{MAX} (\tau = 0)$, by construction $P_x(\tau_{MAX}) = c_x + P_y(\tau_{MAX})$; b) for $\tau_{MIN} (\tau = 0)$, $P_x(\tau_{MIN}) = c_x + P_y(\tau_{MIN})$. Replacing in the expenditure function, we obtain $e(P_x(\tau_{MIN}), P_y, U) < e(P_x(\tau_{MAX}), P_y, U)$, which is equivalent to say that $SW(\tau_{MIN}) < SW(\tau_{MAX})$. 

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Proposition: The relationship between social welfare and pollution policy takes a concave-shaped form.

Understanding this proposition is crucial to understand most of the results below. To see the intuition underlying this relationship, consider the three terms in eq. (17) above. The first term represents what is labeled the “domestic output effect”: an increase in $\tau$ results in lower domestic firms’ sales, which is welfare diminishing because $x$ is a good whose marginal benefit to consumers ($P_x$) exceeds the marginal cost of producing it. The second term represents the “trade effect” of an increase in $\tau$: an increase in $\tau$ results in an augment in $y$, which increase the welfare of domestic consumers. Finally, the third term (the marginal damage cost) represents the “pollution effect”: an increase $\tau$ results in lower levels of emissions and, therefore, in a higher level of social welfare.

Note that a high value of $\tau$ ($\tau > \tau^*$) is associated with a weak “trade effect” (because consumption of $y$ is large) and a strong “domestic output effect” (because the distortion in the domestic market is small); therefore, the net effect of an increase in $\tau$ is to lower $SW$. By contrast, a low value of $\tau$ ($\tau < \tau^*$) is associated with a strong “trade effect” (because consumption of $y$ is small) and a weak “domestic output effect” (because the distortion in the domestic market is large); the net effect of an increase in $\tau$ is to increase $SW$.

From the above, it is clear that the positive or negative value of $\tau^*$ (tax-subsidy) will depend on the specific characteristics of a given economy.

3. The effects of international trade

The model describes above provides a tractable framework within which to examine the policy issues associated with trade. We begin by exploring the effect of imports on social welfare in the domestic economy. This issue is analyzed by comparing the welfare level attained under autarchy (i.e. no imports) with the welfare level attained under international trade. Under autarchy, the domestic firms are the sole owner, and the level of social welfare, $SW^A$, is given by the distance $0B$ in the figure above. Under international trade, the social welfare level attained $SW^T$, is given by $SW(\tau)$, where $\tau$ must be less than $\tau^{MAX}$ and greater than $\tau^{MIN}$ if there is to be any trade. Then, it follows immediately that $SW^T$ exceeds $SW^A$. Hence, we conclude that:

Theorem 1: International trade unambiguously increases social welfare.

Now we turn to analyze the role of an increase in the domestic tariff on optimal pollution tax. From (17), the effect of increasing the level of the domestic tariff, $t_s$, on environmental tax (subsidy) can be shown to be

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1 The superscript $A$ over any variable denotes its value under autarchy, while the superscript $T$ denotes its value under international trade.
The increase in the domestic tariff thus has two effects: an uncertain "domestic output effect", implying that the increase in domestic output, which is tax-declining (welfare-enhancing) because price exceeds marginal cost, is associated with higher levels of emissions (welfare-declining), and a positive "trade effect", measuring the change in the social cost of acquiring $y$, and implying that the increase in the social cost of $y$ is tax-enhancing (welfare-declining) because there is a complete pass-through of the tariff into the consumer price of good $y$.

**Theorem 2:** The effect of an increase in the level of the domestic tariff is uncertain on optimal pollution tax.

### 4-Conclusions

This paper is only a first step towards an understanding of the effects of strategic environmental policy. Even the simple framework developed here provides interesting insights. As the precedent analysis has made clear, the optimal pollution policy under domestic distortions can be decomposed into a "domestic output effect", a "trade effect", and a "pollution effect". The "domestic output effect" captures the change in welfare coming from a change in domestic firms sale, the "trade effect" captures the change in welfare coming from a change in the level of imports, while the "pollution effect" captures the negative effect on welfare of domestic emissions. Then, the optimal pollution policy can imply a tax or subsidy for the domestic industry, which will depend on the specific characteristics of a given economy. This result emphasizes the idea, as is well known, that the outcomes for the case of one distortion do not hold in an optimal-second best pollution policy.

With respect to the issues of international trade, we showed that international trade unambiguously increases social welfare and that the effect of an increase in the level of the domestic tariff is uncertain on optimal pollution tax.

The analysis presented appears robust to other specifications of functional forms; the use of specific and relatively simple functional forms allowed calculation of closed-form solutions for variables of interest and allowed a clear understanding of the underlying economic principles at work in the analysis.

There are many additional of research that could be pursued. A natural extension is to consider a simple two-country model with endogenous world prices.

### References


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5 From (7a), $\partial x / \partial t_y = k (\partial P_y / \partial t_y)$, with $\partial P_y / \partial t_y > 0$. 
