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Environmental taxation and international trade
in a tax-distorted economy

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Abstract

International environmental agreements have met with the reluctance of some countries to accept general commitments aimed at reducing greenhouse gas emissions. While acknowledging the crucial significance of the climate change process, politicians and regulators in some export-oriented countries have argued that pollution measures would have a negative impact on their domestic welfare. Despite the literature having thoroughly analysed those impacts from various points of view, using different methodological approaches, the second-best general equilibrium analysis has not to date been used to analyse the relationship between environmental taxation and trade. This paper fills this gap by presenting a general equilibrium model to examine the welfare effects of taxing a polluting exported good through an explicit representation of the trade relations of the economy in the presence of pre-existing taxes. The results extend the scope of the literature on second-best taxation by demonstrating that trade affects all the traditional welfare components proposed in the previous studies. In addition, trade neutrality on welfare not only depends on partial equilibrium effects but also general equilibrium impacts, involving the ability to replace the distortionary income tax with the new tax and the influence of environmental improvements on the labour-leisure choice.

Keywords: environmental taxation; trade-substitution effect; welfare trade neutrality.

JEL classification: F18, H21, H23.
1. Introduction

Nowadays it is generally accepted that the fight against climate change requires a worldwide strategy, including a global commitment. This global approach is needed to address a generalised problem, which has causes and consequences beyond the administrative borders of individual countries. However, the recent history of the international agreements aimed at reducing greenhouse gas emissions has revealed the reluctance of some countries to accept measures that could harm their domestic industry, especially in the case of export-oriented economies.

In particular, during the Kyoto Protocol negotiations the points of view of the United States and other countries in the Umbrella Group\(^1\) regarding how to achieve reductions in greenhouse gas emissions opposed those of the European Union. The Americans were keen on the broadest and most generous definitions of sinks absorbing greenhouse gases in the atmosphere, while the Europeans advocated a more strict definition. Moreover, the United States and other Umbrella members advocated unrestricted emissions trading while the European Union put forward a proposal for quantitative ceilings on the use of flexibility mechanisms, insisting that domestic abatement actions should be the main means of meeting the emissions reductions required. This controversy led to a deep division between the European Union and the Umbrella Group, and was regarded as one of the main causes for the collapse of the Kyoto Protocol negotiations. Finally, on March 2001 President Bush decided that the United States would withdraw from the Kyoto Protocol. The European Union subsequently made a sustained diplomatic effort to keep the Kyoto Protocol alive until the United

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\(^1\) This is an informal group, usually made up of Japan, the United States, Iceland, Switzerland, Canada, Australia, Norway, New Zealand and the Russian Federation. It was an active coalition during the Kyoto Protocol negotiations. Countries in the Umbrella Group exchanged information and discussed strategies on issues of common interest.
Nations Conference on Climate Change (COP21) in Paris in November 2015. This new agreement opens up an optimistic perspective for the future fight against climate change, and seems to be a turning point in the willingness of sceptical countries to consider and accept reductions in harmful pollution.

Indeed, obtaining a significant decrease in greenhouse emissions requires a structural transformation of the economic system, adapting both the production and consumption processes to obtain energy from clean sources, which simultaneously means that energy from fossil fuels must be abandoned. This is not a trivial issue from the socioeconomic and technological points of view, at least in the short and medium run.

Past experience shows that countries’ willingness to reduce emissions is inversely related to their level of industrialization, which at the same time, positively determines a country’s openness to trade and propensity to export. A latent reason for countries being reluctant to reach climate agreements has been to preserve their domestic exports industry. In fact, environmental measures generate an increase in effective prices for exported goods, and this is viewed as damaging for the competitiveness of domestic industries while benefiting the competitiveness of foreign industries, especially if the competing countries have weak environmental standards. According to this point of view, international agreements cause exports to decline and this generates a negative knock-on effect on domestic activity and domestic income. This conventional wisdom therefore suggests that environmental interventions are welfare-reducing policies which worsen internal welfare in favour of foreign agents. All in all, these expected (and aprioristic) negative impacts of environmental regulations have proven to be a major obstacle to the acceptance of general agreements in international forums.

2 The countries have one year to sign the text approved in Paris. At the end of the Conference, 177 parties had signed the Paris agreement of keeping the rise in temperature below 2 degrees above pre-industrial levels.
Over the last 40 years, the debate about trade and environment has been accompanied by an extensive literature, which has evolved in various specific areas while making use of various methodological frameworks. In particular, the impacts of free trade on the environment and the relationship between environmental regulation, competitiveness, economic growth and the comparative advantage of countries and firms have been studied based on both empirical and analytical approaches. The interactions and potential conflicts between free trade and ecological policies have also been analysed within this area of research.

Another set of contributions analysed the welfare costs associated with environmental regulation, using a general equilibrium perspective that takes into account the initial tax distortions of an economy. In all these studies, pre-existing taxes are a crucial starting point that places this literature in a second-best setting. Within this field, the pioneering papers pointed out the existence of two welfare effects caused by environmental taxation: the primary welfare effect or the partial equilibrium impact of the new taxation on reducing the polluting good, and the revenue-recycling effect or the benefit of replacing pre-existing distortionary taxes with the new pollution tax. These initial

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4 Among others, Jorgenson and Wilcoxon (1990), Jaffe et al. (1995) and Xu (2000) have provided empirical analyses; Pethig (1976), Sartzetakis and Constantatos (1995) and Simpson and Bradford (1996) have proposed theoretical evaluations.
5 For example, Markusen (1975) developed a model with two trading economies characterised by a bilateral production externality; Krutilla (1991) proposed the need for modifying the structure of environmental taxes when the economy trades with the external markets; Barrett (1994) examined the government incentives to define environmental standards for industries competing in the world market; Kennedy (1994) argued that imperfect competition in global markets generates strategic interactions between governments that can lead to inefficient ecological taxes; Walz and Wellisch (1997) showed that free trade is preferable for exporting countries even in cases of ecological dumping; Burguet and Sempere (2003) analytically analysed how trade liberalization affects environmental policies in a bilateral context of imperfect competition; Charnovitz (2003) described some ideas of the interplay between environmental preservation and commercial policies; and Limao (2005) presented a model to analyse whether linking cooperation in trade policy to environmental policy generates more cooperation in both policies.
results concluded that environmental regulation could generate increases in welfare if pre-existing distorting taxes were replaced by the new environmental taxes.\(^7\)

Later, an extensive set of papers suggested the existence of an additional (negative) welfare effect: the *tax-interaction effect*, reflecting a loss of welfare due to the increase in real prices generated by the new taxation, which reduces the real wage and subsequently diminishes the labour supply and aggravates the distortions of the pre-existing tax system.\(^8\) These papers demonstrated that the efficiency costs of environmental interventions are higher in a world with initial tax distortions in factor markets in comparison with a situation with an absence of those distortions. The latest finding in this literature was proposed by Williams (2002, 2003), who defined an additional *benefit-side tax-interaction effect* to be added to the welfare impact measurement. This new component captures the positive impacts of environmental taxation on consumers’ health and labour productivity that can (partially or completely) offset the costs of environmental taxation.\(^9\)

All the contributions on second-best taxation to date have focused on the welfare consequences of environmental taxes in a context of a closed economy, while the effects on exports has not warranted much attention within this area of research. Nonetheless, bearing in mind that ecological measures also have consequences on an economy’s trade activity, an interesting question that comes into play in the study of environmental taxation is how domestic welfare is affected in the case of an export-oriented country. To the best of my knowledge, however, the literature does not provide any contribution that focuses on the relationship between trade and environmental

\(^7\) This positive impact on welfare has been defined as the *double dividend hypothesis*.

\(^8\) Among others, the papers by Bovenberg and de Mooij (1994a, 1994b), Goulder (1995), Parry (1995) and Parry *et al.* (1999) first proposed the tax-interaction effect.

\(^9\) Alternatively, Schwartz and Repetto (2000) analysed in depth how the previous results of the literature would change if environmental quality did impact on consumers’ labour-leisure decision through the introduction of environmental quality as a non-separable argument in the utility function of consumers.
regulations, while simultaneously taking into consideration pre-existing taxes. This paper fills this gap and includes the link between the new ecological taxes, trade operations and the initial tax distortions of an economy to analyse the general equilibrium welfare impacts of environmental taxation.

Among the complete set of welfare effects when a new ecological tax is implemented, the results enable identification of the impacts that are channelled through the trade activity. In particular, and linked to the primary impact of trade, which has traditionally been a latent impediment to international commitments, the model shows two (almost unknown) additional general equilibrium trade contributions to welfare. The first is based on the new tax revenues coming from abroad, which allow a cut in the distortionary income tax. The second contribution shows the impacts of a better environment on reducing labour supply and encouraging leisure after the detrimental effect of the new taxation on exports. The general equilibrium trade channels and its effects on welfare proposed in this paper, which are typically ignored by the (partial equilibrium) conventional wisdom, provide a better understanding of the consequences of an emissions tax in the case of open economies.

The rest of the paper is organised as follows. The next section describes an analytical general equilibrium model that explicitly defines the trade activity of the economy. Section 3 analyses the welfare impact of implementing an environmental tax on a polluting exported good, and gives details about trade’s contribution to welfare. Section 4 studies trade’s neutrality on welfare of the environmental tax. The final section of the paper concludes.

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10 Using a second-best analysis of general equilibrium, Williams (1999) analysed the welfare impacts of trade policies taking into account the pre-existing tax distortions in the labour market.
2. The analytical model

This section presents a simple general equilibrium model that will be used to study the welfare effects of environmental taxes in an open economy. The model uses a similar approach to Williams (1999), which analyses the welfare effects of trade policies in an open economy context with pre-existing tax distortions. Unlike Williams’ model, however, this framework incorporates environmental externalities and derives the welfare impacts when the burden of (domestic) environmental taxation is partially translated to external agents through increases in the effective price of exports.

For the sake of simplicity, the model is limited to showing two consumption goods: $X$, the production of which generates air pollution, and $Y$, the production of which does not generate the negative externality. There is a representative household in the economy with the utility coming from the two consumption goods ($X$ and $Y$). Households also enjoy utility from leisure ($l$) and environmental quality ($Q$). The utility function responds to:

$$ U(V(X,Y,l),Q), $$

which is quasi-concave and continuous. In accordance with most of the literature, expression (1) assumes that environmental quality is a separable argument from consumption goods and leisure.\footnote{Bovenberg and de Mooij (1994a, 1994b), Goulder \textit{et al.} (1997), Goulder \textit{et al.} (1999), Parry \textit{et al.} (1999) and Williams (2002, 2003), among others, use the separability assumption of environmental quality in general equilibrium approaches of environmental taxation. See for example Swartz and Repetto (2000) and Carbone and Smith (2008) for an analysis of non-separability between consumption goods and environmental quality.}

The household’s time constraint is defined as:

$$ T = L_X + L_Y + l, $$

(2)
where \( T \) is the total time endowment, \( L_X \) and \( L_Y \) represent the amount of labour used in the production of \( X \) and \( Y \), respectively, and \( L_X + L_Y = L \).

In order to simplify the trade relations, \( X \) is assumed to be exported and \( Y \) is assumed to be imported. The domestic consumption of each good therefore responds to total production net of trade relations, in the form:

\[
X = F_X(L_X) - M_X; \tag{3}
\]

\[
Y = F_Y(L_Y) + M_Y. \tag{4}
\]

In these expressions, \( M_X \) are the exports of the economy and \( M_Y \) are the imports. In addition, \( F_X(L_X) \) and \( F_Y(L_Y) \) are the production functions that if they are not homogenous of degree one, will generate profits (\( \pi \)) that are assumed to be an income of households. By normalising wages to one, profits can be written in the following way:

\[
\pi = P_X F_X(L_X) + P_Y F_Y(L_Y) - L_X - L_Y, \tag{5}
\]

where \( P_X \) is the price of \( X \) and \( P_Y \) is the domestic price of \( Y \).

The production of \( X \) generates pollution and therefore reduces environmental quality. The model assumes that \( Q \) has a negative relationship with the production of the polluting good:

\[
Q = \tilde{Q} - F_X(L_X) = \tilde{Q} - (X + M_X), \tag{6}
\]

with \( F_X(L_X) \leq \tilde{Q} \), so that \( Q \geq 0 \). Environmental quality is equal to the difference between an initial exogenous level (\( \tilde{Q} \)) minus the quantity of the dirty good produced. In this expression, the units are equivalent so that the production of one unit of \( X \) reduces the baseline level \( \tilde{Q} \) by exactly the same amount.
Pre-existing tax distortions come from an initial income tax, which taxes all household income (labour earnings, profits and government transfers) at a proportional rate $\tau_L$. By normalising wage to one, the consumers’ budget constraint can be written as:

$$
(1 - \tau_L)(L + \pi + G) = P_X X + P_Y Y,
$$

where $G$ is a government lump-sum transfer to households, which is assumed to be constant in real terms:

$$
G = \tau_L (L + \pi + G).
$$

In the model, the trade relations of the economy are balanced so that:

$$
P(M_Y)M_Y - P_X M_X = 0,
$$

where $\frac{\partial P(M_Y)}{\partial M_Y} \leq 0$. In this expression, $P(M_Y)$ is the world price for the imported good, representing the units of $X$ per each unit of $Y$.

Households maximise utility (1) subject to their time constraint (2) and budget constraint (7), by taking the income tax rate, the government transfers, the prices of final goods, profits and environmental quality as given. This yields the corresponding first-order expressions for consumers:

$$
U_V V_X = \lambda P_X; U_V V_Y = \lambda P_Y; U_V V_l = \lambda(1 - \tau_L),
$$

denoting the subscripts on $U$ and $V$ partial derivatives and $\lambda$ being the marginal utility of income. The uncompensated Marshallian demand functions for both the consumption goods and leisure are then derived by applying these consumers’ first-order conditions, together with the households’ time constraint (2) and the households’ budget constraint (7):

$$
X(P_X, P_Y, \tau_L, \pi, Q); Y(P_X, P_Y, \tau_L, \pi, Q); l(P_X, P_Y, \tau_L, \pi, Q).
$$
3. Effects of taxing the polluting good

3.1. Welfare measurement

The analytical model described above is used to measure the welfare consequences of a new tax implemented on the dirty-exported good. Specifically, the model assumes a tax rate falling on the production of $X$ ($\tau_X$), and this implies that both domestic demand and external demand support the burden of the new taxation. Indeed, taxing the exported good raises its effective price and consequently, this measure creates a disincentive for both internal consumption and exports. However, as our focus is on analysing the impacts on the internal economy that implements the environmental tax, the following welfare analysis is limited to showing the effects on domestic agents.

The ecological tax modifies expression (5) corresponding to the firms’ profits, as follows:

$$
\pi = (P_X - \tau_X)F_X(L_X) + P_Y F_Y(L_Y) - L_X - L_Y. \quad (5')
$$

Meanwhile, the households’ budget constraint and government budget constraint are now modified to:

$$
(1 - \tau_L)(L + \pi + G) = (1 + \tau_X)P_XX + P_Y Y. \quad (7')
$$

$$
G = \tau_L(L + \pi + G) + \tau_X F_X(L_X). \quad (8')
$$

In this situation, the first-order conditions for firms’ profits maximisation are:

$$
P_X = \frac{1}{\partial P_X / \partial L_X} + \tau_X;
$$

$$
P_Y = \frac{1}{\partial P_Y / \partial L_Y}. \quad (10)
$$
Totally differentiating the utility function (1) with respect to $\tau_X$, then substituting the first-order conditions of consumers, and subsequently dividing by the marginal utility of income ($\lambda$) yields:

$$\frac{1}{\lambda} \frac{du}{d\tau_X} = (1 + \tau_X)P_X \frac{dX}{d\tau_X} + P_Y \frac{dY}{d\tau_X} + (1 - \tau_L) \frac{dl}{d\tau_X} - \frac{1}{\lambda} \frac{dU}{dQ} \left( \frac{dX}{d\tau_X} + \frac{dM_X}{d\tau_X} \right).$$  \hspace{1cm} (11)

Taking the total derivative of the domestic consumption of $X$ (expression (3)) with respect to $\tau_X$, substituting it into equation (10) for the price of $X$ and solving for $\frac{dL_X}{d\tau_X}$, gives the following expression:

$$\frac{dL_X}{d\tau_X} = (P_X - \tau_X) \left[ \frac{dX}{d\tau_X} + \frac{dM_X}{d\tau_X} \right].$$  \hspace{1cm} (12)

and a similar procedure for good $Y$ gives rise to:

$$\frac{dL_Y}{d\tau_X} = P_Y \left( \frac{dY}{d\tau_X} - \frac{dM_Y}{d\tau_X} \right).$$  \hspace{1cm} (13)

Totally differentiating the consumers’ time constraint (2) with respect to $\tau_X$, using $\frac{dt}{d\tau_X} = 0$, introducing expressions (12) and (13), and then subtracting the result from (11) yields:

$$\frac{1}{\lambda} \frac{dU}{d\tau_X} = [\tau_X (1 + P_X) - \tau_P] \left[ \frac{dX}{d\tau_X} + \frac{dM_X}{d\tau_X} \right] + P_Y \frac{dM_Y}{d\tau_X} - P_X (1 + \tau_X) \frac{dM_X}{d\tau_X} - \tau_L \frac{dl}{d\tau_X}.$$

where $\tau_P = \frac{1}{\lambda} \frac{dU}{dQ}$ is the Pigouvian tax level that measures the marginal damage due to air pollution arising from the effects of the polluting good on utility.

Differentiating the new government budget constraint (8’), using $\frac{dg}{d\tau_X} = 0$, subsequently substituting into $\frac{dl}{d\tau_X} = \frac{\partial l}{\partial P_X} \frac{dP_X}{d\tau_X} + \frac{\partial l}{\partial P_Y} \frac{dP_Y}{d\tau_X} + \frac{\partial l}{\partial \tau_L} \frac{d\tau_L}{d\tau_X} + \frac{\partial l}{\partial \tau} \frac{d\tau}{d\tau_X} + \frac{\partial l}{\partial Q} \frac{dQ}{d\tau_X}$, and operating terms gives:
\[
\frac{d\tau_L}{d\tau_X} = - \frac{X + M_X + \tau_X \left( \frac{dX}{d\tau_X} + \frac{dM_X}{d\tau_X} \right)}{L + \pi + G - \tau_L \frac{d\tau}{d\tau_L}}. \tag{15}
\]

Substituting expression (15) into the preceding expression for \(\frac{d\mu}{d\tau_X}\), introducing the result into expression (14), using \(\frac{dQ}{d\tau_X} = - \left( \frac{dX}{d\tau_X} + \frac{dM_X}{d\tau_X} \right)\), and finally grouping terms yields:

\[
\frac{1}{\lambda} \frac{d\mu}{d\tau_X} = \frac{\tau_X (1 + P_X) - \tau_P}{dW^P} \left[ \frac{dX}{d\tau_X} + \frac{dM_X}{d\tau_X} \right] + \left[ P_Y \frac{dM_Y}{d\tau_X} - (1 + \tau_X) P_X \frac{dM_X}{d\tau_X} \right] + \\
(\mu - 1) \left[ X + M_X + \tau_X \left( \frac{dX}{d\tau_X} + \frac{dM_X}{d\tau_X} \right) + \tau_L \frac{d\tau}{d\tau_X} \right] - \\
\mu \frac{t_{\tau_L}}{dW^R} \left[ \frac{\partial t}{\partial P_X} \frac{dP_X}{d\tau_X} + \frac{\partial t}{\partial P_Y} \frac{dP_Y}{d\tau_X} + \frac{\partial t}{\partial \pi} \frac{d\pi}{d\tau_X} + \frac{\partial t}{\partial Q} \left( \frac{dX}{d\tau_X} + \frac{dM_X}{d\tau_X} \right) \right]. \tag{16}
\]

This expression monetarily quantifies the welfare general equilibrium impact of the tax on \(X\), which is a calculation of the marginal welfare effect of implementing the new environmental taxation.

In the equation (16) above, \(\mu\) is defined as the marginal cost of public funds and is equal to:

\[
\mu = \frac{\tau_L \frac{d\tau}{d\tau_L}}{(L + \pi + G) - \tau_L \frac{d\tau}{d\tau_L}} + 1. \tag{17}
\]

This expression does not take into account the indirect effects of labour taxation on the new tax revenues and is therefore a partial equilibrium concept, which shows the efficiency cost of an additional monetary unit of public revenues obtained by an increase in the income tax rate. In particular, the quotient in (17) is equal to the welfare loss from a marginal increase in the income tax per monetary unit of new revenue: the numerator is the marginal rise in taxation and the denominator is the increase in
government revenues from a marginal increase in \( \tau_L \). The cost to consumers is therefore equal to the deadweight loss (the quotient) plus the additional income (one) of a marginal increase in the income taxation.

Expression (16) decomposes the total welfare effects of the environmental tax into four different components: the primary welfare effect \( (dW^p) \), the trade-substitution effect \( (dW^T) \), the revenue-recycling effect \( (dW^R) \) and finally, the tax-interaction effect \( (dW^I) \). The primary welfare effect is the partial-equilibrium impact of implementing \( \tau_X \) previously defined in prior literature. This impact is equal to the difference between the private costs of taxation and the social costs of the externality. The former is obtained by multiplying the effective price of \( X \) by the reduction in the production of the polluting good; the latter is derived from multiplying the Pigouvian tax rate by the decrease in the production of \( X \).

The second component in expression (16), \( dW^T \) or the trade-substitution effect, is a welfare element that has not appeared in the previous contributions based on the welfare impacts of ecological taxes in closed economies. This component captures the influence of the new tax on the trade balance. In specific terms, the trade-substitution effect is equal to the difference between the marginal change in imports, valued at the internal price, minus the marginal change in exports, valued at the effective price (i.e. final price plus environmental tax rate). Note that this is in fact a partial equilibrium measure as it does not take into account the interactions of the new taxation with the pre-existing tax system.

The revenue-recycling effect, \( dW^R \), reflects a positive welfare impact of substituting the distortionary income tax by the new taxation. This efficiency improvement is equal to the product of the marginal revenue from the new tax (in square brackets) and the
welfare loss due to income taxation: \( (\mu - 1) \). In contrast to the conventional approaches, the revenue-recycling effect of expression (16) distinguishes between the new revenues attributed to the domestic economy and the new revenues attributed to exporting activity.

The last component in (16) contains the tax-interaction effect: \( dW \). This element measures the welfare loss generated by the new tax on the labour market, which is channelled through an increase in final prices that also reduces real wage, decreases benefits and improves environmental quality. All these impacts discourage labour supply, which simultaneously generates an increase in leisure and any change in the labour supply-leisure decisions exerts two different general equilibrium impacts on welfare. The first is based on the fact that as income tax revenue is directly related to the labour supply, when the labour supply increases (decreases) there is a simultaneous increase (decrease) in taxation revenues. Changes in labour therefore require the tax rate to be modified in the opposite direction to compensate for the income tax revenues. The second impact is explained by the difference between the private cost of leisure (wage net of taxation) and its social cost (pre-tax wage), with the latter higher than the former.

As a result of these two general equilibrium channels, when leisure increases there is an associated welfare loss, which is captured by the tax-interaction effect.

By considering the neutral assumption that goods \( X \) and \( Y \) are equal substitutes for leisure, the tax-interaction effect can alternatively be written as (see the appendix for the details on derivation): \(^{12}\)

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\(^{12}\) Previous literature has shown that a polluting good being a relative complement to leisure implies a lower welfare cost of environmental tax than a polluting good being a relative substitute for leisure (see, for instance, Parry, 1995). Other studies assume equality in the substitution between consumption goods and leisure de facto, as this property is always accomplished in a homothetic utility function that defines weak separability between leisure and consumption goods (see for instance Bovenberg and de Mooij, 1994a). On the other hand, the neutral assumption of identical substitution between the consumption goods and leisure has also been used in Williams (1999, 2002).
\[ dW^l = (\mu - 1) \left[ X \frac{dP_x}{d\tau_x} + Y \frac{dP_y}{d\tau_x} \right] + \mu \tau_L \left[ \varepsilon_{lm} Y_l \frac{d\tau}{d\tau_x} \right] - \mu \tau_L \left[ \frac{\partial l}{\partial q} \left( \frac{dX}{d\tau_x} + \frac{dM_X}{d\tau_x} \right) \right], \]

where \( \varepsilon_{lm} \) is the uncompensated after-tax income elasticity of leisure and \( \gamma_l \) is the share of leisure in relation to pre-tax household income.

The tax-interaction effect of expression (18) is compounded by three different elements. The first captures the negative influence on welfare of the marginal changes in consumption prices, which are directly related to the level of consumption of each good. The second element shows the influence of the lower benefits on reducing the tax-interaction effect when the new tax is implemented, which directly depends on the uncompensated elasticity of leisure with respect to after-tax income and the proportion of leisure compared to pre-tax household income. As a result, the higher the income elasticity of leisure and the higher the income leisure share, the lower the welfare loss will be. Finally, the third element in (18) is the influence of the tax on reducing the production of the polluting good (i.e. increasing environmental quality) and its positive effects on leisure demand (i.e. negative effects on welfare). Note that if environmental quality is assumed not to exert any influence on the consumer’s labour-leisure decision, this component would be null, and the environmental externality would not appear in the tax-interaction effect.

3.2. The trade-substitution effect

In order to analyse the trade effects on welfare of a new tax on the polluting good in depth, this section provides detailed results, which while being generally and aprioristically accepted, have previously been ignored by the second-best taxation literature. In specific terms, these results involve the partial equilibrium welfare impacts that are channelled by the trade activity.

In expression (16), the trade-substitution effect was defined as:
\[ dW^T = P_Y \frac{dM_Y}{d\tau_X} - (1 + \tau_X)P_X \frac{dM_X}{d\tau_X}. \]  

Note that the new ecological tax modifies expression (9) for the balanced trade as follows:

\[ P(M_Y)M_Y - (1 + \tau_X)P_X M_X = 0. \]  

(9’)

Totally differentiating (9’) with respect to \( \tau_X \) yields:

\[ M_Y P'(M_Y) \frac{dM_Y}{d\tau_X} + P(M_Y) \frac{dM_Y}{d\tau_X} - P_X (1 + \tau_X) \frac{dM_X}{d\tau_X} = 0, \]  

(20)

where \( P'(M_Y) \) is the marginal change in the world price for the imported good \( Y \). This expression is equivalent to:

\[ \frac{dM_Y}{d\tau_X} = \frac{P_X (1 + \tau_X) dM_X}{M_Y P'(M_Y) + P(M_Y) d\tau_X}. \]

By substituting this result into expression (19), it follows that:

\[ dW^T = P_X (1 + \tau_X) \left[ \frac{P_Y - (M_Y P'(M_Y) + P(M_Y))}{M_Y P'(M_Y) + P(M_Y)} \right] \frac{dM_X}{d\tau_X} \]  

(21)

where the trade substitution effect has been broken down into three multiplicative elements. The first is the effective export price (EEP), showing the price of exports plus the cost increase due to the new environmental taxation (\( \tau_X \)). The second element is the rate price difference (RPD) of imports, containing the difference between the internal price for the imported goods and the effective world price, which is equal to the world price plus the marginal change in the world price multiplied by imports (or the marginal change in the cost for the imported goods), in relation to (i. e. divided by) the world effective price. Finally, the last element in equation (21) shows the marginal exports change (MEC) when the ecological tax is implemented.
As the environmental taxation increases the effective price of exports, the economy loses competitiveness in the external markets and this implies that $\frac{dM_X}{d\tau_X} < 0$.\(^{13}\)

In addition, the rate price difference ($RPD$) is expected to be positive if the economy is importing from abroad.\(^{14}\) Furthermore, the last component in expression (21), the effective export price ($EEP$), is a non-negative element.

The contribution of the trade-substitution effect to welfare therefore depends on the combination of three well-known factors: the effective cost of exports, the imports’ price differential and the exports response to $\tau_X$. As a result, the higher (lower) the effective export price and the higher (lower) the rate price difference of imports, the higher (lower) the welfare loss for a given marginal change in exports.

Based on the assumption that the economy has no market power in the market of the imported good $Y$, the world price would not suffer any change after implementing the (national) environmental tax on $X$, so that $P' (M_Y) = 0$. In this situation, expression (21) simplifies to:

$$dW_T = \frac{P_X(1 + \tau_X)}{EEP} \left[ \frac{P_Y - P'(M_Y)}{P(M_Y)} \right] \frac{dM_X}{d\tau_X}$$  \hspace{1cm} (21’)

Alternatively, expression (20) can also be written as:

$$\frac{dM_X}{d\tau_X} = \frac{1}{P_X(1+\tau_X)} \left[ (M_Y P'(M_Y) + P(M_Y)) \right] \frac{dM_Y}{d\tau_X}.$$

And after substituting this new equation into expression (19) for the trade-substitution effect, it follows that:

---

\(^{13}\) This assumption follows the conventional wisdom that increasing the cost of exported goods hinders firms’ ability to compete in global markets, which is believed to be linked to a decline in exports (Jaffe et al., 1995).

\(^{14}\) As the model assumes perfect homogeneity between the domestically-produced good $Y$ and imports from abroad ($M_Y$), the only reason for importing is explained by a price difference through which goods coming from the external markets are more competitive than internal ones.
\[ dW^T = \left[ P_Y - (M_Y P'(M_Y) + P(M_Y)) \right] \frac{dM_Y}{d\tau x}, \] (22)

The trade-substitution effect has now been divided into two different components. The first is the import price difference (IPD) containing the difference, in absolute terms, between the internal price of the imported good and the effective external price for imports once the new tax has been implemented. The second term in expression (22) is the marginal imports change (MIC), and shows the (marginal) negative impact of the pollution taxation on imports.\(^{15}\)

If the economy does not exert any influence on the world price for the imported good \((P'(M_Y) = 0)\), expression (22) simplifies to:

\[ dW^T = \left[ P_Y - P(M_Y) \right] \frac{dM_Y}{d\tau x}. \] (22')

The trade-substitution effect described above captures a detrimental welfare impact when an ecological tax is applied to the polluting-exported goods, by reflecting the primary (partial equilibrium) drivers of trade on welfare. Although this component does not reflect other (general equilibrium) trade channels, such as the revenue-recycling effect and the tax-interaction effect, this partial equilibrium outcome is consistent with the widespread idea that any policy affecting (i.e. increasing) the price of the exporting industries negatively affects the internal economy.

4. Welfare trade neutrality

The previous welfare evaluation of the ecological tax shows two different channels of impacts, comprising domestic welfare impacts, which are materialised through the internal relations of the economy, and external impacts, which are channelled through

\(^{15}\) Note that based on the assumption of balanced trade (expression (9)), any change in exports is linked to a change in imports in the same direction to maintain the trade equilibrium.
trade activity. By specifically focusing on the perspective of trade, its influence on welfare involves two partial equilibrium components (the primary welfare effect and the trade-substitution effect) and two general equilibrium components (the revenue-recycling effect and the tax-interaction effect). The complete impact of trade on welfare is therefore more complex than a simple partial equilibrium view of ecological taxation would suggest.

To be more specific, the effect on welfare due to the external activity \((dW^E)\) of the economy can be specified by taking into account the parts in expression (16) that depend on trade, as follows:

\[
dW^E = [\tau_x (1 + P_x) - \tau_P] \frac{dM_X}{d\tau_x} + P_y \frac{dM_Y}{d\tau_x} - (1 + \tau_x)P_x \frac{dM_X}{d\tau_x} + (\mu - 1) \left[ M_X + \tau_x \left[ \frac{dM_X}{d\tau_x} \right] + \mu \tau_L \left[ \frac{\partial}{\partial Q} \left( \frac{dM_X}{d\tau_x} \right) \right] \right], \tag{23}
\]

which shows the various transmission mechanisms through which the trade activity alters welfare.

An analysis of the complete trade effects determines under which circumstances the environmental regulation will not cause any impact on welfare due to the trade activity. In fact, if trade does not exert any influence on welfare, the total welfare measurement would be the same as it would be for a closed economy. This is an important question for economies with a high propensity to export industrial goods linked to negative pressures on the environment. For these economies, trade neutrality would lead to null trade welfare effects when adopting global climate agreements, and this situation would encourage them to accept environmental commitments.

Welfare trade neutrality is accomplished by means of a null value in expression (23) \((dW^E = 0)\):
\[
\tau_X(1 + P_X) - \tau_P \frac{dM_X}{d\tau_X} + P_Y \frac{dM_Y}{d\tau_X} - (1 + \tau_X) P_X \frac{dM_X}{d\tau_X} + \mu - 1 \left[ M_X + \tau_X \left( \frac{dM_X}{d\tau_X} \right) \right] +
\]

\[
\mu \tau_L \left[ \frac{\partial l}{\partial Q} \left( \frac{dM_X}{d\tau_X} \right) \right] = 0.
\]

Solving this equation for the ecological tax, the level of trade neutral taxation \((\tau^N_X)\) will be equal to:

\[
\tau^N_X = \frac{\tau_P + P_X}{\mu} - \frac{1}{\mu} \left[ P_Y \frac{dM_Y}{d\tau_X} \right] - \frac{\mu - 1}{\mu} \left[ M_X \frac{dM_X}{d\tau_X} \right] - \tau_L \left[ \frac{\partial l}{\partial Q} \right].
\] (24)

The first term on the right-hand side is equal to marginal damages (i.e. the Pigouvian tax) and the price of the taxed good \(X\) divided by the marginal cost of public funds. Note that this element is equal to the relation between the sum of the social and private unitary costs of the dirty good, divided by the efficiency cost of an additional unit of public revenues coming from the income taxation. The other terms in equation (24) show negative contributions to neutral tax, specifically comprising the negative influences of the trade-substitution effect, the revenue-recycling effect and the tax-interaction effect.

In the absence of pre-existing taxes in the economy \((\tau_L = 0 \text{ and } \mu = 1)\), note that the trade neutral tax simplifies to:

\[
\tau^N_X = \tau_P + P_X - P_Y \left[ \frac{dM_Y}{d\tau_X} \right],
\] (24)

which is the first-best partial equilibrium tax level that guarantees trade neutrality on welfare.

By considering the potentialities of the welfare trade neutrality, exporting countries could theoretically accept environmental agreements if the level of taxation ensures null trade welfare effects. In this situation, ecological taxes would generate identical welfare
impacts on closed economies as on open-exporting countries. Nonetheless, aprioristic considerations of the negative consequences of ecological measures on welfare, as well as political constraints such as individual interests and the pressure from some stakeholders, severely restrict the feasibility and acceptability of this result in practice.

5. Conclusions

Environmental taxation affects the competitiveness of a small country without power in the global market. The expected negative impact on the domestic economy has proven to be a major argument for exporting-oriented countries to reject international climate agreements. As ecological measures increase the effective price of the exported goods, aprioristic views of environmental regulations postulate reductions in exports and in domestic welfare in the case of open economies.

The model presented in this paper focuses on this issue. In particular, it uses a general equilibrium perspective to analyse the impact of an environmental tax by capturing the interactions with the existing tax system. In contrast to prior literature, the study explicitly defines the links between the domestic economy and the external sector, as well as environmental externalities in the calculation of welfare impacts.

Environmental regulation in the context of an open economy involves a more complex process of welfare consequences than previous contributions, based on a closed economy context, have suggested. In particular, the trade welfare impact is explained by the negative influence of taxation on an economy’s terms of trade and exports, as has been claimed by some national authorities in international climate forums. However, the paper shows that this is only part of the total effects involved. Indeed, the conventional arguments used to reject ecological agreements have neglected the potential positive influence of environmental taxes on generating new tax revenues, and their ability to
replace other pre-existing distortionary taxes. Furthermore, the impacts on the labour supply-leisure choice that reinforce the welfare loss have usually not been taken into account when analysing ecological measures applied to exporting economies.

This analysis extends the scope of the literature on the implications of ecological taxation, by adding trade welfare impacts to the well-known domestic welfare impacts. Future research, beyond the scope of this paper, should consider the completeness of the general equilibrium impacts involved in the empirical estimation of the potential gains of international agreements. Additionally, a multi-country general equilibrium analysis of the welfare effects able to explicitly capture the interconnections between trade partners would improve the definition of welfare interdependences when environmental measures are multilaterally implemented.

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Appendix

In expression (16), the tax-interaction effect is defined as:

$$
\begin{align*}
\delta W_l &= \mu \tau_L \left[ \frac{\partial l}{\partial P_X} \frac{dP_X}{d\tau_X} + \frac{\partial l}{\partial P_Y} \frac{dP_Y}{d\tau_X} + \frac{\partial l}{\partial \pi} \frac{d\pi}{d\tau_X} - \frac{\partial l}{\partial Q} \frac{dQ}{d\tau_X} + \frac{dM_X}{d\tau_X} \right].
\end{align*}
$$

(A.1)

Using the Slutsky equation, it follows that:

$$
\frac{\partial l}{\partial P_X} = \frac{\partial l^C}{\partial P_X} - \frac{\partial l}{\partial m} X, \\
\frac{\partial l}{\partial \tau_L} = \frac{\partial l^C}{\partial \tau_L} - \frac{\partial l}{\partial m} (L + \pi + G).
$$

(A.2)  
(A.3)
where the superscript \( c \) denotes the corresponding compensated demand and \( m \) is after-tax household income: 
\[
m = (1 - \tau_L)(L + \pi + G).
\]

Taking a total derivative of the consumers utility function (1) with respect to \( \tau_L \), maintaining the levels of utility and environmental quality constant and subsequently substituting the consumer’s first-order conditions yields:

\[
\frac{\partial l^c}{\partial \tau_L} = -\frac{\partial l^c}{\partial (1-\tau_L)} = \frac{\partial X^c}{\partial (1-\tau_L)} \frac{p_x}{(1-\tau_L)(1-\tau_L)} + \frac{\partial Y^c}{\partial (1-\tau_L)} \frac{p_y}{(1-\tau_L)(1-\tau_L)}. \tag{A.4}
\]

Using the Slutsky symmetry property:

\[
\frac{\partial l^c}{\partial p_x} = \frac{\partial X^c}{\partial (1-\tau_L)}, \tag{A.5}
\]
\[
\frac{\partial l^c}{\partial p_y} = \frac{\partial Y^c}{\partial (1-\tau_L)}. \tag{A.6}
\]

The neutral assumption that consumption goods are equal substitutes for leisure implies that:

\[
\frac{\partial X^c}{\partial (1-\tau_L)} \frac{(1-\tau_L)}{x} = \frac{\partial Y^c}{\partial (1-\tau_L)} \frac{(1-\tau_L)}{y}. \tag{A.7}
\]

Substituting equations (A.3), (A.4), (A.5), (A.6) and (A.7) into (A.2) and arranging terms gives:

\[
\frac{\partial l}{\partial p_x} = \frac{\partial l}{\partial \tau_L} \frac{X}{L + \pi + G}. \tag{A.8}
\]

And following a similar procedure for good \( Y \):

\[
\frac{\partial l}{\partial p_y} = \frac{\partial l}{\partial \tau_L} \frac{Y}{L + \pi + G}. \tag{A.9}
\]

Bearing in mind that \( \pi \) represents pre-tax income and \( m \) is after-tax income, it follows that:

\[
\frac{\partial l}{\partial \pi} = (1 - \tau_L) \frac{\partial l}{\partial m}.  
\]
And this expression can be transformed as follows:

\[
\frac{\partial l}{\partial \pi} = \frac{\partial l}{\partial m} m \frac{L}{L+\pi+G} = \epsilon_{lm}Y_l. \tag{A.10}
\]

Finally, substituting expressions (A.8), (A.9) and (A.10) into (A.1), using expression (17) that defines the marginal cost of public funds and grouping terms yields equation (18) for the tax-interaction effect.

**References**


