THE EFFECTS OF TAX COMPETITION ON ENVIRONMENTAL PRODUCT QUALITY AND WELFARE IN VERTICALLY DIFFERENTIATED MARKETS

by

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Abstract: This paper—within a two-country, vertically differentiated international duopoly model—analyzes the effects of commodity tax competition on environmental product quality, pollution and welfare. It shows that equilibrium commodity taxes are inefficiently high, with the degree of environmental awareness of consumers playing a crucial role for the magnitude of the results. This paper also explores tax competition when commodity and emission taxes with border tax adjustments interact. With two policy instruments available, tax rates in the non-cooperative equilibrium can be either below or above the global welfare maximizing levels depending on the values of consumers’ marginal willingness to pay for environmental quality and the marginal damage of pollution.

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1 Introduction

It is common, in many markets, one or several environmentally-friendly variants to compete with the standard versions of the products. Some consumers are willing to pay more to buy “green” electricity (electricity produced from renewable energy sources), products with eco-friendly packing or recycled paper. In the literature, models of vertical differentiation have been used to study the provision of environmental product quality where environment-friendliness is considered as a particular quality attribute of the product. The market is vertically differentiated, if, when all variants of the product are offered in the market at the same price, only the one with the high environmental quality (the environmentally friendly good) is bought.

According to Shaked and Sutton (1982), when the quality of the products is an endogenous variable and under price competition, only two firms can survive in equilibrium and they will choose different qualities. One interesting aspect in such models is the impact of commodity taxation on the choice of product quality. Taxation in vertical differentiation model affects the economy through different channels than usual ones and has different impact on welfare. Using a model with two firms, where each of them produces a variant of a differentiated good, Cremer and Thisse (1994) have shown that a small tax is always welfare improving over the no tax equilibrium because it brings the quality choice of firms closer to the socially optimal.

The quality attribute has been interpreted as an inverse measure of pollutant emissions in some papers. Moraga-Gonzalez and Padron-Fumero (2002), investigate the effect of three environmental policies on aggregate emissions and welfare: that of unit emission standards, technology subsidies and product taxes. Bansal and Gangopadhyay (2003) consider ad valorem tax/subsidy policies, not only uniform but also discriminatory. Finally Bansal (2008) find the second best emission tax and ad valorem tax/subsidy policy and compares them. A common element of these studies is that they concentrate to one country with a vertically differentiated duopoly\(^1\).

The objective of this paper is, in an open economy version of a vertically differentiated duopoly framework, to ask how tax competition between countries affects the

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\(^1\) A notable exception is Petropoulou (2013) where in a two-country, vertically differentiated duopoly model shows that under international trade, unilateral minimum standards can be inefficiently high and inefficiently low relative to the global welfare-maximizing international standard.
equilibrium provision of environmental product quality, pollution and welfare. To put it more precisely, and in the form it will be addressed, this paper asks: Starting from the non-cooperative equilibrium would consumers and environmental quality benefit from some degree of tax coordination, and what form this coordination will have, between governments? An interesting feature of the model is that in such a framework with green consumers, environmental product quality is endogenous and therefore commodity taxes affect the choice of firms regarding their emissions, whereas in a simple model of international duopoly firms’ abatement choice is not affected by the commodity taxes. It is shown that commodity taxation is inefficiently high in equilibrium, with the degree of environmental awareness of consumers playing a crucial role for the magnitude of the results.

Another issue that is addressed in this paper is the effects of tax competition when not only commodity but also emission taxes with border tax adjustments (BTAs) exist. The last years there are proposals for BTAs especially by countries that have committed to reduce emissions. The rationale behind these proposals is that, by imposing the same emission tax on imports as in the domestic products, the competitive disadvantage of domestic producers is eliminated. The present work seeks to understand how tax competition operates when governments have two policy instruments at their disposal. It is shown that with two policy instruments available, cooperative and non cooperative equilibrium commodity taxes are higher. Moreover, non cooperative taxes can be either too high or too low, depending on the values of specific parameters.

To address these issues the analysis makes use of a vertical product differentiation model (appropriately applied to an international duopoly setting). A key ingredient in the analysis is the “environment friendliness” which is considered to be the quality attribute of the product. Consumers are environmentally conscious, meaning that they are willing to pay a higher price to buy the eco friendly version of the product, instead of the cheaper, but otherwise equivalent, one. National firms (which produce a good with different environmental quality) compete in both markets in quality and price. First governments set their taxes. Then, given the tax rates, firms first choose the environmental quality of their product and then, maximize their profits by the appropriate choice of prices.

The paper is structured as follows. Section 2 provides the background against which
the analysis is conducted. Section 3 deals with the fiscal externalities arising from the
tax competition and solves for the non-cooperative and cooperative equilibrium under
the different tax regimes. Section 4 summarizes and concludes.

2 The model

There is a continuum of consumers who differ in their marginal willingness to pay $\theta$
for environmentally friendly goods. $\theta$ is distributed uniformly on the interval $[a, a + 1]$. Consumers buy at most one unit of the vertically differentiated good. The indirect utility that a consumer of type $\theta$ derives by the consumption of one unit of quality $q$ at price $p$
is given by

$$u = \theta q - p.$$  \hspace{1cm} (1)

Consider two countries with a single firm located in each. National firms compete in
both markets, not only in prices but also in quality. Quality in this framework represents
the environment-friendliness of the product. The higher the quality of the product is the
lower is its damage to the environment. So the product of the two firms differs only in its
environmental characteristics. Therefore the firm of the one country is the high quality
supplier ($h$) and the firm of the other the low quality ($l$). One can think of quality as the
cleanup level of firm. The production cost is a variable cost, that is, increases in both
quality and quantity.

It is assumed that markets are segmented and therefore each firm chooses what price
and what quality will set in each of the two markets independently. Therefore firms can
differentiate not only the price but also the quality of their exports from that of their
domestic sales. Following (1), consumer of type $\hat{\theta}$ is indifferent between consuming the
environmentally friendly product or the low quality version

$$\hat{\theta} = \frac{p_{hi} - p_{li}}{q_{hi} - q_{li}} \quad i = h, l$$  \hspace{1cm} (2)

where $q_{hi}$ ($q_{li}$) denotes the quality level of the good produced in country $h$ (i.e. in the
country with the high quality supplier) ($l$) and consumed in country $i$.

The demand functions are given by

$$d_{hi} = a + 1 - \hat{\theta}, \quad d_{li} = \hat{\theta} - a \quad i = h, l$$  \hspace{1cm} (3)
where \( d_{hi}(d_{li}) \) denotes the demand of good \( h \) (\( l \)) in country \( i \).

The total pollution that is generated by the production in each country is determined by the per unit emissions multiplied by the quantity of the product sold in each market

\[
Z_i = (D - q_{ii}) d_{ii} + (D - q_{ij}) d_{ij}
\]  

(4)

where \( D \) denotes the per unit emissions if firms does not have cleaning technology. Cleaning technology reduces per unit emissions to \( D - q \), but comes at a cost \( cq^2 \). Assume for simplicity that \( c = 1/2 \).

An ad valorem commodity tax, denoted by \( t_i \) and an emission tax, denoted by \( t^e_i \), are levied by each country. There are border tax adjustments, meaning that countries impose the same emission tax on imports as in the domestically produced products that are consumed within the country. The profit functions are given by

\[
\Pi_i = ((1 - t_i) p_{ii} - cq_{ii}^2) d_{ii} + ((1 - t_j) p_{ij} - cq_{ij}^2) d_{ij} - t_i^e (D - q_{ii}) d_{ii} - t_j^e (D - q_{ij}) d_{ij}, \ i = h, l.
\]  

(5)

Consumer surplus in each country is the sum in the surplus of the consumption of high and low quality goods given by

\[
CS_i = \int_a^{\hat{\theta}} (\theta q_{ii} - p_{ii}) df(\theta) + \int_{\theta}^{a+1} (\theta q_{hi} - p_{hi}) df(\theta).
\]  

(6)

Tax revenues are

\[
R_i = t_i (p_{ii} d_{ii} + p_{ji} d_{ji}) + t_i^e [(D - q_{ii}) d_{ii} + (D - q_{ji}) d_{ji}], \ i, j = h, l, \text{ with } i \neq j.
\]  

(7)

The welfare in each country is given by the sum of the consumer surplus, the profit of the domestic firm, the government’s tax revenues minus pollution

\[
W_i = CS_i + \Pi_i + R - gZ_i, \ i = h, l
\]  

(8)

where \( g \) denotes the marginal damage of pollution.

The game consists of three stages. In the first stage governments choose their taxes. Then, given the tax rates, firms first choose the environmental quality of their product and in the last stage, maximize their profits by the appropriate choice of prices. We solve the game using backwards induction.

Maximizing profits with respect to prices, given quality levels and taxes, one obtains
Firms choose their quality levels (cleanup level). Solving simultaneously the first order conditions for profit maximization gives four equilibria. The following pair is the only one that satisfies the second order conditions

\[ q_{hi} = t_h^* + \frac{1}{4} (1 - t_i) (4a + 5), \quad q_{li} = t_l^* + \frac{1}{4} (1 - t_i) (4a - 1) \quad i = h, l. \]  

(10)

Note that by substituting (9) and (10) in (2), one obtains \( \hat{\theta} = a + \frac{1}{2} \). Therefore taxes cannot affect the demand for each product and the total demand.

3 Tax competition

In this section we characterize the cooperative and non cooperative equilibrium in two cases: i) when countries use only destination commodity taxes ii) when countries use both commodity taxes and emission taxes with border tax adjustments.

3.1 Destination commodity tax rates

In this case it is assumed that countries make use of commodity taxes only. One interesting aspect in a vertical differentiation model like this is that commodity taxation affects welfare through different channels than usual ones. A commodity tax affects the choice of product environmental quality (i.e. the clean up level) and as a consequence prices and welfare.

By setting \( t_h^* = t_l^* = 0 \) in (10) one obtains the cleanup levels in this case

\[ q_{hi} = \frac{1}{4} (1 - t_i) (4a + 5), \quad q_{li} = \frac{1}{4} (1 - t_i) (4a - 1) \quad i = h, l. \]

and it is easy to show that a tax increase reduces the clean up efforts by both firms

\[ \frac{\partial q_{hi}}{\partial t_i} = -a - \frac{5}{4}, \quad \frac{\partial q_{li}}{\partial t_i} = \frac{1}{4} - a < 0 \quad i = h, l. \]  

(11)

\[ 2 \text{Note that } a > 1/4 \text{ so as } q_{li} > 0. \]
Then the optimal tax rates are given by

\[
\begin{align*}
    t_{hT} &= \frac{2(9 - g(5 + 4a))}{16a_h(1 + a) + 25}, \\
    t_{lT} &= \frac{2(9 - g(-1 + 4a))}{16a_l(1 + a) + 25}.
\end{align*}
\]  

(12)

It is evident that the optimal commodity tax in the country with the more polluting firm is higher than the tax in the country with the environmentally friendlier firm. This is surprising, given the fact that a rise in commodity taxes results in more pollution. The intuition behind this result is the following. A commodity tax increase reduces more the cleanup level of the environmentally friendlier firm than that of its competitor (as one can see from (11)) and therefore increases more the pollution in the country with that firm. As a consequence, it is optimal for the country with the more polluting firm to impose a higher tax, since a tax rise increases the revenues without increasing the pollution as much as in the other country.

To summarize

**Proposition 1** A country’s optimal commodity tax is higher if the domestic firm is the low environmental product quality supplier.

one can observe that the Nash taxes can be positive for a sufficiently low \( g \). Assume that \( g = 0 \), that is government doesn’t care about the environment. In this case countries choose a positive tax because it affects the quality choice of firms in a beneficial way. The qualities that firms choose without taxation is different from the optimal qualities, the low quality is too low and the high too high. This happens because firms has an incentive to differentiate qualities so as to relax price competition. As Cremer and Thisse (1994) have shown, a tax reduces the high quality (and brings it closer to the optimal level) but lowers also the low quality (and so drives the low quality more far away from the optimal level). The tax decreases more the high quality than the low, so the positive effect dominates. As a consequence, a small tax is always welfare improving over the no tax equilibrium. Of course the higher is the tax, the lower is the environmental quality of the products and the higher the pollution. When governments care about the environment, the tend to lower the commodity taxes.

Note, for later use, that, using (10),

\[
q_{hi} - q_{li} = \frac{3}{2}(1 - t_i).
\]  

(13)

\(^3\)Note that for both taxes to be positive \( g \) should be lower than a threshold value \( g < \frac{9}{4a+5} \).
It is important one to understand through which channels a domestic tax increase affects the prices. Since both firms sell their products in both markets, the foreign firm’s profits are affected by a domestic tax reduction. In particular a domestic tax reduction, increases the environmental product quality and consequently the prices$^4$ in the domestic market$^5$. This increase in prices does not come only from the increase in the environmental product quality. Part of this change comes from the reduced price competition due to the widening in quality differentiation, as can be seen from (13).

The noncooperative behavior of countries creates externalities, since each government neglects the impact its tax decision has on the other country. To see these externalities perturb (8), and using the differentials of (3)-(4) as well as (9) and (10) to obtain,

$$
\begin{align*}
    dW_h &= - \left[ \frac{3}{4} (1 - t_l) + \frac{1}{2} g \left( a + \frac{5}{4} \right) \right] dt_l, \\
    dW_l &= - \left[ \frac{3}{4} (1 - t_h) + \frac{1}{2} g \left( a - \frac{1}{4} \right) \right] dt_h. \\
\end{align*}
$$

When markets are segmented, a reduction in the domestic tax increases domestically the environmental product quality and the prices, but has no effect on the variables in the foreign market. However, a reduction in the tax in one country increases the welfare of the other, since increases the profits of the foreign firm (by affecting the environmental product quality and the price of its exports) and decreases pollution there.

Equation (14) gives the externalities incurred on one country from the tax setting behavior of the other. The first externality, given by $- \frac{3}{4} (1 - t_l)$, is through the change in profits in country $l$, a change that country $h$ ignores when setting taxes. In raising destination-based taxes, country $h$ reduces the domestic prices of the two variants of the good and reduces their environmental product quality, and since country $l$ exports its product in country $h$, it affects negatively its profits. The second externality concerns the change in pollution in country $l$, a change that country $h$ ignores when setting taxes, as well. In setting the commodity tax, country $h$ ignores the increase in pollution

$$
\begin{align*}
    \frac{\partial p_l}{\partial t_l} &= - \frac{5}{2} a - \frac{a^2}{2} - \frac{49}{32}, \\
    \frac{\partial p_h}{\partial t_h} &= \frac{1}{4} a - \frac{a^2}{2} - \frac{25}{32} \\
\end{align*}
$$

$^4$Although a tax increase does not affect the demand of the product ($d_{hh} = d_{lh} = d_{hl} = d_{ll} = \frac{1}{2}$), it affects the welfare by changing the cleanup level choice of firms and the prices.
incurred to country \( l \), since an increase in the tax rate causes the environmental product quality of both goods to decrease thereby increasing the per unit emissions of exports and consequently pollution in country \( l \). The magnitude of this externality is strictly negative for both countries\(^6\). It is clear, then, that both externalities point toward taxes that are too high in equilibrium.

By maximizing the joint welfare of the two countries, it is straightforward to derive the cooperative taxes

\[
t^c_{lT} = t^c_{hT} = -\frac{2(4g(1 + 2a) - 3)}{16a(1 + a) + 13}. \tag{15}\]

By comparing (12) and (15) one can find that the commodity tax rates at the non cooperative equilibrium are above their cooperative level. This happens because, as noted before, each government, when setting each tax rate, does not take into account the externalities that it creates to the other country. Substituting the Nash taxes in (14), one obtains

\[
\begin{align*}
\frac{\partial W^2_h}{\partial t_i / \partial a} &= -\frac{1432(2a + 1) + g [7(128a + 139) + 32a^2(27 + 8a^2 + 16a)]}{16a(1 + a) + 25} < 0, \\
\frac{\partial W^2_l}{\partial t_h / \partial a} &= -\frac{1432(2a + 1) + g [5(64a + 137) + 32a^2(27 + 8a^2 + 16a)]}{16a(1 + a) + 25} < 0. \tag{16}
\end{align*}
\]

Observe that the higher is the environmental awareness of consumers the greater is the pollution reduction\(^7\) and the welfare gains. This happens because the increase in the cleanup level of firms due to a tax reduction is greater the higher is the degree of environmental awareness (i.e. a high \( a \))\(^8\).

Also note that, after substituting the non cooperative taxes, \( \left| \frac{\partial W_h}{\partial t_i / \partial a} \right| > \left| \frac{\partial W_l}{\partial t_j / \partial a} \right| \), which means that the effect of a neighbouring’s country tax change is not the same for all countries. Inspection of (11) reveals that a change in each country’s tax affects differently the choice of the environmental quality levels of the two firms. In particular a tax reduction increases more the cleanup level of the environmentally friendlier firm than that of its competitor and therefore affects the pollution, the profits and consequently the welfare of the two countries differently\(^9\).

\(^6\)Following from (10), \( a > \frac{1}{4} \) so as \( q_l > 0 \).

\(^7\)Perturbing (4), and using the differentials of (3), (9), (10) and the Nash taxes, one obtains \( \frac{\partial Z_i}{\partial t_i / \partial a} = \frac{1}{2} > 0 \).

\(^8\)Note that \( \frac{\partial q_i}{\partial t_i / \partial a} = -1 < 0 \).

\(^9\)Note that \( \frac{\partial W_l}{\partial t_i / \partial a} < 0 \), but since \( \frac{\partial W_i}{\partial t_j} < 0 \), it means that an increase in \( a \) will decrease \( \frac{\partial W_i}{\partial t_j} \), that is
To summarize

**Proposition 2** Starting from the non cooperative commodity tax equilibrium, welfare in each country is strictly increased and pollution decreased by a small reduction in tax rates. The higher is the environmental awareness of consumers, the greater is the pollution reduction and the welfare gains from the tax reduction.

### 3.2 Commodity and emissions taxes with border tax adjustments

We now turn to the case where governments have two policy instruments at their disposal: commodity taxes and emission taxes with border tax adjustments. As noted in the introductory section, there is an incentive for countries which use emission taxes to use border tax adjustments, aiming to ensure that foreign exporters do not attain a competitive advantage in the domestic market. In this section, we explore the interaction between the two policy instruments.

The non cooperative tax rates in this case can be found by maximizing (8), after using (3)-(4), (9) and (10) and are given by

\[
\begin{align*}
    t_h &= \frac{6 - 2g}{7}, \\
    t_l &= \frac{6 + 2g}{7}, \\
    t_h^c &= \frac{6 (2a + 1) + g (5 - 4a)}{14}, \\
    t_l^c &= \frac{6 (2a + 1) + g (9 + 4a)}{14}
\end{align*}
\]

while the cooperative taxes are

\[
\begin{align*}
    t_h^c &= t_l^c = \frac{2}{3}, \\
    t_h^{cc} &= t_l^{cc} = \frac{2a + 1 + 3g}{3}.
\end{align*}
\]

Clearly, the non cooperative equilibrium commodity tax of the country with the more polluting firm is always inefficiently high, while the one of the other country is higher than the cooperative equilibrium if \(g < \frac{2}{3}\).

By comparing the cooperative commodity taxes when commodity taxes are the only policy instrument with this case, one obtains \(t_h^{cT} < t_h^c\) and \(t_l^{cT} < t_l^c\), meaning that the cooperative commodity taxes are now higher. The intuition behind this result is the following. When there is only one policy instrument, the commodity tax should be low enough so as the cleanup level of firm is higher and the pollution low. In the case where governments have two policy instruments at their disposal, the central planner can use the emission tax to affect pollution and therefore, commodity taxes does not need to be

it will become more negative, meaning that the change in welfare will be greater.
so low any more. For the same reason, the Nash commodity taxes when countries have two policy instruments at their disposal, are higher than those when commodity taxes are the only available policy instrument, as well\(^\text{10}\).

Regarding emission taxes, from (17) and (18), it can be seen that the optimal non cooperative tax rate in the country with the environmentally friendlier firm is higher than the cooperative tax if \(g < \frac{4}{3} \frac{2a+1}{4a+9}\). The non cooperative tax rate in the other country is higher than the cooperative one \((t_t^i > t_t^{cc})\) when \(a < \frac{5}{4}\) and \(g < \frac{4}{3} \frac{2a+1}{5-4a}\) or \(a > \frac{5}{4}\).

To summarize

**Proposition 3** Tax rates in the non-cooperative equilibrium can be either below or above the global welfare maximizing level depending on the values of consumers’ marginal willingness to pay for environmental quality and the marginal damage of pollution.

### 4 Conclusions

The main objective of this paper has been to identify the fiscal externalities arising from two-tax-types tax competition between two countries when the markets are vertically differentiated. Consumers are environmentally conscious, meaning that they are willing to pay a higher price to buy the eco friendly version of the product. Since in this model the quantities of the products do not vary with the taxes, the only way that taxes affect pollution is through the choice of the cleanup level of firms. Within such framework, the tax externalities associated with international trade is explored. It has been shown that, under destination principle of taxation, commodity ad valorem taxes are too high in Nash equilibrium. The reason for this is the existence of two horizontal externalities, caused by the fact that a country’s tax behavior ignores its impact on the welfare of the other.

We also extend the analysis to the case where both commodity and emission taxes with border tax adjustments coexist. The rationale behind border tax adjustments for environmental taxes is clear cut: they offset the disadvantage of domestic producers caused by the emission taxes. It is shown that non-cooperative tax rates can be either below or above the optimal level according to the global welfare maximizing policy.

\(^{10}\) Note that \(t_{kT} - t_h = -\frac{4}{7} \frac{[b(2a+1)+g(5-4a)][2a+1]}{16a(1+a)+25}\) which is negative for \(t_{kT} > 0\). Also \(t_{cT} - t_i = \frac{4}{7} \frac{(12a+4g+9g+6)(2a+1)}{16a(1+a)+25} < 0\).
The limitations of the paper suggest avenues for future research. It remains, for instance, an open question whether the results would be the same if the market was not covered. However it would be a difficult task, given the fact that the analytics of this case in an international duopoly model are extremely cumbersome.
References


