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Trade liberalization and environmental tax in differentiated oligopoly with consumption externalities

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Abstract

This paper investigates the environment tax and trade liberalization with different market structures (pure oligopoly or mixed oligopoly) juxtaposing the substitutability of the goods (homogenous goods and differentiated goods), wherein environmental damage is associated with consumption. It shows that the environmental tax in mixed oligopoly is higher than in pure oligopoly irrespective of the properties of goods. In addition, it demonstrates that when the domestic market increases its openings, the tariff reduction does not always bring positive effects on the environment in mixed oligopoly; but, in pure oligopoly with homogeneous goods, the tariff reduction is bad for the environment.

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1. Introduction

Controlling pollution emission has become the most important and pressing issue for most governments to deal with. In particular, many developing countries face the alternatives between poor environmental-quality improvement and development of the economy. With market opening, the impact of trade liberalization on the environment has become the focus of much attention and debate. Many existing studies are concerned about internalizing pollution externalities by using environmental tax like Krutilla (1991) who has focused attention on the determination of environmental regulations, and disregard the effect of trade liberalization on pollution control.

Few studies have considered negative externalities associated with consumption of the good such as gum-chewing, cigarette smoking and gasoline consumption that cause environmental damage. Anderson (1992) showed that liberalizing trade in a good whose consumption gives rise to pollution will cause a country's environment to deteriorate if the good is imported. Metcalfe and Beghin (1998) argued that when pollution intensities emitted in consumption endogenously respond to environmental policy, and when this policy differs between trading partners, an additional policy instrument is required to cap pollution intensities, such as a standard or a prohibitive tax on any increase in the intensity of consumption pollution.

Lai (2004) examined trade and environmental policies in a pure duopoly market, while Ohori (2006) extended Lai's work in a mixed duopoly model and showed that the optimal environmental tax in a mixed duopoly is higher than the Pigouvian level and the optimal tax in a pure duopoly. Furthermore, Lai and Hu (2005) demonstrated that trade liberalization will enhance global welfare if transboundary pollution-associated consumption is sufficiently strong as well as if bilateral reduction in tariffs is beneficial to the global environment.

In this paper, we investigate the optimal environmental tax and the environmental effect of trade liberalization in a mixed oligopoly and pure oligopoly, wherein firms produce the differentiated goods and the environmental damage is associated with consumption.[1] As a benchmark, we used the study conducted by Lai (2004), who demonstrates that trade liberalization on "dirty" goods leads to environmental improvement and Ohori (2006), who demonstrates that trade liberalization on such dirty goods has no influence on environmental improvement. We then compared the environmental tax before privatization with that after privatization, and that of producing differentiated goods with homogeneous goods. We found that when the domestic market increases its openings, the tariff reduction does not always bring positive effects on the environment in mixed oligopoly; but, in pure oligopoly with homogeneous goods, the tariff reduction is bad for the environment.

[1] Mixed oligopoly models with foreign competition, see Fjell and Pal (1996), Pal and White (1998), and Fjell and Heywood (2002)

This paper is organized as follows. Section 2 provides the basic model. Section 3 includes the results of the analysis in oligopoly with differentiated goods and does a comparison. Section 4 analyzes the effects of trade liberalization. Section 5 presents concluding remarks.

2. The Model

The model follows Ohori's (2006) basic set-up but includes product differentiation. Consider a single international market in which there exists one domestic firm (firm 0) and several private foreign firms (firm i, $i = 1,...,n$) competing in a domestic country. Under the Cournot-Nash assumption, if the domestic firm is public, it selects its output in order to maximize the sum of consumer surplus and its own profit U ; if the domestic firm is private, it chooses its output in order to maximize its own profit π_0. The domestic and foreign firms produce a differentiated good, given by q_i (i =0, 1… n), and this leads to pollution. The domestic government sets the environmental tax t to control the pollution that results from environmentally harmful consumption. We assume that all consumers in the domestic country are the same, and normalize the size of the population in the domestic country to one. The representative consumer derives utility from consuming the good under consideration, and suffers from consumption-type pollution. The utility function of the representative consumer in the domestic country is as follows Häckner (2000) in generalizing the utility function to allow for n foreign firms and one domestic firm producing differentiated goods,

$$V = a(q_0 + \sum_{i=1}^{n} q_i) - \frac{1}{2}(q_0^2 + \sum_{i=1}^{n} q_i^{\ 2} + 2\gamma \sum_{i \neq j} q_i q_j) + I - \theta Q \qquad (1)$$

Where I is the composite goods, and θ is the coefficient of the marginal pollution damage. By solving the optimization problem of the domestic consumer, we can derive the domestic inverse demand function for the good, $p \equiv p(Q)$, where $Q = q_0 + \gamma \sum_{i=1}^{n} q_i$. Q denotes the aggregate output. We assume $p' < 0$. In order to sharpen the study, it is also assumed that the inverse demand function is linear (i.e. $p(Q) = a - Q$). The profit function of firm 0,

$$\pi_0 = (p - c_0 - t)q_0,$$

where c_0 is the constant marginal production cost.

The public firm's objective function is defined as the sum of consumer surplus and the firm's profit,

$$U = \int_0^Q p(\eta)d\eta - pQ + \pi_0. \qquad (2)$$

The environmental damage function is given by $D = \theta Q$, where θ denotes the marginal environmental damage and $\theta \geq 1$. Social welfare in the domestic country is

$$W = \int_0^Q p(\eta)d\eta - pQ + \pi_0 + tQ + \tau\sum_{i=1}^{n} q_i - D. \quad (3)$$

The foreign private firm selects its own output in order to maximize its profit,

$$\pi_i = (p - c_f - t - \tau)q_i, \quad i = 1, 2, ..., n, \quad (4)$$

where c_f is the constant marginal production cost and τ is the tariff rate, $\tau \geq 0$. When we examine the duopoly case, in equation (2)、(3) and (4) assuming $n = 1$ to represent one foreign firm. For simplicity, each firm does not have fixed cost. It also assumes that the marginal production cost of the domestic firm is higher than that of the foreign firm ($c_0 > c_f > 0$).[2] Moreover, as in Lai and Ohori, we consider trade liberalization to be a form of tariff reduction.

3. Environmental Tax in Oligopoly

We extend the basic model concerning the number of foreign firms in which there is one domestic firm and n foreign private firms producing differentiated goods.

3.1 Pure Oligopoly

We first derive the optimal environmental tax in the pure oligopoly with differentiated goods. Under the Cournot-Nash assumption, the domestic private firm selects its output in order to maximize its own profit π_0, while the foreign private firm chooses its output in order to maximize its own profit π_i. We obtain the following first-order conditions:

$$p - c_0 - t + p'q_0 = 0, \text{ and} \quad (5)$$

$$p - c_f - t - \tau + p'\gamma q_i = 0, \quad i = 1, 2, ..., n. \quad (6)$$

The output effects of the taxes are obtained by differentiating (5) and (6) with respect to t and q_i, $\delta q_0 / \delta t = 1/(n+2)p'$ and $\sum_{i=1}^{n}(\delta q_i / \delta t) = n/\gamma(n+2)p'$. This demonstrates that an increase in the environmental tax reduces the market share of all firms. Having obtained these results, we differentiate social welfare equation with respect to t and set $dW/dt = 0$ to obtain optimal environmental tax,

$$t^{DP} = \frac{1}{(n+1)^2}[2n(c_0 - c_f) - (n-1)p'Q^*] - \frac{n}{n+1}[\frac{n+2\gamma+1}{\gamma(n+1)}]\tau + \theta, \quad (7)$$

where Q^* denotes optimal aggregate output[3].

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[2] See Cremer et al (1989) for a justification of this assumption.

[3] (a) We use the superscripts M、P、DM and DP for the mixed Cournot-Nash with homogeneous goods,

3.2 Mixed Oligopoly

We derive the optimal environmental tax in the mixed oligopoly with differentiated goods. Under the Cournot-Nash assumption, the domestic firm selects its output in order to maximize the sum of consumer surplus and its own profits U, while the foreign private firm chooses its output in order to maximize its own profit π_i. We obtain the following first-order conditions,

$$p - c_0 - t - p'\gamma \sum_{i=1}^{n} q_i = 0 \text{, and} \tag{8}$$

$$p - c_f - t - \tau + p'\gamma q_i = 0, \quad i = 1, 2, \ldots\ldots, n. \tag{9}$$

The output effects of the taxes are obtained by differentiating (8) and (9) with respect to t and q_i, $\delta q_0 / \delta t = 1/p'$ and $\sum_{i=1}^{n} (\delta q_i / \delta t) = 0$. These demonstrate that an increase in the environmental tax reduces the market share of the less efficient public firm. Having obtained these results, we differentiate social welfare equation with respect to t and set $dW/dt = 0$ to obtain optimal environmental tax,

$$t^{DM} = \frac{n(c_0 - c_f - \tau)}{n+1} + \theta. \tag{10}$$

From equation (7)、(10)、(A.1.4) and (A.2.4)[4], we find that the optimal environmental tax in different market with different properties of goods is,

$$t^{M} = t^{DM} > t^{P} > t^{DP}.$$

We have the following proposition.

Proposition 1: *In an international oligopoly market wherein the environmental damage is associated with consumption, the order of optimal environmental tax parallels the results of the duopoly model.*

4. The Effects of Trade Liberalization

We now consider the impact of a change in the tariff rate on the outputs of one domestic firm and n foreign private firms in the domestic market. We derive the total impact of trade liberalization on the environment by differentiating the environmental damage function with respect to τ,

$$\frac{dD}{d\tau} = \frac{\delta D}{\delta \tau} + \frac{\delta D}{\delta t}\frac{\delta t}{\delta \tau} = 0.$$

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pure Cournot-Nash homogeneous goods, mixed Cournot-Nash with differentiated goods, and pure Cournot-Nash with differentiated goods oligopoly respectively.

(b) Because the form of optimal environmental tax in pure duopoly is not as usual, there exists a $p'Q^*$ term. Therefore, we supply a special case to simplify this equation in appendix B.

4 See appendix A. for deriving optimal tax rate in pure and mixed oligopoly homogeneous goods.

We obtained the following four results for different market structures and commodities properties:

Case (i): pure oligopoly with homogeneous goods

$$\frac{dD^P}{d\tau} = \frac{(n^4 + 2n^3 - 11n^2 - 4n)}{(n+2)^2 (n+1)^2 p'} \quad \begin{cases} \dfrac{dD^P}{d\tau} > 0 \quad if \quad n \leq 2 \\ \dfrac{dD^P}{d\tau} < 0 \quad if \quad n \geq 3 \end{cases}$$

$$\frac{\delta t^P}{\delta \tau} = \frac{-(n^3 + 8n^2 + 3n)}{(n+1)^2 (n+2)} < 0$$

Case (ii): mixed oligopoly with homogeneous goods

$$\frac{dD^M}{d\tau} = 0 \ ;$$

$$\frac{\delta t^M}{\delta \tau} = \frac{-n}{n+1} < 0$$

Case (iii): pure oligopoly with differentiated goods

$$\frac{dD^{DP}}{d\tau} = \frac{-[(\gamma-1)^2 n^4 + (-4\gamma^2 + 4\gamma - 3)n^3 + (-8\gamma^2 + 4\gamma - 2)n^2 + (-5\gamma^2 + 2\gamma)n]}{(n+2)^2 (n+1)^2 \gamma^2 p'} > 0 \ ;$$

$$\frac{\delta t^{DP}}{\delta \tau} = \frac{-[n^3 + 3(\gamma+1)n^2 + (3\gamma+2)n]}{\gamma (n+1)^2 (n+2)} < 0$$

Case (iv): mixed oligopoly with differentiated goods

$$\frac{dD^{DM}}{d\tau} = \frac{(1-\gamma)n\theta}{(n+1)\gamma p'} < 0 \ ;$$

$$\frac{\delta t^{DM}}{\delta \tau} = \frac{-n}{n+1} < 0$$

According to the above results, we know no matter what types of market structures, there is a negative relationship between tariff rate τ and environmental taxes t; that is, if the government opens the market wholly to make the numbers of foreign firms increase from 1 to n, it may cause more pollution; hence, the government should raise the environmental tax.

In pure oligopoly with homogeneous goods, if the numbers of firms are equal and less than two (i.e. $n \leq 2$), a tariff reduction will improve the environment；however, if the numbers of firms are equal and greater than three (i.e. $n \geq 3$), a tariff reduction has harmful effect on the environment. In mixed oligopoly with homogeneous goods, a tariff reduction has no effect on the environmental damage associated with consumption, which is the same as Ohori's (2006) result. However, in the pure oligopoly with differentiated goods, a tariff reduction has a positive impact on the environment; but, in mixed oligopoly with differentiated goods, a tariff reduction has harmful effect on the environment. When exogenous variables n or γ equal 1, we obtain the same results as in the duopoly market (Lai and Ohori's work). We have the following proposition.

Proposition 2: *The effects of trade liberalization in oligopoly coincide with that in duopoly; except for the one in pure oligopoly with homogeneous goods. When the domestic market increases its openings, the tariff reduction does not always bring positive effects on the environment in mixed oligopoly; but, in pure oligopoly with homogeneous goods, the tariff reduction is bad for the environment.*

5. Concluding Remarks

Using the simple linear demand model, part of our findings are consistent with what has been shown in Lai (2004) and Ohori (2006), even though they considered all firms producing homogeneous goods. In an international oligopoly market wherein the environmental damage is associated with consumption, the order of optimal environmental tax parallels the results of the duopoly model irrespective of the properties of the goods. In addition, we have shown that when the domestic market increases its openings, the tariff reduction does not always bring positive effects on the environment in mixed oligopoly; but, in pure oligopoly with homogeneous goods, the tariff reduction is bad for the environment.

Appendix A

A.1 Pure Oligopoly with Homogeneous Goods

Under the Cournot-Nash assumption, we obtain the following first-order conditions,

$$p - c_0 - t + p' q_0 = 0 \text{, and} \tag{A.1.1}$$

$$p - c_f - t - \tau + p' q_i = 0 \text{,} \quad i = 1, 2, ..., n. \tag{A.1.2}$$

Having obtained the results, we then differentiate social welfare equation with respect to t,

$$\begin{aligned} \frac{dW}{dt} &= \frac{\delta W}{\delta t} + \frac{\delta W}{\delta q_0}\frac{\delta q_0}{\delta t} + \sum_{i=1}^{n}\frac{\delta W}{\delta q_i}\frac{q_i}{\delta t} \\ &= \sum_{i=1}^{n} q_i + [p - c_0 + nt + n\tau - (n+1)\theta]\frac{1}{p'} = 0 \end{aligned} \tag{A.1.3}$$

The optimal environmental tax,

$$t^P = \frac{1}{(n+1)^2}[2n(c_0 - c_f) - (n-1)p'Q^*] - \frac{n(n+3)}{(n+1)^2}\tau + \theta. \tag{A.1.4}$$

A.2 Mixed Oligopoly with Homogeneous Goods

Under the Cournot-Nash assumption, we obtain the following first-order conditions,

$$p - c_0 - t - p'\sum_{i=1}^{n} q_i = 0 \text{, and} \tag{A.2.1}$$

$$p - c_f - t - \tau + p' q_i = 0 \text{,} \quad i = 1, 2, ..., n. \tag{A.2.2}$$

Then differentiating social welfare equation with respect to t, it yields

$$\begin{aligned} \frac{dW}{dt} &= \frac{\delta W}{\delta t} + \frac{\delta W}{\delta q_0}\frac{\delta q_0}{\delta t} + \sum_{i=1}^{n}\frac{\delta W}{\delta q_i}\frac{q_i}{\delta t} \\ &= (p - c_0 - \theta)\frac{1}{p'} = 0 \end{aligned} \tag{A.2.3}$$

The optimal environmental tax,

$$t^M = \theta + \frac{n(c_0 - c_f - r)}{n+1}. \tag{A.2.4}$$

Appendix B

We follow Lai's (2004) basic set-up but assume the linear inverse demand function is $p = a - q_0 - \gamma\sum_{i=1}^{n} q_i$. Differentiating domestic and foreign firms' total profits with respect to their own output, we obtain the following first-order conditions,

$$a - 2q_0 - \gamma\sum_{i=1}^{n} q_i - c_0 - t = 0 \text{ ,and} \tag{B1}$$

$$a-q_0-2\gamma q_i-\gamma\sum_{i\neq j}q_j-c_f-t-\tau=0,\quad i,j=1,2,......,n. \tag{B2}$$

Then, the outputs are given by

$$q_0^{DP}=\frac{1}{n+2}[a-(n+1)c_0+nc_f+n\tau-t]; \tag{B3}$$

$$q_i^{DP}=\frac{1}{\gamma(n+2)}(a+c_0-2c_f-2\tau-t). \tag{B4}$$

The optimal environmental tax is

$$t^{DP}=\frac{[(2n+1)c_0-3nc_f+(n-1)a]}{n^2+4n+1}-[1+\frac{(3\gamma-2)n-1}{n^2+4n+1}]\frac{1}{\gamma}\tau+(1-\frac{n-1}{n^2+4n+1})\theta \tag{B5}$$

If all firms produce homogeneous goods, let $\tau=1$, the optimal output and environmental tax are

$$q_0^{P}=\frac{1}{n+2}[a-(n+1)c_0+nc_f+n\tau-t]; \tag{B6}$$

$$q_i^{P}=\frac{1}{(n+2)}(a+c_0-2c_f-2\tau-t); \tag{B7}$$

$$t^{P}=\frac{[(2n+1)c_0-3nc_f+(n-1)a]}{n^2+4n+1}-[1+\frac{n-1}{n^2+4n+1}]\tau+(1-\frac{n-1}{n^2+4n+1})\theta. \tag{B8}$$

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