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ENVIRONMENTAL TAXES AND CROSS-OWNERSHIP*

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0 RESUMEN

Este artículo analiza el efecto de la propiedad cruzada de las empresas sobre el nivel de protección ambiental que fija un gobierno a través de impuestos medioambientales. Suponemos que hay dos empresas y dos accionistas, una empresa es propiedad únicamente de un accionista mientras que la otra empresa es propiedad de ambos accionistas. Los resultados obtenidos muestran que el impuesto medioambiental fijado por el gobierno, las emisiones y el daño medioambiental decrecen con el porcentaje que una empresa mantiene en la otra.

Palabras clave

Propiedad cruzada, impuestos medioambientales, daño medioambiental, duopolio.

1 INTRODUCCIÓN

This paper examines the incentive of governments to protect the environment when there is cross-participation at ownership level. Specifically, it analyzes how cross-ownership affects the environmental policies of governments. We believe this analysis to be highly relevant since, on the one hand, the literature on the environment usually assumes that each firm is owned by a different shareholder (see, for example, Barnett, 1980; Ulph, 1996; Bárcena-Ruiz, 2006). On the other hand, the literature that studies cross-ownership does not take into account that firms pollute the environment (see, for example, Malueg, 1992; Reitman, 1994; Gilo et *al*., 2006; Bárcena-Ruiz y Campo, 2010).

The determination of optimal environmental taxes has received considerable attention in the economic literature analyzing the environment. Pigouvian taxation is regarded as a benchmark according to which under perfect competition the optimal environmental tax is equal to the marginal environmental cost. However, as markets are not perfectly competitive it is of general interest to analyze optimal environmental taxes under imperfect competition[1]. The problem of optimal environmental taxation considering a single market and imperfectly competitive firms was analyzed first in Buchanan (1969) and then in Barnett (1980). They show that for an externality produced by a monopolist the optimal tax is lower than the marginal environmental cost. The optimal tax consists of two parts: a Pigouvian tax (i.e. the marginal environmental cost), and a correction part due to the market power of the monopolist firm. This analysis has been extended to consider an oligopoly market (see, for example, Carlsson, 2000).

In order to analyze the above issue we consider an oligopolistic industry consisting of two firms that produce a homogeneous good whose production process generates pollutant emissions. Environmental damage is local. The government sets an environmental tax to protect the environment. There is technology available to abate pollutant emissions and the firms invest in emission abatement. The ownership structure has the following characteristics. There are two shareholders: one firm is wholly owned by one shareholder while the other firm is owned by both. We consider that one investor acquires his rival's stock as passive investments that give him a share in the rivals' profit but not in the rival's decision making. The interesting problem we address is the analysis of the implications of this particular structure of ownership on the incentives of the government to protect the environment.

The issue that we analyze in this paper can be illustrated by taking the automobile industry as an example. In this industry there are examples of partial cross-ownership of rivals, e.g. the French firm Renault has formed a partnership with the Japanese firm Nissan. Renault currently holds a

(1) See Requate (2006) for an excellent survey on this issue.

44.3% equity stake in Nissan Motor and Nissan Motor owns a 15% stake in Renault (see www.renault.com)[2]. Moreover, in advanced countries governments set environmental taxes to get firms to internalize the damage generated by their pollutant emissions (see, for example, European Environmental Agency, 2007). We set our model in this context.

Given that we consider imperfectly competitive firms whose production process damages the environment, when each firm is owned by a different investor there are two types of distortion (see, for example, Kennedy, 1994): first, the underproduction associated with the exercise of the market power of firms; second, the fact that in the absence of environmental policies polluting firms do not internalize the damage caused by their emissions. Thus, when each firm is owned by a different investor a tax on pollution emissions reduces the environmental damage caused by firms but it also causes firms to reduce their production further since the tax does not take into account the social cost of further output reduction by firms whose output is already below the optimal level. As a result, the government sets an environmental tax below marginal environmental damage.

We show in the paper that cross-ownership reduces the output of the industry since when the firm that holds a percentage of its rival's stock decides its production it takes into account how its output level affects the profit of the other firm; therefore, cross-ownership intensifies underproduction. Moreover, marginal environmental damage decreases with the percentage of the stock of one firm that is owned by its rival since the output of industry and thus total emissions decrease; therefore, cross-ownership provides incentives for the government to set a lower tax. These two effects reinforce each other and thus the environmental tax set by the government decreases with the percentage of the stock of one firm that is owned by its rival. This means that the government sets a lower tax under cross-ownership than when the two firms are owned by different investors. In addition, the environmental tax set by the government is lower than the marginal environmental damage. However, the difference between the marginal environmental damage and the tax increases with the percentage of the stock of one firm that is owned by the other firm since the market power of firms increases with this percentage. Finally, total emissions and thus environmental damage decrease with this percentage.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 presents the results and Section 4 draws conclusions.

(2) Another example is the partial acquisition of Wilkinson by Gillette: Gillette acquired 22.9% of the non-voting stock and approximately 13.6% of the debt of Wilkinson Sword, one of its largest rivals (see Gilo et al., 2006); the former is from the U.S.A while the latter is from the U.K.

2 THE MODEL

We consider two firms, denoted by 1 and 2, that produce a homogeneous good whose production process generates pollutant emissions. Both firms have identical constant marginal costs of production, denoted by c. The inverse demand function is given by: $p = A - q_1 - q_2$, where p is the price of the good and q_i is the amount of the good produced by firm i[3]. The consumer surplus is given by:

$$CS = \frac{1}{2}(q_1 + q_2)^2 \qquad (1)$$

There is a pollutant associated with the production of the good. Specifically, each unit of output produced causes one unit of pollutant emissions. However, firms have technology available for abating this pollution. Firms can abate emissions so we denote by a_i the abatement level of firm i. As a result, the total pollutant emissions level of firm i is: $e_i = q_i - a_i$. Abating emissions entails a positive cost. We assume that the total cost of pollution abatement is: $C(a_i)=k\,(a_i)^2$, where parameter k measures the efficiency of this technology and thus a lower value of parameter k implies a more efficient abatement technology. This function increases strictly with a_i and is strictly convex.

We consider that there is cross-participation at ownership level. Firm 1 owns α percent of the stock of firm 2, $\alpha<1/2$; therefore this firm does not have a share in its rival's decision making. Firm 1 is owned by a single owner. As firm 1 owns α percent of the stock of firm 2 it chooses the output level, q_1, that maximizes $\pi_1+\alpha\pi_2$. Firm 2 chooses the output level, q_2, that maximizes $(1-\alpha)\,\pi_2$.

Firm i pays an environmental tax, t, per unit of pollution emitted. As the two firms generate the same type of emissions, they pay the same environmental tax. This tax is set by the government. Therefore, the total taxes collected by government are: $T = t(e_1 + e_2)$. Each firm has to pay an environmental tax per unit of pollution emitted and to abate emissions, which has a cost. Thus, the profit of firm i is:

$$\pi_i = (A - q_i - q_j - c)q_i - t\,(q_i - a_i) - k\,(a_i)^2,\ i \neq j;\ i, j = 1, 2. \qquad (2)$$

We assume a quadratic functional form in the emission level to measure the environmental damage generated by the firms:[4]

$$ED = \lambda\,(e_1 + e_2)^2. \qquad (3)$$

where parameter λ measures the value allocated to the environment by the government. This function strictly increases the emission level of the firms and is strictly convex. Given that we consider a single market we assume that environmental damage is local. From (3), marginal environmental damage is given by:

$$MED = 2\lambda\,(e_1 + e_2). \qquad (4)$$

(3) The main results of the paper hold if goods are imperfect substitutes.

(4) The literature on the environment usually assumes that environmental damage is a convex function of the total pollution level. See, for example, Falk and Mendelsohn (1993), Van der Ploeg and Zeeuw (1992) and Ulph (1996).

The social welfare function considered by the government comprises the consumer surplus (*CS*), the producer surplus (*PS*), the total taxes collected by the government (*T*), and the environmental damage caused by the production process (*ED*). The social welfare function is:

$$W = CS + PS + T - ED, \tag{5}$$

where $PS = \pi_1 + \pi_2$.

In order to analyze how cross-ownership affects the environmental policy of the government we consider the following timing. In the first stage, the government decides the environmental tax. In the second stage, the firms simultaneously choose their output and pollution abatement levels. We solve the game by backward induction from the last stage of the game to obtain a Subgame Perfect Nash equilibrium.

For the sake of simplicity we assume that $k = 1$ and $\lambda = 1$. The main results obtained hold for values of parameters k and λ other than 1.

3 RESULTS

In the second stage, firms simultaneously choose the output and abatement levels that maximize their objective functions. As firm 1 owns α percent of the stock of firm 2 its objective is to choose the output level q_1 that maximizes $\pi_1+\alpha\pi_2$. Firm 2 chooses the output level q_2 that maximizes $(1-\alpha)\pi_2$. Solving these problems we obtain the equilibrium output and abatement levels, as a function of environmental taxes:

$$q_1 = \frac{(A-c-t)(1-\alpha)}{3-\alpha}, \quad q_2 = \frac{A-c-t}{3-\alpha}, \quad a_1 = a_2 = \frac{t}{2}. \tag{6}$$

From expression (6) we obtain that the output level of firm 2 increases with parameter α while the output level of firm 1 decreases with this parameter. When firm 1 chooses q_1 it takes into account how it affects the profit of the other firm. Thus, for a given value of t, the higher the value of α the lower the output of firm 1, q_1, and the higher the output of firm 2, q_2[5]. As a result, for a given value of t, the output of the industry, q_1+q_2, decreases with parameter α which means that crossed-ownership reduces market competition. Moreover, expression (6) also shows that $a_i = t/2$, which is just the usual condition that firm i abates pollution to the point where marginal abatement cost equals the tax.

Next we solve the first stage of the game. In this stage, the government sets the environmental tax that maximizes social welfare, given by (5). Solving this problem we obtain:

$$t = \frac{(A-c)(18-17\alpha+4\alpha^2)}{63-50\alpha+10\alpha^2}, \tag{7}$$

(5) It easy to see that the reaction functions in quantities of firm 1 and 2, respectively, are: $q_1 = (A - c - t - q_2(1 + \alpha))/2$, $q_2 = (A - c - t - q_1)/2$. Therefore, for a given value of t, only the reaction function in quantities of firm 1 varies with parameter α. If α rises the reaction function in quantities of firm 1 rotates to the left which means that firm 1 (firm 2) lowers (increases) its output.

From (7) we obtain the marginal environmental damage, the abatement level and the output of the firms, the consumer and producer surpluses, the environmental damage, the total taxes collected by the government and social welfare:

$$MED = \frac{4(A-c)(6-5\alpha+\alpha^2)}{63-50\alpha+10\alpha^2},\ a_1 = a_2 = \frac{(A-c)(18-17\alpha+4\alpha^2)}{2(63-50\alpha+10\alpha^2)},$$

$$q_1 = \frac{3(A-c)(1-\alpha)(5-2\alpha)}{63-50\alpha+10\alpha^2},\ q_2 = \frac{3(A-c)(5-2\alpha)}{63-50\alpha+10\alpha^2},\ CS = \frac{9(A-c)^2(10-9\alpha+2\alpha^2)^2}{2(63-50\alpha+10\alpha^2)^2},$$

$$PS = \frac{(A-c)^2(1224-1782\alpha+937\alpha^2-208\alpha^3+16\alpha^4)}{2(63-50\alpha+10\alpha^2)^2},\ ED = \frac{4(A-c)^2(6-5\alpha+\alpha^2)^2}{(63-50\alpha+10\alpha^2)^2},$$

$$T = \frac{2(A-c)^2(2-\alpha)^2(27-21\alpha+4\alpha^2)}{(63-50\alpha+10\alpha^2)^2},\ W = \frac{3(A-c)^2(6-5\alpha+\alpha^2)}{63-50\alpha+10\alpha^2}.$$

Taking into account the above expressions, we obtain the following result.

Proposition 1. In equilibrium:

$$i)\ t < MED,\ \frac{\partial t}{\partial \alpha} < 0,\ \frac{\partial MED}{\partial \alpha} < 0,\ \frac{\partial (MED-t)}{\partial \alpha} > 0;$$

$$ii)\ \frac{\partial a_1}{\partial \alpha} = \frac{\partial a_2}{\partial \alpha} < 0,\ \frac{\partial q_1}{\partial \alpha} < 0,\ \frac{\partial q_2}{\partial \alpha} > 0,\ \frac{\partial CS}{\partial \alpha} < 0,\ \frac{\partial PS}{\partial \alpha} > 0;$$

$$iii)\ \frac{\partial e_1}{\partial \alpha} < 0,\ \frac{\partial e_2}{\partial \alpha} > 0,\ \frac{\partial (e_1+e_2)}{\partial \alpha} < 0,\ \frac{\partial T}{\partial \alpha} < 0,\ \frac{\partial ED}{\partial \alpha} < 0,\ \frac{\partial W}{\partial \alpha} < 0.$$

Proof. See Appendix.

We analyze first the case in which each firm is owned by a single investor (i.e., $\alpha = 0$). In this case, given that we consider imperfectly competitive firms whose production process generates pollution that damages the environment there are two types of distortions. The first distortion is due to the underproduction generally associated with the exercise of the market power of firms. The second distortion is due to the fact that, in the absence of environmental policies, polluting firms do not internalize the environmental damage caused by their pollutant emissions. Thus, a tax on pollutant emissions reduces the environmental damage caused by firms but also causes firms to reduce their production further. This is due to the fact that the tax does not take into account the social cost of further output reduction by firms whose output is already below the optimal level. Therefore, the government sets an environmental tax below marginal environmental damage to avoid an excessive reduction of production by firms.

As we have seen in the paper, cross-ownership reduces the output of industry; thus, the market power of the firms increases with α, which reinforces the first distortion. On the other hand, marginal environmental damage decreases with α since the output of industry and thus total emissions decrease with this parameter; therefore, the second distortion is weakened. These two effects reinforce each other and, thus, the environmental tax decreases with α. This means that the government sets a lower tax under cross-ownership than when the firms are owned by different investors. As a result, under cross-ownership we obtain the usual result stating that the environmental tax set by the government is lower than the marginal environmental damage. However, the difference between the marginal environmental damage and the tax increases with parameter α. This is due to the fact that the market power of firms increases with α (i.e. the output of industry decreases with α); thus, the tax decreases by more than the marginal environmental damage with parameter α.

Given that the environmental tax decreases with α the pollution abatement level of the firms also decreases with this parameter. On the other hand, as q_1 (q_2) decreases (increases) with α, the total emission level of firm 1 decreases (increases) with this parameter. Moreover, given that the output of the industry decreases with α, total emissions and thus environmental damage decrease with this parameter. As both the tax and total emissions decrease with α, total taxes collected by the government also decrease with this parameter. On the other hand, as the output of industry decreases with α, the consumer (producer) surplus decreases (increases) with this parameter. Finally, social welfare decreases with α since the reduction in the consumer surplus and total taxes collected by the government has a greater effect on social welfare than the reduction in the environmental damage and the increase in the producer surplus.

4 CONCLUSIONS

This paper examines the incentive of the governments to protect the environment when there is cross-participation at ownership level. This analysis is highly relevant since, on the one hand, the literature on the environment usually assumes that each firm is owned by a different shareholder. On the other hand, the literature that studies cross-ownership does not take into account that firms pollute the environment.

We show in the paper that cross-ownership affects the environmental policy of the government. Specifically, we show that the environmental tax set by the government is lower the greater the percentage of one firm that is owned by the other. This means that the government sets a lower tax under cross-ownership than when firms are owned by different investors. As a result, under cross-ownership the environmental tax set by the government is lower than the marginal environmental damage. However, the difference between the marginal environmental damage and the tax increases with the percentage of one firm that is owned by the other, since the market power of firms increases with this percentage. Finally, total emissions and thus environmental damage decrease with the percentage of one firm that is owned by the other firm.

The main results obtained in the paper hold if it is assumed that firms have different marginal costs of production or different abatement costs since they are due to the effects arising in the model. We leave for future research the analysis of the case in which damage is global and thus governments may act strategically when setting their environmental taxes. This could substantially alter the results obtained in the paper since new effects arise in the model.

5 APPENDIX

$$MED - t = \frac{3(A-c)(2-\alpha)}{63-50\alpha+10\alpha^2} > 0,\ \frac{\partial MED}{\partial \alpha} = -\frac{12(A-c)(5-2\alpha)}{(63-50\alpha+10\alpha^2)^2} < 0,$$

$$\frac{\partial(MED-t)}{\partial \alpha} = \frac{3(A-c)(37-40\alpha+10\alpha^2)}{(63-50\alpha+10\alpha^2)^2} > 0, \frac{\partial t}{\partial \alpha} = -\frac{3(A-c)(57-48\alpha+10\alpha^2)}{(63-50\alpha+10\alpha^2)^2} < 0,$$

$$\frac{\partial a_1}{\partial \alpha} = \frac{\partial a_2}{\partial \alpha} = -\frac{3(A-c)(57-48\alpha+10\alpha^2)}{2(63-50\alpha+10\alpha^2)^2} < 0,\ \frac{\partial q_1}{\partial \alpha} = -\frac{3(A-c)(191-152\alpha+30\alpha^2)}{(63-50\alpha+10\alpha^2)^2} < 0,$$

$$\frac{\partial q_2}{\partial \alpha} = \frac{12(A-c)(31-25\alpha+5\alpha^2)}{(63-50\alpha+10\alpha^2)^2} > 0,\ \frac{\partial e_1}{\partial \alpha} = -\frac{3(A-c)(325-256\alpha+50\alpha^2)}{2(63-50\alpha+10\alpha^2)^2} < 0,$$

$$\frac{\partial e_2}{\partial \alpha} = \frac{3(A-c)(305-248\alpha+50\alpha^2)}{2(63-50\alpha+10\alpha^2)^2} > 0,\ \frac{\partial(e_1+e_2)}{\partial \alpha} = -\frac{6(A-c)(5-2\alpha)}{(63-50\alpha+10\alpha^2)^2} < 0,$$

$$\frac{\partial PS}{\partial \alpha} = \frac{3(A-c)^2(1689-3333\alpha+2358\alpha^2-718\alpha^3+80\alpha^4)}{(63-50\alpha+10\alpha^2)^3} > 0,$$

$$\frac{\partial T}{\partial \alpha} = -\frac{6(A-c)^2(432-694\alpha+411\alpha^2-106\alpha^3+10\alpha^4)}{(63-50\alpha+10\alpha^2)^3} < 0,$$

$$\frac{\partial ED}{\partial \alpha} = -\frac{24(A-c)^2(30-37\alpha+15\alpha^2-2\alpha^3)}{(63-50\alpha+10\alpha^2)^3} < 0,$$

$$\frac{\partial CS}{\partial \alpha} = -\frac{9(A-c)^2(670-1123\alpha+702\alpha^2-194\alpha^3+20\alpha^4)}{(63-50\alpha+10\alpha^2)^3} < 0,$$

$$\frac{\partial W}{\partial \alpha} = -\frac{9(A-c)^2(5-2\alpha)}{(63-50\alpha+10\alpha^2)^2} < 0.$$

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