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Pollution quotas and differentiated environmental technology in the presence of foreign direct investment

Cuotas de contaminación y tecnología medioambiental diferenciada en presencia de inversión extranjera directa

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Abstract

The objective of this document, based on a theoretical model, is to determine optimal differentiated pollution quotas established by a country receiving foreign direct investment. Foreign firms compete against national firms for a homogeneous product in an oligopolistic market. It is assumed that foreign firms are more efficient in abating pollution than national firms. It is concluded that, if the disutility produced by pollution is considerably high, the domestic country government imposes a zero pollution quota on both local and foreign companies. But in the event that the disutility is sufficiently low, the domestic government allows both firms a certain amount of emissions depending on the relative efficiency of each type of company.

JEL Code: Q52, F18, F21
Keywords: pollution quotas; environmental policies

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Resumen

El propósito de este trabajo, a partir de un modelo teórico, es determinar las políticas ambientales que maximicen el bienestar de un país receptor de inversión extranjera directa. En un mercado de un bien homogéneo las empresas foráneas compiten contra empresas nacionales bajo condiciones oligopolísticas. Se utiliza como instrumento de control la cuota de contaminación diferenciada, y se asume que las empresas de la inversión extranjera directa poseen tecnología más eficiente para abatir la contaminación. Se concluye que, si la desutilidad por contaminar es considerablemente elevada, el gobierno del país anfitrión impone una cuota de contaminación cero tanto a las empresas locales como extranjeras; pero en el caso que la desutilidad por contaminar no sea muy alta, el gobierno permite a estas firmas cierta cantidad de emisiones dependiendo de la eficiencia relativa de cada tipo de empresa.

Código JEL: Q52, F18, F21
Palabras clave: cuotas de contaminación; políticas medioambientales

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Introduction

Foreign direct investment (FDI) has been considered a source of progress for many developing economies. Some claim that FDI promotes positive externalities in developing economies, such as technological spillovers, employment, and financial opportunities. Thus, foreign companies can promote access to new technologies, capital formation, stimulation of local industry, low commodity prices, new jobs, and reduction of environmental degradation since these companies generally possess more efficient technology. Therefore, in developing countries, FDI inflows are crucial for their development. According to the United Nations Conference on Trade and Development (2017), in 1995 the global flow of FDI was US$341.137 billion; in 2005 it reached US$948.933 billion, reaching its historical maximum in 2015 with US$1.921306 trillion. The same trend is true for FDI flows to developing countries, which received 117.767 billion, 331.468 billion, and 744.032 billion in the same periods, representing 33%, 34%, and 39% of global FDI flows.

There is extensive literature concerning FDI, such as Caves (2009), Cantwell (1994), Gregorio and Lee (1998), and Markusen and Venables (1999), to name a few. These studies show that FDI does not necessarily guarantee a country's development. In addition, FDI is supposed to interact with domestic investment and specifically consider the environmental issue. One of the basic characteristics of FDI in the developed model is that these companies are technologically more efficient in reducing pollution.

On the other hand, according to the United Nations Environment Programme (2018), the increasingly intensive use of natural resources in production processes causes greater pollution (mainly due to the emission of large amounts of CO_2), the effects of which are increasingly devastating and costly. The adverse consequences are manifested both in human health with increasing rates of respiratory, intestinal, and auditory diseases and in the environment with the accelerated increase in global warming and the greenhouse effect, which in turn increases the frequency and intensity of storms, hurricanes, and tornadoes, causing the alteration of certain ecosystems and the possible extinction of species. Nonetheless, governments are wary of implementing extreme measures to reduce pollution, as such policies can significantly increase industrial costs and considerably reduce companies' international competitiveness.

Regarding FDI inflows and the environmental factor on the microeconomic side (i.e., at the level of companies or productive sectors), which is the focus of interest for this study, the literature is generally divided into two positions: the pollution havens hypothesis and the pollution halos hypothesis.[1]

The pollution haven hypothesis refers to the fact that multinational companies prefer to invest in countries with less stringent environmental controls, which translates into lower production costs (Eskeland & Harrison, 2003; Kanbur, Keen, & Wijnbergen, 1995; and Chilchinisky, 1994). Thus, countries with lax pollution controls will specialize in dirty technologies, and those with stricter controls will specialize in clean technologies. In this regard, Xing and Kolstad (2002) conducted an econometric study using a sample of 20 countries in different industries and found that for the chemical sector, there is evidence that less stringent environmental controls do indeed attract foreign direct investment. Andonova (2003) studies environmental policies in Eastern European economies in their process of orientation and conversion to a market economy, citing cases of highly polluting companies that have relocated to these countries and operate under the minimum permissible standards of environmental control, far below those implemented in plants in their countries of origin. Queiroz (2018) analyzes the conduct and environmental performance of foreign pulp companies in Argentina, Brazil, Chile, and Uruguay; his results confirm that there is indeed an imminent process of pollution havens in the region due to the installation of many large foreign industrial plants. Even so, the existence of pollution havens is highly debatable, as there is insufficient empirical evidence that multinational companies prefer to invest and settle in countries that allow high pollution levels.

On the other hand, some authors such as Gentry (1998), Zarsky (1997), and Antweiler, Copeland, and Taylor (2001) suggest that multinational companies help to improve the environment of the countries receiving FDI—the so-called pollution halo hypothesis—since the technology of these companies generally surpasses that of local countries, which is usually more obsolete. There are empirical studies that support this hypothesis. Motta (2006) evaluates Brazilian industry and concludes that foreign multinationals generally adopt more and better environmental controls. Almeida and Rocha (2009) analyzed a sample of companies in Brazil's pulp, paper, and petrochemical industries, concluding that large foreign companies are leaders in environmental management control. Cole, Elliot, and Strobl (2008)

[1]See Silva and Madeira (2015) for a detailed review of the literature analysis concerning the existing relationships between FDI and environment from microeconomic, macroeconomic, and political approaches

conducted an econometric study for foreign manufacturing companies in Ghana. Their results suggest that higher levels of training, managerial experience, and technical capability translate into better environmental performance for foreign multinational companies. Haibo, Ayamba, Agyemang, Afriyie, and Anaba (2019) analyze the effect of foreign direct investment on China's economic development and environmental sustainability. They conclude that, in general, this has been positive since the installation of foreign companies in different sectors has favored China's adherence to better global policies and practices for emissions control, has contributed international assistance to address its environmental challenges, and has favored the creation of a solid legal framework that regulates the pollution emitted by companies. However, regulations on CO_2 emissions remain lax. Li, Dong, Huang, and Failler (2019) conducted an econometric study based on a sample of 40 countries that included environmental performance variables. They concluded that for developed countries, FDI has a positive and significant effect on the environmental performance of the FDI host country, while for developing countries, it also had a positive but marginal effect.

The literature on theoretical models linking FDI and the implementation of environmental policies is rather scarce, despite the relevance they have acquired recently. To this end, this paper develops a partial equilibrium model for a country receiving FDI in the market of a homogeneous good, where companies compete in an oligopolistic model. It is also assumed that both domestic and foreign companies have the technology to reduce pollution, but that FDI companies have more efficient technology to abate it. The government in the host country must consider the welfare of all local and foreign businesses and consumers, and the social costs of pollution. To regulate company emissions, the government uses pollution quotas, which are quantitative limits on the amount of emissions applied to companies, as an instrument of environmental control (Cropper & Oates, 1992). In this regard, companies must assume the costs of reducing their emissions through appropriate technology to comply with the emission limits determined by the government (Kolstad, 2012).

Among the few studies similar to the one developed in this paper are Palomera and Espinosa (2003) and Lahiri and Ono (2000). In the first paper cited, the authors analyze the case of an oligopolistic market where national companies and FDI compete, determining the optimal quotas for the emission of pollutants. The model is a partial equilibrium model for a homogeneous good. Lahiri and Ono (2000) compare two environmental policy instruments, quotas and taxes (a pollution tax is an amount that the government charges companies per unit of pollution emitted - Cropper and Oates, 1992) for the production of a homogeneous good in the presence of FDI, in competition with local companies in an oligopoly, in addition to considering that the host country is small compared to the investor.

Thus, the model developed in this paper differs from both the work of Palomera and Espinosa (2003) and the study of Lahiri and Ono (2000) in the assumption of the difference in pollution abatement technologies between local and FDI companies. Palomera and Espinosa (2003) study how environmental policies affect foreign direct investment. However, the authors do not consider that the government has the explicit intention of attracting foreign direct investment, only how it affects it. Moreover, they assume that companies are homogeneous regarding environmental costs, which is highly unrealistic. In this paper, unlike Palomera and Espinosa (2003), it is considered that the differentiation of environmental costs of companies is essential when analyzing a policy of attracting foreign direct investment, and also that the government intends to attract foreign direct investment taking into account the pollution externality that this investment may bring from this wide range of environmental costs of companies.

The work of Lahiri and Ono (2000), on the other hand, assumes that domestic and foreign companies use the same technology to abate pollution, which is far from reality in terms of technological differences between companies and does not allow the establishment of a more realistic environmental policy for attracting foreign direct investment. In this paper, unlike Lahiri and Ono (2000), the widely differing nature of pollution abatement technology used by local and foreign companies is considered, which provides a better policy approach as it can generate differentiated results that do not exist in the case of Lahiri and Ono (2000). Unlike the work of Lahiri and Ono (2000), the optimal environmental policy in this paper depends on the ability of domestic and foreign companies to differentiate pollution abatement technologies.

This study relates competition between foreign and domestic companies to technological differences in pollution abatement and environmental policies. It also determines the optimal pollution quota as a strategic policy established by the host government to encourage the entry of foreign companies, but at the same time to contribute to the conservation of the environment through the control and reduction of pollutants.

The structure of the paper is as follows: it starts with the specification and delineation of the model in section 2; in section 3 the comparative statics analysis is performed; in section 4 the optimal pollution quota is calculated. Finally, conclusions are drawn in section 5.

The model

Following Lahiri and Ono (2000), a partial equilibrium model of an oligopolistic industry is considered in which several domestic and foreign companies in a host country compete in the market for a non-tradable product. Foreign companies may be considered as Foreign Direct Investment (FDI) in the host country. Implicitly, there is one numeraire good produced under conditions of perfect competition, and there is only one mobile factor of production—labor—with constant returns to scale in all sectors.

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Therefore, the wage is determined in the competitive sector, and marginal costs in the oligopolistic sector are constant.

The existence of n identical local companies and m identical foreign FDI companies is assumed, where n and m are integers and $n \geq 1$ and $m \geq 1$. Each company has a perception based on Cournot's assumptions, i.e., it presupposes the production of other companies as given while maximizing its production.[2] Both types of companies produce the same homogeneous good and emit a certain amount of pollution in the production process. Accordingly, it is assumed that there is a negative externality caused by this contamination. These companies have specific and differentiated technology to reduce pollution.

The cost structure between n local companies and between m foreign companies is symmetric for its own type. Therefore, it can be assumed that each company's production in the host country is the same for its own type. The marginal costs for each company are k_d and k_f for domestic and foreign companies, respectively. Here and for the rest of the paper, d and f are the notations for domestic and foreign companies (their components and policies) located in the host country. As mentioned above, these marginal costs are considered constant and therefore equivalent to the average variable costs. A part of $k_i(i = d, f)$ is given by technology and market conditions, and another part is induced by environmental policy and will be explained later.

The number of domestic companies is fixed, but the number of foreign companies—and thus FDI—may be affected by the host country government's use of environmental control policy. The FDI equilibrium is determined by equating the profits of each foreign company with an exogenously given level of reserves that foreign companies could earn if they locate in alternative markets.

In this partial equilibrium model, the homogeneous and non-tradable product is produced under the Cournot oligopoly model through an inverse and linear demand function as described below,

$$p = a - bQ \tag{1}$$

Where p and Q are respectively the price and total homogeneous good demand. Since the product is not tradable, total domestic demand must equal total production, so that,

$$Q = nx_d + mx_f \tag{2}$$

[2]Cournot's assumptions for oligopolies consider that there is a constant number of identical companies that compete (not cooperate) with each other, produce only one homogeneous good, and have market power, simultaneously choosing the quantities produced of the good while maximizing their profits.

Where x_d and x_f represent the total production of each domestic and foreign company, respectively. Considering constant returns to scale and perfectly competitive markets, the marginal costs of domestic and foreign companies can be assumed to be constant. The earnings of each domestic and foreign company are given respectively by

$$\pi_d = (p - k_d)x_d \tag{3}$$

$$\pi_f = (p - k_f)x_f \tag{4}$$

k_i is defined as,

$$k_i = c + T_i \tag{5}$$

Where c is the technological cost determined by market conditions, which can be considered constant and identical for both local and foreign companies. Since the production of x_d and x_f implies pollution emission, $T_i(i = d, f)$ is the unit cost induced by the pollution abatement policy in each company. This environmental policy-induced cost is defined by Lahiri and Ono (2000) as follows,

$$T_i = \lambda_i(\theta - z_i) \tag{6}$$

Where θ is the amount of pollution per unit produced, so that θx_d and θx_f are the total amount of pollution emitted per company (before applying the environmental policy) located in the host country.[3] Both types of companies have the same production technology, and the level of pollution they emit is the same for all companies. Let z_i $(i = d, f)$ be the pollution quota per unit produced that the host government imposes on companies. On the other hand, the abatement technology is such that it costs each company a constant amount of λ_i $(i = d, f)$ to abate one unit of pollution. These costs are assumed to be different between the two types of companies. Foreign companies are considered to have better technology for pollution abatement so that

$$\lambda_d > \lambda_f \tag{7}$$

[3]Implicitly, this unit contamination parameter, *θ,* is considered to be above the level that the World Health Organization (WHO) considers harmless.

This crucial assumption differentiates this work from that of Lahiri and Ono (2000) and is much more realistic, especially in developing countries. On the other hand, the number of domestic companies is fixed, while the number of foreign companies is endogenous. The government can affect the number of foreign companies by changing the values of the pollution quota z_i. It is assumed that the host country is small with respect to the FDI market. The foreign company moves or leaves the host country if the profit it earns in the host country, π_f, is larger or smaller than the reserve profit $\overline{\pi}$, which it can earn in the rest of the world. Therefore, the FDI equilibrium is given by

$$\pi_f = \overline{\pi} \tag{8}$$

Domestic and foreign companies are assumed to behave under Cournot-Nash assumptions. Each company makes its production decisions considering the production levels of other companies, the number of companies, and the pollution quota set by the host government. Equilibrium is defined by a three-stage model: first, the government chooses the level of differentiated quotas taking everything else as given; second, the number of foreign companies is determined given the level of subsidies and production levels; finally, production levels are determined. Using (3) and (4), the first-order conditions that maximize the utility of the companies are obtained,

$$bx_d = (p - k_d) \tag{9}$$

$$bx_f = (p - k_f) \tag{10}$$

The optimal production of each company is obtained from (9) and (10) using (1) - (4), such that the optimal solutions are

$$x_d = \frac{a + mk_f - (m+1)k_d}{\Delta b} \tag{11}$$

$$x_f = \frac{a + nk_d - (n+1)k_f}{\Delta b} \tag{12}$$

Where

$$\Delta = m + n + 1$$

Using (11) and (12) in (3) and (4) results in

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$$\pi_d = bx_d^2 \tag{13}$$

$$\pi_f = bx_f^2 \tag{14}$$

Equations (1) - (6) and (11) - (14) form the backbone for the subsequent analysis. Now, the host country's welfare is defined considering the application of the pollution quota. The welfare of the host country, W, can be written as

$$W = n\pi_d + m\pi_f + EC - \delta R \tag{15}$$

Where the first two terms in (15) are the total profits of domestic and foreign companies, the third term represents the consumer surplus, and the last term refers to the disutility caused by pollution.[4] It is well known that the consumer surplus *EC* can be expressed as

$$EC = bQ^2/2 \tag{16}$$

$$R = nz_d x_d + mz_f x_f \tag{17}$$

Where z_i (i = d, f) is the pollution quota per unit produced imposed by the government on each company in the host country, which is the same for all domestic companies and for all foreign companies. If companies did not pollute, R would be zero. Finally, in the last term (15), δ is the marginal disutility from polluting that is assumed to be constant, as done by Lahiri and Ono (2000) and Markusen, Morey, and Olewiler (1993 and 1995).[5] The next section will determine some comparative statics results of applying pollution quotas as an environmental control policy.

[4]In this document it was only considered that pollution damages the country where it is generated. Therefore, the analysis of transboundary contamination is omitted. See, for example, Copeland (1996), Copeland and Taylor (1995) and Hatzipanayotou, Lahiri and Michael (2002) for analysis of transboundary pollution.
[5]Other authors, such as Asako (1979), consider that marginal disutility is an increasing function of production. Nonetheless, this alternative assumption does not contradict the results and a constant marginal disutility is a more convenient assumption.

Comparative statics

Having described the properties of the model, the comparative statics of applying the pollution quota for the key variables will be analyzed. The effect of a pollution quota on production, consumer surplus, producer surplus, and pollution disutility will be considered. From (5) is obtained

$$\frac{dk_d}{dz_d} = -\lambda_d > 0 \tag{18}$$

$$\frac{dk_f}{dz_f} = -\lambda_f > 0 \tag{19}$$

An increase in the pollution quota of either company reduces its cost of abating pollution and consequently the total marginal cost. From (8), (12) and (14), using implicit derivation, it follows that

$$\frac{dm}{dz_d} = -\frac{n\lambda_d}{bx_f} < 0 \tag{20}$$

$$\frac{dm}{dz_f} = \frac{(n+1)\lambda_f}{bx_f} > 0 \tag{21}$$

The higher the pollution quota allowed to domestic companies, the lower the number of foreign companies entering the market, as they become less competitive with domestic companies. Conversely, the higher the pollution quota allowed to foreign companies, the greater the number of these companies that enter the host country, as they reduce their production costs and gain competitiveness. Using (20) and (21) in (11) and (12), the following is obtained

$$\frac{dx_d}{dz_d} = \frac{\lambda_d}{b} > 0 \tag{22}$$

$$\frac{dx_d}{dz_f} = -\frac{\lambda_f}{b} < 0 \tag{23}$$

An increase in the pollution quota for domestic companies reduces their marginal production costs, which incentivizes their production. However, an increase in the pollution quota for foreign companies reduces the competitiveness of local companies by reducing their productivity.

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$$\frac{dx_f}{dz_d} = \frac{dx_f}{dz_f} = 0$$

(24)

Given by the endogeneity of the number of foreign companies, the change in pollution quotas does not affect the optimal domestic production of foreign companies. From (2), and taking (22) - (24), the following is obtained

$$\frac{dQ}{dz_d} = 0$$

(25)

$$\frac{dQ}{dz_f} = \frac{\lambda_f}{b} > 0$$

(26)

Total production in the host country is not affected by changes in the quota imposed on local companies because FDI production adjusts for such changes by the entry or exit of foreign companies, depending on whether the quota rises or falls, respectively. On the other hand, total production increases if the pollution quota of foreign companies increases, as the marginal costs of these companies decrease. Using (25) and (26) in (16) results in

$$\frac{dEC}{dz_d} = 0$$

(27)

$$\frac{dEC}{dz_f} = Q\lambda_f > 0$$

(28)

Due to the endogeneity of FDI, the consumer surplus does not change with the variation in the pollution quota of domestic companies. Nonetheless, when the pollution quota for foreign companies increases, the marginal cost of foreign companies falls, more foreign companies enter, and consumer surplus increases. From (13), (14), and (15), using (22), (23), and (24), the following is obtained

$$\frac{d(n\pi_d)}{dz_d} = 2nx_d\lambda_d > 0$$

(29)

$$\frac{d(n\pi_d)}{dz_f} = -2nx_d\lambda_f < 0$$

(30)

An increase in the domestic pollution quota increases the producer surplus of local companies because it decreases the marginal cost of production. An increase in the pollution quota of foreign companies gives them a competitive advantage and reduces the producer surplus of domestic companies. As for the foreign producer's surplus, the following is true

$$\frac{d(m\pi_f)}{dz_d} = -nx_f\lambda_d < 0 \tag{31}$$

$$\frac{d(m\pi_f)}{dz_f} = (n+1)x_f\lambda_f > 0 \tag{32}$$

Similarly, an increase in the domestic pollution quota decreases the production surplus of foreign companies because it puts them at a competitive disadvantage. Conversely, an increase in the foreign pollution quota increases the surplus of foreign producers because it decreases their cost of production. Finally, from (17) and from (20) to (24), the following is obtained

$$\frac{dR}{dz_d} = nx_d + \frac{n\lambda_d}{b}(z_d - z_f) \tag{33}$$

$$\frac{dR}{dz_f} = mx_f + \frac{\lambda_f}{b}(z_f(n+1) - z_d n) \tag{34}$$

The pollution quota's effect on the total pollution emitted is ambiguous. The change in the total amount of pollution emitted by both types of companies depends on the amount of pollution emitted by each type of company. Therefore, the impact of a pollution quota on pollution disutility is also ambiguous.

Optimal quotas

Once the comparative statics results have been determined, the optimal pollution quota will be calculated, provided that the second order conditioning is met. Deriving (15) for the pollution quotas and using (27) - (34) results in

$$\begin{aligned} dW = &\left[2nx_d\lambda_d - nx_f\lambda_d - \delta\left(nx_d + \frac{n\lambda_d}{b}(z_d - z_f)\right)\right]dz_d \\ &+ \left[-nx_d\lambda_f + \Delta x_f\lambda_f - \delta(mx_f + \frac{\lambda_f}{b}(z_f(n+1) - z_d n))\right]dz_f \end{aligned} \tag{35}$$

The concavity condition requires the Second Order Conditioning (SOC) to be

$$SOC = \left(\frac{d^2W}{dz_d^2}\right)\left(\frac{d^2W}{dz_f^2}\right) - \left(\frac{d^2W}{dz_d dz_f}\right)\left(\frac{d^2W}{dz_f dz_d}\right) > 0$$

(36)

However, the SOC also requires that

$$\frac{d^2W}{dz_d^2} = \frac{2n\lambda_d}{b}(\lambda_d - \delta) < 0$$

(37)

$$\frac{d^2W}{dz_f^2} = \frac{\lambda_f}{b}(\lambda_f(2n+1) - \delta 2(n+1))$$

(38)

Which is satisfied only if $\delta > \lambda_d, \lambda_f$. On the other hand

$$\frac{d^2W}{dz_d dz_f} = \frac{d^2W}{dz_f dz_d} = -\frac{n}{b}\left[\lambda_f A_1 + \lambda_d A_2\right]$$

(39)

Where

$$A_1 = (\lambda_d - \delta) < 0$$

$$A_2 = \left(\lambda_f - \delta\right) < 0$$

And by definition

$$A_1 > A_2$$

Substituting (37), (38), and (39) in (36) and simplifying, the following is obtained

$$SOC = \frac{n}{b}\left[2n\lambda_d\lambda_f A_1 A_2 - 2\lambda_d\lambda_f^2 A_1 - n(\lambda_d A_2 - \lambda_f A_1)\right]$$

(40)

The SOC will be positive only if $\delta > \lambda_d > \lambda_f$. That is, if the marginal disutility of polluting is greater than the abatement costs, a corner solution will always be obtained.

Equalizing the terms inside the brackets in (35) to zero and solving for both levels of pollution quotas results in the optimal quotas given below,

$$z_d^* = -\frac{b}{\lambda_d\lambda_f\delta}\left[\delta\left((n+1)\lambda_f x_d + m\lambda_d x_f\right) - \lambda_d\lambda_f\left((n+2)x_d + mx_f\right)\right]$$

(41)

$$z_f^* = -\frac{b}{\lambda_d\lambda_f\delta}\left[\delta\left(n\lambda_f x_d + m\lambda_d x_f\right) - \lambda_d\lambda_f\left(nx_d + (m+1)x_f\right)\right]$$

(42)

Considering the fulfillment of the second-order conditions, it is easy to see from (41) and (42) that if $\delta \gg \lambda_d > \lambda_f$, then the optimal policy will be $z_d^* = z_f^* = 0$. This can be summarized in the following proposition.

Proposition 1. In the non-cooperative equilibrium, if $\delta \gg \lambda_d > \lambda_f$, the optimal pollution quotas are zero ($z_d^* = z_f^* = 0$)

Intuitively, if the marginal disutility of polluting is quite large, the government applies the greatest possible restriction, which is to require companies not to pollute at all to reduce the negative impact of pollution damage on people's health. In this case, there is an increase in marginal production costs due to the significant increase in the costs of reducing pollution in local and foreign companies, which negatively affects the producer and consumer surplus. On the other hand, the benefits of reducing pollution for people's health are greater than the loss in consumer and producer surplus.

From (41) and (42), it is also observed that when the marginal disutility of pollution approaches from the right and is close to the cost of abating pollution by domestic companies; and the cost of abating pollution by foreign companies approaches from the left and is close to the cost of abating pollution by domestic companies. That is, if $\delta \rightarrow \lambda_d \leftarrow \lambda_f$, it can be assumed, satisfying SOC, that $\delta \approx \lambda_d \approx \lambda_f$, so that (41) and (42) can be rewritten as

$$z_d^* = \frac{bx_d}{\lambda_d} > 0 \tag{43}$$

$$z_f^* = \frac{bx_f}{\lambda_d} > 0 \tag{44}$$

The two previous formulas and the preceding paragraph can be stated in the following proposition.

Proposition 2. In the non-cooperative equilibrium, if $\delta \rightarrow \lambda_d \leftarrow \lambda_f$, the optimal pollution quotas are ($z_d^* > 0$ and $z_f^* > 0$).

Intuitively, if the marginal damage caused by pollution is not significant and, by concavity, similar to the cost of abating pollution for domestic and foreign companies, the government allows both domestic and foreign companies a certain amount of emissions, which favors company profits and consumer surplus; and increases the social cost of polluting. In this case, positive pollution quotas represent significant savings for both local and foreign companies since the marginal cost of production is reduced. Now, from (41) and (42), the following is obtained

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$$z_f^* - z_d^* = \frac{b}{\lambda_d \delta}\left[\lambda_d x_f + x_d(\delta - 2\lambda_d)\right] > 0$$

Clearly, the above expression is positive in either of the two previously mentioned cases since, by definition and given that the cost of abating pollution is lower in the foreign company than in the domestic one, the production of the foreign company is higher than that of the domestic company, and because of this, it is allowed a higher quota.

Conclusions

The relationship between the environment and FDI is an issue that has grown rapidly since FDI has become a pillar for the economic development of nations and environmental concerns have been a hot topic in social policy. Foreign companies may be more environmentally efficient, but they also may be more polluting than domestic companies. In this paper, foreign companies are considered technically more efficient in reducing pollution. This study develops a theoretical partial equilibrium model in an oligopolistic framework in a country that receives FDI and has domestic investment for the market of a homogeneous good, in which foreign companies are also assumed to possess more efficient technology to decrease pollution.

The host government imposes a pollution quota to maximize its citizens' welfare. The host government considers the profits made by foreign and domestic companies, the consumer surplus, and the damage caused by pollution to people's health. Determining the optimal pollution quota involves two important cases regarding welfare-maximizing environmental policy implementation in the host country.

The first case is when the marginal disutility of polluting is significantly high. In this situation, a zero-pollution quota is always established, which ostensibly increases the costs of reducing pollution and obviously the marginal costs of production, which decreases both consumer surplus and the profits of both local and foreign companies. Additionally, the emission of pollutants into the environment is substantially reduced, which reduces the social cost of polluting.

In the second case, when the marginal disutility to pollute is not significant, the government decides to apply a positive pollution quota, which allows companies to emit only a certain amount of pollutants, thus reducing abatement costs and marginal production costs and favoring the profits of domestic and foreign companies, and consumer surplus—even if the increase in emissions increases the social cost of polluting and negatively affects the local population's health.

However, the model developed is entirely theoretical and is not supported by empirical evidence, although the authors are working on econometric tests to validate the results obtained for an industrial sector of homogeneous goods. The model can be extended in future studies to differentiated goods markets; furthermore, other environmental control instruments such as pollution taxes, transferable pollution permits, or subsidies can be established, and specific optimal policies can be determined depending on the environmental regulation mechanism chosen.

In conclusion, the proposed model emphasizes the importance of the rational establishment of strategic environmental policies, which act for the benefit of all economic agents involved in the FDI recipient country, both local and foreign companies, consumers, and the environment, by selecting those policies that also lead to the sustainable development of the economy. All these elements are integrated into the general welfare function.

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