Does A Stricter Environmental Policy Discourage Foreign Direct Investment?

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We set up a two-country model in which a foreign firm chooses FDI or exporting to enter the host market, and plays a Cournot competition game with n host firms. Facing the host country's emission tax policy, all firms located in the host country use the same abatement technology to abate emissions. The major findings are as follows. When the trade cost is high and the abatement technology is efficient, a higher emission tax rate may encourage FDI. Moreover, under plausible parameters, raising the emission tax to drive the foreign firm out of the host country will be detrimental to environmental quality but raise consumer surplus in the host country. The interaction of the abatement technological efficiency and trade cost with emission tax plays a key role in the entry mode of the foreign firm and the associate welfare of the host country.

Keywords: emission tax, entry mode, emission abatement, foreign direct investment
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1 Introduction

Under the trend of globalization and WTO regulations, many countries are repealing import quotas and tariffs and starting to allow multinational enterprises to enter their markets. Indirect policies to interfere with trade

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have emerged as potential instrument. One of the most popular is environment policy. In addition to maintaining environmental quality, many countries set up environmental regulations to improve the competitiveness of their firms. Facing the environmental policy of the host country, foreign firms can choose several modes to enter the host market, such as export, foreign direct investment (FDI), acquisition, joint venture, etc.. Among these modes, choice between FDI and export had drawn much attention in the trade literature. Since trade barriers are being removed gradually, many scholars had turned to explore the relationship between the severity of environmental regulations and a foreign firm's entry mode, therefore, pollution haven hypothesis (PHH) emerged. The purposes of this paper is to explore how the emission tax policy in the host country affects a foreign firm's entry mode (FDI or export) and the associate welfare of the host country by considering firms' emission abatement behavior.

There is a lot of trade literature on the entry choice of foreign firms, such as Motta (1992), Horstmann and Markusen (1992), Ethier and Markusen (1996), Qiu and Tao (2001), Sinha (2010), etc. There are also a lot of literature studying the impact of environmental policies on foreign firms' entry decisions, such as Markusen et al. (1993), Motta and Thisse (1994), Markusen et al. (1995), Hoel (1997), Ulph and Valentini (2001), Greaker (2003), Kayalica and Lahiri (2005), Cole et al. (2006), Dijkstra et al. (2011) etc. Under a two-country and two-firm structure, Markusen et al. (1993) find that a small adjustment on the pollution tax may change firms' location decision and the related welfare. Motta and Thisse (1994) develop a two-country and two-firm structure where one firm locates in one country while the other one chooses to locate in either of the two countries. By the model, they study the pollution tax policy on the location decision of the firm and welfare effects of the host country. Both Markusen et al. (1995) and Hoel (1997) take into account firms' plant locations to discuss two countries' environmental regulation race. Markusen et al. (1995) find that when the marginal damage of pollution is high (low), both countries will set stricter (lax) environmental regulations. Hoel (1997) reaches a similar conclusion. Ulph and Valentini (2001) build a two-country and two-firm model to compare the environment dumping effects of two different move structures, one is that firms chooses location before the environmental policy decision, while the other is the reverse. They find, the environment dumping effect of the former structure is greater. Greaker (2003) builds a two-country and two-firm model to discuss the two governments' decisions on environmental reg-

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ulations, given that their domestic firms may threaten to relocate. Kayalica and Lahiri (2005) build a three-country model to discuss how host country and domestic country compete in environmental regulations in order to attract FDI, showing that when the foreign firms can not freely enter the host country, then the environmental regulation set by the host country will be stricter than that in the domestic country, but if foreign firms can freely enter the host market, the result will reverse. Cole et al. (2006) develop an imperfect competition model where local and foreign firms jointly lobby the local government for a favorable pollution tax to explore the relationship between the stringency of environmental policies and FDI. If the degree of corruptibility is sufficiently high (low), FDI leads to less (more) stringent environmental policy, thus, FDI may create a pollution haven. Their empirical results support the predictions. Dijkstra et al. (2011) discuss how the foreign firm's entry modes affect two countries' decisions on pollution taxes. They find, the foreign firm may strategically undertake FDI to induce the host country to set a higher emission tax rate than its home country.

Most of the empirical literature focus on testing PHH. The empirical studies of List et al. (2003) and Cole and Elliot (2005) support PHH, but Eskeland and Harrison (2003) and Javorcik and Wei (2004) note that there is no significant relationship between environmental regulations and firms' location decisions. McConnell and Schwab (1990), Friedman et al. (1992), and Levinson (1996) find that FDI is sometimes positively related to environmental regulations. However, Dean et al. (2009) offer that an environmental regulation and FDI can be either positively or negatively related. By the state data in the U.S., Keller and Levinson (2002) examine weather a low emission abatement cost can attract FDI. They take abatement cost as a proxy to represent the degree of severity of environmental regulations in different states, finding that for low polluting industries, the severity of the environmental regulation has no significant impact on FDI, but for highly polluting industries this relationship is negative. Xing and Kolstad (2002) gather 26 countries' data and take the amount of emissions as a proxy to represent the severity of an environmental regulation. They find that for highly polluting industries, a stricter environmental regulation does reduce the incentive for an U.S. firm to undertake FDI, but it is not significant in low polluting industries. Levinson and Taylor (2008) set up a theoretical model and use the 1977–1986 data of U.S. regulations and trade with Canada and Mexico for 130 manufacturing industries to examine the effect of environmental regulations on trade flows, they indicate that industries

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whose abatement costs increased most experienced the largest increases in net imports.

From the above review, the relationship between the entry mode of foreign firms and environmental policies has been an important issue in environmental economics. Although a lot of empirical papers make use of abatement cost as a proxy to test PHH, however, to the best of our knowledge, these is no theoretical article studying the effects of the interaction of emission tax, abatement technology and trade cost on the FDI decision of a polluting foreign firm. Therefore, the purpose of this paper is to fill up this gap to explore the impact of the emission tax policy on foreign firms' entry choice.

We build a two-country model where one foreign firm chooses FDI or export to entry the host country and plays Cournot competition wth n host firms in the output market. By this model, we intend to examine how the emission tax policy of the host country affects a foreign firm's entry choice, as well as the associated environmental quality and consumer surplus in the host country. The model is a two stage game. The first stage is the entry choice of the foreign firm, and the second stage is the $n + 1$ firms playing Cournot competition. Thus, it is similar to that of Motta and Thisse (1994).[1] The interesting findings are as follows. First of all, raising the emission tax rate in the host country creates three effects — emission tax effect, emission abatement effect, and tax avoidance effect in the incentive for the foreign firm to FDI. Second, when the trade cost is high enough and the emission abatement technology is more efficient, a higher emission tax rate can attract the foreign firm to adopt FDI due to the positive emission abatement effect dominating the other two negative effects, especially, if the number of host firms is no less than 3, a newly enforced stricter emission tax policy may attract the foreign firm to adopt FDI. Third, when abatement technology is more efficient and the fixed cost of FDI is low, if a higher emission tax rate induces the FDI foreign firm to export, then it may raise the total amount of emissions in the host country. These findings show that the interaction of the abatement technological efficiency and trade cost with emission tax rate plays key role in the entry choice of a foreign firm, which is overlooked in the previous literature.

[1]The difference between Motta and Thisse (1994) and this paper is that in the model of the former, both the two countries has a final good market, as the firm chooses one of the two country to locate in, he can serve the two countries.

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This paper is organized as follows. Section 2 introduces the model setting. Section 3 discusses market equilibrium and the impact of the emission tax on the foreign firm's optimal entry choice. Section 4 discusses the impact of the emission tax adjustment on the associate welfare of the host country. Finally, section 5 concludes.

2 Model Setting

We consider a two-country model. A foreign firm f chooses export or FDI to enter the host market and compete with n host firms (denoted as hi, $i = 1, 2, 3 \cdots, n$, respectively). All firms produce homogenous goods and compete in a Cournot fashion.[2] The host market demand is $P(Q) = a - Q$, where $Q = \sum_{i=1}^{n} q_{hi} + q_f$, q_f and q_{hi} are the output of the foreign firm f and a representative host firm hi, respectively. All firms produce at a constant marginal cost c, and without loss of generality, one output produced generates one unit of emission. In order to regulate the environment, the host government imposes a specific emission tax rate t on the pollution emitted in the host country, while the foreign country has no regulation policy.

If a firm locates in the host country, it can abate emissions to reduce emission tax payment. Each firm locating in the host country has the same abatement cost function $\phi(b) = \alpha \cdot b^2/2$, where α represents the abatement technological efficiency, a lower (high) α implies a more(less) efficient abatement technology. If any firm j located in the host country produces q_j unit of output and abates b_j unit of pollution, then its total emission is $q_j - b_j$ and total operation cost function is:[3]

$$\psi^j\left(q_j, b_j, t\right) = c \cdot q_j + t\left(q_j - b_j\right) + \frac{\alpha \cdot b_j^2}{2}, \tag{1}$$

the first term in (1) is total production cost, the second term is emission tax payment and the third term is abatement cost. Given q_j, differentiating $\psi^j(q_j, b_j, t)$ with respect to b_j, we get $\partial\psi^j(q_j, b_j, t)/\partial b_j \equiv \psi_2^j = -t + \alpha \cdot b_j$. Solving $\psi_2^j = 0$, we have $b_j^* = t/\alpha$ for minimizing total cost.

[2]The market structure is like that of Qiu and Tao (2001), Sinha (2010), and Dijkstra et al. (2011).

[3]The abatement cost function is the same as in Jung et al. (1996), Lahiri and Ono (2007), and Ohori (2011).

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Because firms located in the host country face the same tax rate, hereafter, we simplify b_j^* as $b(t) = t/\alpha$ for all j. Substituting $b(t) = t/\alpha$ into (1), firm j's total operation costs can be rewritten as:

$$\psi^j\left(q_j, b(t), t\right) = c \cdot q_j + tq_j - \frac{t^2}{2\alpha}, \tag{2}$$

where $\psi_1^j = \partial\psi^j/\partial q_j = c + t$ is firm j's total marginal cost including marginal production cost and emission tax rate. $\partial\psi^j/\partial t = \psi_3^j = q_j - (t/\alpha) > 0$ shows that a rise in the emission tax rate raises the total operation costs.[4] (2) also reveals that $t^2/2\alpha$ is emission tax payment saving from abatement. In addition to the operation costs, if firm f decides to FDI, it needs to pay a fixed cost G.[5]

If the foreign firm f decides to export, then per unit of export needs to bear a trade cost τ (such as transportation cost and tariff of the host country), so its total cost for producing q_f is $(c + \tau)q_f$.

Based the above settings, if firm f decides to adopt FDI, then its total profit function is:

$$\Pi_f^F = p(Q)q_f^F - \psi^f\left(q_f^F, b(t), t\right) - G, \tag{3}$$

Alternatively, if it adopts export, then its profit function is:

$$\pi_f^E = p(Q)q_f^E - (c + \tau)q_f^E. \tag{4}$$

For a representative host firm hi, its profit function is:

$$\pi_{hi} = p(Q)q_{hi} - \psi^{hi}\left(q_{hi}, b(t), t\right). \tag{5}$$

There are two stages in the game. In the first stage, given t, the foreign firm f chooses between export and FDI to maximize profit. In the second stage, given t and the entry mode of firm f, all firms compete in a Cournot fashion. The subgame perfect equilibrium of this model is solved by backward induction.

By this model, we will explore foreign firm f's optimal entry mode and then examine the impacts of emission tax on the entry mode and the associated welfare of the host country.

[4]We assume t is not high enough with $q_j - b = q_j - (t/\alpha) > 0$, i.e. the emission is not complete eliminated.

[5]To simplify the analysis, we do not consider the possibility that the host country may use strategic regulations to deter foreign firms' entry.

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3 Market Equilibrium and Optimal Entry Mode of the Foreign Firm

In this section, we first solve the market equilibrium in the second stage, and then find out the optimal entry mode of the foreign firm in the first stage of the game.

3.1 Market Equilibrium

3.1.1 FDI Mode

If the foreign firm chooses FDI, then by substituting (2) into (3) and (5), we have the first order conditions as follows:

$$\frac{\partial \pi_f^F}{\partial q_f^F} = a - Q - q_f^F - (c + t) = 0, \tag{6}$$

$$\frac{\partial \pi_{hi}^F}{\partial q_{hi}^F} = a - Q - q_{hi}^F - (c + t) = 0. \tag{7}$$

The symmetric equilibrium outputs of all of firms can be solved as $q_{hi}^F = q_h^F = q_f^F = (a-c-t)/(n+2) = (A-t)/(n+2)$, where $A \equiv a-c$. We can further get the equilibrium profits of firm f and a representative host firm as $\Pi_f^F(t;\alpha,G) = (A-t)^2/(n+2)^2 + t^2/2\alpha - G$ and $\pi_h^F(t,\alpha) = (A-t)^2/(n+2)^2 + t^2/2\alpha$, respectively. Because total pollution abated by every firm is t/α, thus total emission emitted by each firm is $\rho_{hi}^F = \rho_f^F = (A-t)/(n+2) - t/\alpha$. The comparative-statics is shown in the following lemma.

Lemma 1. $(dq^F/dt) < 0$, $(dq^F/dn) < 0$, $(d\Pi_f^F/dn) < 0$, $(d\Pi_f^F/dt) \gtreqless 0$.

The intuition of the first three results of Lemma 1 is straightforward. As for the last one, $d\Pi_f^F/dt = -2(A-t)/(n+2)^2 + t/\alpha \gtreqless 0$ shows to us, the first term is negative, this is because emission tax rate can be treated as a part of marginal cost of firm f from (6), a higher tax rate leads to a higher marginal cost and reduces the FDI profit of firm f, thus, it reduces the incentive for firm f to conduct FDI, we call it as "emission tax effect" (hereafter as "e.t.e."); whereas, the second term is positive, this is because a higher tax rate induces firm f to abate more emission and causes a tax payment saving, therefore, it raises the incentive for firm f to conduct

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FDI, we call it as "emission abatement effect" (hereafter as "e.a.e."), thus, the impact of t on π^F is ambiguous. If e.t.e dominates (is dominated by) e.a.e., then firm f's profit decreases (increases) with t.

3.1.2 Export Mode

When the foreign firm adopts export, then according to (4) and (5), we can derive the following first-order conditions:

$$\frac{\partial \pi_f^E}{\partial q_f^F} = a - Q^E - q_f^E - (c+\tau) = 0, \tag{8}$$

$$\frac{\partial \pi_{hi}^E}{\partial q_{hi}^E} = a - Q^E - q_{hi}^E - (c+t) = 0. \tag{9}$$

Therefore, the market equilibrium outputs can be solved as $q_f^E = [A+nt-(n+1)\tau]/(n+2)$ and $q_h^E = (A-2t+\tau)/(n+2)$, and the equilibrium profits are $\pi_f^E(t;\tau) = [A+nt-(n+1)\tau]^2/(n+2)^2$ and $\pi_h^E(t;\alpha,\tau) = [A-2t+\tau]^2/(n+2)^2 + t^2/2\alpha$, respectively. Besides, total pollutions emitted by each host firm is $\rho_h^E = (A-2t+\tau)/(n+2) - t/\alpha$ and that by firm f is $\rho_f^E = 0$.

A comparative-static analysis shows us the following results.

Lemma 2. $(dq_h^E/dt) < 0$, $(dq_f^E/dt) > 0$; $(dq_h^E/d\tau) > 0$, $(dq_f^E/d\tau) < 0$; $(d\pi_h^E/dt) \gtreqless 0$, $(d\pi_f^E/dt) > 0$; and $(d\pi_h^E/d\tau) > 0$, $(d\pi_f^E/d\tau) < 0$.

The reason for an uncertain sign of $d\pi_h^E/dt$ is similar to that of $d\pi^F/dt$ in Lemma 1, nevertheless, the rise of the emission tax definitely enhances foreign firm f's competitiveness so that $d\pi_h^E/dt > 0$. The straightforward intuition of the others needs not to be mentioned.

3.2 Optimal Entry Mode of the Foreign Firm

Market equilibriums reveal that n, α, τ, G and t determines firm f's profit. To save the space, we assume the emission tax rate is confined to the rate where the emissions are not completely eliminated, and all firms' operation profit in the two modes are positive.[6] Denoting $t^F(\alpha)$ and $t^E(\alpha)$ as the

[6]We assume that under any level of emission tax and trade cost, the firms' equilibrium outputs must be positive. As $q_f^F = (A-t)/(n+2)$ and $q_f^E(t=0) = [A-(n+1)\tau]^2/(n+2)^2$, therefore, $A-t>0$ and $A-(n+1)\tau > 0$.

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critical t where a firm just completely cleans up the emission under the two modes and solving $\rho_h^F = \rho_f^F = 0$ and $\rho_h^E = 0$, we get $t^F(\alpha) = \alpha A/(n + 2 + \alpha)$ and $t^E(\alpha) = \alpha(A + \tau)/(n + 2 + 2\alpha)$.[7] Therefore, t is confined to be less than $\bar{t}(\alpha) \equiv \min(t^F(\alpha), t^E(\alpha))$.

Given t, foreign firm f' will choose an entry mode that makes a higher profit. We define the profit difference under the two modes as:

$$\begin{aligned}\Delta\Pi &= \Delta\Pi(t; \alpha, \tau, G) = \pi_f^F(t; \alpha) - G - \pi_f^E(t; \tau) \\ &= \frac{[A - t]^2}{(n + 2)^2} + \frac{t^2}{2\alpha} - G - \frac{[A + nt - (n + 1)\tau]^2}{(n + 2)^2}. \end{aligned} \tag{10}$$

Based on (10), the decision rule of the foreign firm's optimal entry mode is:

$$\text{If } \Delta\Pi > (<)0, \quad \text{then adopts FDI (export).} \tag{11}$$

To find out the foreign firm's optimal entry mode, we observe the firm's profit difference in the two modes. As mentioned above, the domain of $\Delta\Pi$ is on $t \in [0, \bar{t}(\alpha)]$, and $\tau < A/(n + 1)$ assures a positive output for firm f in the export mode when there is no emission tax policy in the host country.

Differentiating (10) with respect to t, we have:

$$\frac{\partial\Delta\Pi}{\partial t} = \frac{-2(A - t)}{(n + 2)^2} + \frac{t}{\alpha} - \frac{2n[A + nt - (n + 1)\tau]}{(n + 2)^2}. \tag{12}$$

(12) tells us, the effect of t on $\Delta\Pi$ is uncertain. The first two terms is the aforementioned negative e.t.e. and positive e.a.e., respectively, and the last term is the negative tax avoidance effect (hereafter as "t.a.e.") when firm f adopts export mode. Based on (10) and (12), the property of $\Delta\Pi$ on $t \in [0, \bar{t}(\alpha)]$ is presented in Lemma 3, 4, and 5.

Lemma 3. For any given n and τ, defining $\alpha^\tau \equiv (n + 2)\tau/(A - \tau)$ as the critical α that make $\rho_h^F = \rho_f^F = 0$ at $t = \tau$, then we have:

(i) for $\alpha = \alpha^\tau$, $\bar{t}(\alpha) = t^F(\alpha) = t^F(\alpha) = \tau$; (ii) $\forall\alpha \in (0, \alpha^\tau)$, $\bar{t}(\alpha) = t^F(\alpha) < \tau$; (iii) $\forall\alpha \in (\alpha^\tau, \infty)$, $\bar{t}(\alpha) = t^E(\alpha) > \tau$.

Because the host firm always locates in the host country, we can illustrate the intuition of Lemma 3 from the viewpoint of the host firm.

[7] In the FDI mode, if $t > t^F(\alpha)$ then both e.t.e. and e.a.e. will disappear. In the export mode, if $t > t^E(\alpha)$, then t.a.e will disappear, therefore, the raise of tax rate will not affect the equilibrium output in the mode, to simplify the analysis, we do not pay attention to them.

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(i) When $\alpha = \alpha^\tau$, at $t = \tau$, if firm f adopts FDI, then both host firm and foreign firm f have the same total marginal cost $c + t = c + \tau$ and just completely abate their emissions by the definition of α^τ, thus, $t = \tau$ fits the definition of $t^F(\alpha^\tau)$, i.e. $t^F(\alpha^\tau) = \tau$. On the contrary, if firm f switches to export mode, because $t = \tau$, its total marginal cost $(c + \tau)$ is equal to that of host firms $(c + t)$, thus, we have $q_f^F = q_{hi}^F = q_f^E = q_{hi}^E$ and $\rho_f^F = \rho_{hi}^F = \rho_{hi}^E = 0$ at $t = \tau$, this is to say, when $\alpha = \alpha^\tau$, $t = \tau$ also fits the definition of $t^E(\alpha^\tau)$. Therefore, we have $\bar{t}(\alpha^\tau) = t^F(\alpha^\tau) = t^F(\alpha^\tau) = \tau$.

(ii) When $\alpha > \alpha^\tau$, then no matter which mode f adopts, we also have $q_f^F = q_{hi}^F = q_f^E = q_{hi}^E$ at $t = \tau$, however, a less efficient abatement technology $(\alpha > \alpha^\tau)$ cannot clean up all of the emissions as before $(\alpha = \alpha^\tau)$, i.e. $\rho_f^F = \rho_{hi}^F = \rho_{hi}^E > 0$, thus, to clean up all of the emissions needs a higher $t > \tau$, that is to say, both $t^F(\alpha) > \tau$ and $t^E(\alpha) > \tau$. Moreover, when $\alpha > \alpha^\tau$, if $t = t^F(\alpha) > \tau$, all firms clean up the emissions in FDI mode, whereas, if firm f adopts export, then the total marginal of the host firm $(c + t^F(\alpha))$ is greater than that of firm $f(c + \tau)$, thus, we have $q_f^F = q_{hi}^F = q_f^E > q_{hi}^E$ and $\rho_f^F = \rho_{hi}^F = 0 > \rho_{hi}^E$, therefore, for the host firm to clean up all of the emissions, a tax rate less than $t^F(\alpha)$ is needed, that is, $t^E(\alpha) < t^F(\alpha)$. To sum up, we have $t^E(\alpha) < t^F(\alpha) < \tau$.

(iii) When $\alpha < \alpha^\tau$, the same logic of (ii) is applied.

Lemma 4. Given n and $\tau \in (0, A/(n + 1))$:

(i) If $\tau \in (0, A/2(n + 1))$, then $\Delta\Pi$ is decreasing on $t \in (0, \bar{t}(\alpha))$ for all $\alpha > 0$.

(ii) If $\tau \in (A/2(n + 1), A/(n + 1)]$, then defining α^H as the critical α such that $\lim_{t \to \bar{t}(\alpha)^-} \partial\Delta\Pi/\partial t = 0$, we have $\alpha^H < \alpha^\tau$, and, for $\alpha \in (0, \alpha^H)$, $\Delta\Pi(t; \alpha, \tau, 0)$ has a minimum $\Delta\Pi_M > 0$ at $t^M(\alpha) \in (0, \bar{t}(\alpha))$; for $\alpha \in (\alpha^H, \infty)$, $\Delta\Pi$ is decreasing on $t \in (0, \bar{t}(\alpha))$.

The economic intuition of Lemma 4 is as follows. According to (10), $\Delta\Pi(0; \alpha, \tau, 0) = A^2/(n + 2)^2 - [A - (n + 1)\tau]^2/(n + 2)^2 > 0$, it shows to us, without FDI fixed cost, firm f will adopt FDI. Moreover, $\partial\Delta\Pi/\partial t|_{t=0} < 0$ (by (12)) also shows that the incentive for firm f to adopt FDI initially decreases by a rise of the tax rate. When the tax rate is continuously raised, the e.t.e. will decrease, while both the t.a.e and e.a.e will

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increase. If the trade cost is relatively low (i.e. $\tau < A/2(n+1)$), then sum of the two negative effects will always dominates the positive effect owing to a great t.a.e., thus, $\Delta\Pi$ decreases with t, however, if trade cost is high enough (i.e. $A/2(n+1) < \tau < A/(n+1)$) and abatement technology is more efficient ($\alpha < \alpha^H$), then as long as the tax rate is high enough, the sum of the two negative effects will finally be dominated by the positive emission abatement effect, this is why $\Delta\Pi$ is convex on t when τ is high and α is low.

In addition to the above, we further see the values of $\Delta\Pi$ on the two ends ($t = 0$ and $t = \bar{t}(\alpha)$) and combine them with the curvature of $\Delta\Pi$ and fixed cost of FDI to observe the full incentive for the FDI decision. Given n, $\alpha, \tau \in (0, A/(n+1))$ and $t \in [0, \bar{t}(\alpha)]$, denoting $\Delta\Pi_O \equiv \Delta\Pi(0; \alpha, \tau, 0)$ and $\Delta\Pi_C \equiv \Delta\Pi(\bar{t}(\alpha); \alpha, \tau, 0)$,[8] we have Lemma 5.

Lemma 5. Given n and $\tau \in (0, A/(n+1))$:

(i) When $n \leq 2$, $\Delta\Pi_O > \Delta\Pi_C$ for all α.

(ii) When $n \geq 3$, if $\tau \in (0, (3n+2)A/[4n(n+1)])$, then $\Delta\Pi_O > \Delta\Pi_C$ for all α; if $\tau \in ((3n+2)A/[4n(n+1)], A/(n+1))$, and defining α^L as such makes $\Delta\Pi_O(\alpha^L) = \Delta\Pi_C(\alpha^L)$, then $\alpha^L < \alpha^H < \alpha^\tau$ and $\Delta\Pi_O < (>)\Delta\Pi_C$ for $\alpha < (>)\alpha^L$.

(iii) Defining α^U as such that makes $\Delta\Pi(\bar{t}(\alpha^U); \alpha^U, \tau, 0) = 0$, then $\alpha^U > \alpha^\tau$ and $\Delta\Pi_C > (<)0$ for $\alpha < (>)\alpha^U$. (Please see the Appendix for the proof.)

Lemma 5 shows that when $n \leq 2$, no matter what the values of τ and α are, the incentive for firm f to adopt FDI at $t = 0$ (i.e. no emission tax policy) is greater than that at $t = \bar{t}(\alpha)$, i.e. $\Delta\Pi_O > \Delta\Pi_C$, however, when $n \geq 3$, then as long as τ is high enough ($(3n+2)A/[4n(n+1)] < \tau < A/(n+1)$) and α is low enough ($\alpha < \alpha^L$), $\Delta\Pi_C$ will turn out to be greater than $\Delta\Pi_O$. The economic intuition of the above is as follows. As n increases, $\Delta\Pi_O$ will reduce more than $\Delta\Pi_C$ does, this is because at a given $t < \tau$, the operation profit of firm f stolen by the entry of the host firm under the FDI mode is greater than that under the export mode.[9] however, the total marginal cost difference of firm f between the two modes

[8] By definition, given $G = 0$, $\Delta\Pi_O$ is the difference of firm f's profit between the two modes at $t = 0$; $\Delta\Pi_C$ is that when t is at the level where a firm locating in the host country fully abates emissions; and $\Delta\Pi_M$ is the interior minimum of $\Delta\Pi$ at $t^M(\alpha) \in (0, \bar{t}(\alpha))$.

[9] This can be seen by $\partial\Delta\Pi(0; \alpha, \tau, G)/\partial n = -2A\tau/(n+2)^2 < 0$.

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Table 1: Entry mode of firm f when $n \geq 3$ and $(3n+2)A/[4n(n+1)] < \tau < A/(n+1)$

$0 \leq \alpha \leq \alpha^L$	G	$G < \Delta\Pi_M$	$\Delta\Pi_M < G < \Delta\Pi_O$			$\Delta\Pi_O < G < \Delta\Pi_C$		$G > \Delta\Pi_C$
	t	All t	$0 < t < t_1^c$	$t_1^c < t < t_2^c$	$t > t_2^c$	$t < t^c$	$t > t^c$	All t
	m	F	F	E	F	E	F	E
$\alpha^L \leq \alpha \leq \alpha^H$	G	$G < \Delta\Pi_M$	$\Delta\Pi_M < G < \Delta\Pi_C$			$\Delta\Pi_C < G < \Delta\Pi_O$		$G > \Delta\Pi_O$
	t	All t	$0 < t < t_1^c$	$t_1^c < t < t_2^c$	$t > t_2^c$	$t < t^c$	$t > t^c$	All t
	m	F	F	E	F	F	E	E
$\alpha^H \leq \alpha \leq \alpha^U$	G	$G < \Delta\Pi_C$				$\Delta\Pi_C < G < \Delta\Pi_O$		$G > \Delta\Pi_O$
	t	All t				$t < t^c$	$t > t^c$	All t
	m	F				F	E	E
$\alpha^U < \alpha < \infty$	G	$G < \Delta\Pi_O$						$G > \Delta\Pi_O$
	t	$t < t^c$			$t > t^c$			All t
	m	F			E			E

Notes: G: fixed cost of FDI, t: emission tax rate, m: optimal entry mode, F: FDI, E: export.

at $t = \bar{t}(\alpha)$ is less than that at $t = 0$, thus, the magnitude of the reduction of $\Delta\Pi_O$ will be grater than that of $\Delta\Pi_C$, as long as α is low enough and τ is high enough,[10] the persisting entry of the host firm will finally turn $\Delta\Pi_C$ to be greater than $\Delta\Pi_O$. The implication is that, if the abatement technology is more efficient, and both the trade cost and the number of host form is high enough, then a high emission tax rate provides a stronger incentive for firm f to adopt FDI than a zero tax rate.

Based on Lemmas 3, 4, and 5, we can further see the foreign firm f's optimal entry mode under different values of n, τ, α and G. To save the space, we only show the most interesting cases when $n \geq 3$ and $(3n+2)A/[4n(n+1)] < \tau < A/(n+1)$ in Table 1 and establish Proposition 1.[11]

Proposition 1.

(i) When the trade cost is low, a higher emission tax rate will always discourage FDI.

(ii) When the trade cost is high and the abatement technology is efficient, if G lies in some interval, then along with the rise of the emission tax

[10] It's obvious, the emixion abatement effect t/α is not affected by n.

[11] The case that $0 \leq \tau \leq A/2(n+1)$ for any n has only two situations: $0 < \alpha < \alpha^U$ and $\alpha^U < \alpha < \infty$, which are like the last two rows in Table 1; whereas, both $A/2(n+1) \leq \tau \leq A/(n+1)$ for $n \leq 2$ and $A/2(n+1) \leq \tau \leq (3n+2)A/[4n(n+1)]$ for $n \geq 3$ have three situations: $0 < \alpha < \alpha^H$、$\alpha^H < \alpha < \alpha^U$ and $\alpha^U < \alpha < \infty$ which are like the last three rows in Table 1.

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rate, the foreign firm will change from FDI to export first and then switch back from export to FDI.

(iii) When the number of host firms is no less than 3, the trade cost is high enough, and abatement technology is very efficient, then if G lies in some interval, a newly enforced high emission tax rate may attract the foreign firm to conduct FDI.

Proposition 1 (i) is more straightforward, a low trade cost leads to a downward sloping $\Delta\Pi$ because of the sum of negative t.a.e. and e.t.e always dominating positive e.a.e. Proposition 1 (ii), (iii) can be illustrated in Figure 1. If the $\Delta\Pi$ curve is above (below) the horizontal axis, then FDI (export) is favored by firm f. Figure 1 represents the case of $n \geq 3$, $(3n+2)A/[4n(n+1)] < \tau < A/(n+1)$ and $0 < \alpha < \alpha^L$ (Please see the Appendix for proof.). Curve $\Delta\Pi(G=0) = \Delta\Pi(t;\alpha,\tau,0)$ is the case with no FDI fixed cost, which it is above the horizontal axis, thus the foreign firm will always adopt FDI on $t \in (0, \bar{t}(\alpha))$. If G lies between $\Delta\Pi_M$ and $\Delta\Pi_O$ (curve $\Delta\Pi(\Delta\Pi_M < G < \Delta\Pi_O)$), then at $t=0$, firm f will adopt FDI initially, as the tax rate rises to exceed t_1^c, then the negative effect (sum of e.t.e and t.a.e.) will dominate the positive effect (e.a.e.), he will switch to export. If the tax rate continues to increase and exceeds t_2^c, the positive effect will finally dominate the negative effects, then he will switch back to FDI again – this is to say, a higher emission tax rate can attract FDI. If $G$is more high and between $\Delta\Pi_O$ and $\Delta\Pi_C$ (line $\Delta\Pi(\Delta\Pi_O < G < \Delta\Pi_C)$), firm f will adopt export at $t=0$, as t exceeds t^c, he will switch to FDI. This is because when the abatement technology is very efficient and the trade cost is high, a high tax rate create a great e.a.e. but a relatively small t.a.e., providing more incentive for firm f to adopt FDI than a zero tax rate. Furthermore, if τ is low or is high but with a high α, the $\Delta\Pi$ curve is always downward sloping according to Lemma 4, hence, a higher tax rate can only make firm f to switch to export.

The policy implication of Proposition 1 is that, even though a higher tax rate leads to a higher marginal cost, it also brings about a greater emission tax saving owing to the emission abatement effect, if the positive emission abatement effect dominates the other two negative effects, it will contrarily attract FDI, thus, the interaction of trade cost and abatement technological efficiency which had been overlooked in the previous literature plays key role in determining the entry choice of the foreign firm.

In addition to Proposition 1, there are some other interesting points.

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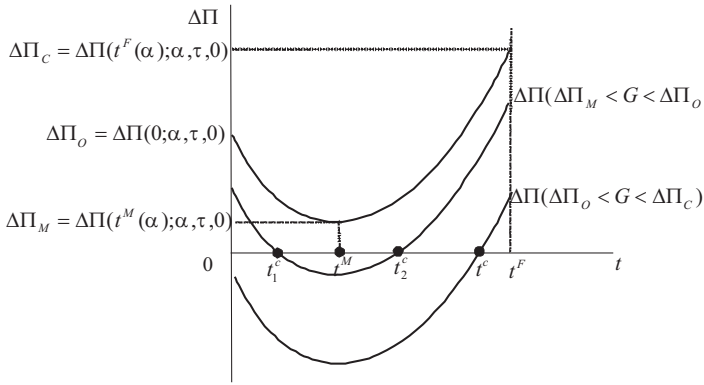


Figure 1: The curve of $\Delta\Pi$ when $n \geq 3$, $((3n+2)A/4n(n+1)) \leq \tau \leq (A/(n+1))$ and $0 < \alpha < \alpha^L$

(1) Firms with no abatement technology is a special case of this model. It can be seen in $\alpha^U < \alpha < \infty$ of Table 1 when α approach ∞, a higher tax rate can only drive firm f out of the host country.
(2) Entry of the host firms may attract FDI.

By (10), we have:

$$\frac{\partial \Delta\Pi}{\partial n} = \frac{2(t-\tau)[nA-(2n+1)t+(n+1)\tau]}{(n+2)^2} \gtreqless 0 \text{ if } t \gtreqless \tau. \quad (13)$$

(13) tells that, if $t > (<)\tau$, entry of host firm will encourage (discourage) FDI. This is because entry of host firm will reduce both the operation profits of firm f in the two modes while the magnitude of the reduction of the profit in the FDI mode will be less (greater) than that in the export mode if $t > (<)\tau$. Furthermore, from Lemma 3 (ii) if $\alpha < \alpha^\tau$, then all $t < \bar{t}(\alpha) < \tau$, thus $\partial\Delta\Pi/\partial n < 0$ by (13), this is to say, when the abatement technology is more efficient, entry of the host firm reduces the incentive for form f to FDI; on the contrary, if $\alpha > \alpha^\tau$, then t may be greater than τ from Lemma 3 (iii), in such a situation, entry of the host firm raises the incentive for form f to FDI. The latter case can be seen in Figure 2.

In Figure 2, as $\alpha > \alpha^\tau$, we have $\bar{t}(\alpha) > \tau$ and $\Delta\Pi$ curve is always downward sloping from Lemmas 3 and 4. (13) reveals that, if n increases

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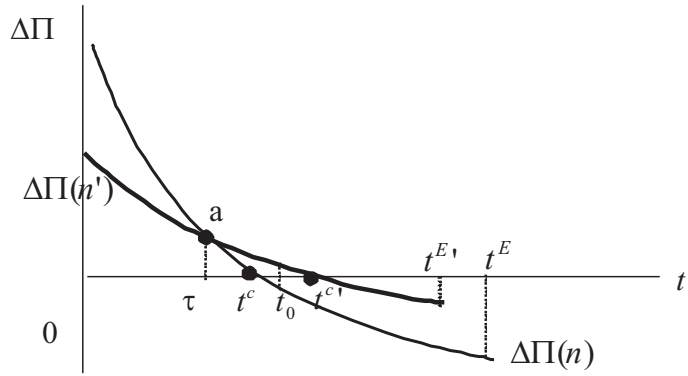


Figure 2: The $\Delta\Pi$ curve when n increases

to n', $\Delta\Pi(n)$ will shift counter-clockwise on point a (where $t = \tau$) to $\Delta\Pi(n')$, if $t = \tau$ and $G < \tau^2/2\alpha$,[12] then the foreign firm will adopt FDI, moreover, if t lies between t^c and $t^{c'}$ (such as t_0), then entry of the host firms will attract firm f to FDI.

Thus, we have Proposition 2.

Proposition 2. If the abatement technology is less efficient and the tax saving of emission abatement exceeds the fixed cost of FDI at $t = \tau$, then, as $t > \tau$, entry of the host firms may induce the foreign firm to switch from export to FDI.

Empirical literature such as Xing and Kolstad (2002) takes cooperate profit as an explanatory variable to estimate the FDI inflow of a country and find that it is positively correlated with FDI inflow. However, the implication of Proposition 2 is that, when there are more host firms, the profit of foreign firm is reduced, while he may turn to FDI under plausible parameters, thus, it's profit is negatively correlated with FDI, this is quite different from that of Xing and Kolstad (2002). The major difference is that previous empirical studies do not consider the interaction of trade cost and the abatement technological efficiency with emission tax rate. Thus, when doing empirical studies, this interaction should not be overlooked.

[12] As $\pi_f^E(\tau;\tau) = (A-\tau)^2/(n+2)^2$, therefore $\tau^2/2\alpha > G$ assures $\Pi_f^E(\tau;\alpha,G) > \pi_h^E(\tau;\tau)$ from (10).

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To sum up, the interaction of trade cost and the abatement technological efficiency with emission tax rate plays key role in foreign firm's location choice, which had not been emphasized in the previous literature.

3.3 Numerical Examples

In this subsection, we provide numerical examples to confirm the aforementioned results. Letting $A = 50$, $n = 3$, we have $\Delta\Pi = (50 - t)^2/5^2 + t^2/2\alpha - G - (50 + 3t - 4\tau)^2/5^2$, and the following cases:

(1) $\tau \in ((3n+2)A/[4n(n+1)], A/(n+1))$ and $\alpha < \alpha^L$

By Lemma 5 (ii), (iii), if $\tau \in ((3\cdot 3+2)50/[4\cdot 3(3+1)], 50/(3+1))$ (i.e.$\tau \in (11.458, 12.5)$) and $\alpha < \alpha^L = 0.198$,[13] then $\Delta\Pi$ is "U" shape and $\Delta\Pi_C > \Delta\Pi_O$. Choosing $\tau = 12.292$ and $\alpha = 0.099$, we can further get $\bar{t}(\alpha) = 0.971$, $\Delta\Pi_O = 99.972$, $\Delta\Pi_C = 100.353$, and $\Delta\Pi_M = 99.04$ at $t^M = 0.444$. Thus, if $G = 99.5$ (lying between $\Delta\Pi_M$ and $\Delta\Pi_O$), the critical tax rates making $\Delta\Pi = 0$ are $t_1^c = 0.132$ and $t_2^c = 0.756$, and that, when $t < t_1^c$, firm f adopts FDI; when $t_1^c < t < t_2^c$, adopts export; when $t_1^c < t < t_2^c$, adopts FDI.

(2) $\tau \in (0, A/2(n+1))$ and $\alpha > \alpha^\tau$

This is the case that $\tau \in (0, 50/[2\cdot(3+1)])$ (i.e. $\tau < 6.25$) and $\alpha^\tau = 0.333$ by Lemma 3. From Lemma 4 (i), $\Delta\Pi$ is always decreasing, if we choose $\tau = 3.125$ and $\alpha = 0.5 > \alpha^\tau$, then $\bar{t} = t^E = 4.427$ and $\Delta\Pi(t = \tau = 3.125;\ \alpha = 0.5,\ n = 3, G) = 9.766 - G$; if $t = 3.385$, $\Delta\Pi(t = 3.385;\ \alpha = 0.5,\ n = 3, G) = 7.533 - G$, thus, as long as $7.533 < G < 9.766$, then if $t = \tau = 3.125$, firm f adopts FDI; if $t = 3.385$, he will adopt export. Other things being equal, if n increases to 4, then $\Delta\Pi(t = \tau = 3.385;\ \alpha = 0.5,\ n = 4, G) = 8.042 - G$. Thus, as long as $7.533 < G < 8.042$, then at $t = 3.385$, firm f will turn to FDI. This is the case of Proposition 2, entry of host firm will attract FDI.

[13] $\alpha^L = (n+2)[4n(n+1)\tau - (3n+2)A]/\{2(n+1)[(n+1)A - 2n\tau]\}$ from the proof of Lemma 5 in the Appendix.

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4 The Impact of the Emission tax Adjustment on the Associate Welfare

This section explores the influence of the emission tax rate on total emission and consumer surplus in the host country by considering the shift of foreign firm's entry mode.

4.1 Total Emission in the Host Country

According to market equilibrium in section 3, the total emission in the host country under the entry modes of FDI and export are $\rho^F(t) = (n+1)[(A-t)/(n+2)-t/\alpha]$ and $\rho^E(t) = n[(A-2t+\tau)/(n+2)-t/\alpha]$, respectively. We have *Lemma 6*.

Lemma 6.

(i) $\rho^E(0) < \rho^F(0)$.

(ii) $\forall\alpha \in (0, \alpha^\tau)$, and there exists a $t^\rho(\alpha) \equiv \alpha(A - n\tau)/[(n+2) - (n-1)\alpha]$ such that $\rho^E(t^\rho(\alpha)) = \rho^F(t^\rho(\alpha))$ and $\rho^E(t) \gtreqless \rho^F(t)$ if $t \gtreqless t^\rho(\alpha)$, where $t^\rho(\alpha) < t^M(\alpha) < t^F(\alpha) < t^E(\alpha)$.

(iii) $\forall\alpha \in (\alpha^\tau, \infty)$, $\rho^E(t) < \rho^F(t)$, and $\forall t \in [0, \bar{t}(\alpha)]$. (Please see the Appendix for proof.)

The economic intuition of Lemma 6 is as follows. (i) When $t = 0$, all firms do not abate emissions, therefore, total emission is equal to total output produced in the host country, however, total output produced in the host country in FDI mode is greater than that in export mode, so is the total emission. (ii) As total pollution emitted in the host country is equal to total emissions generated subtracting total emission abated. For a given $t < \tau$, both the total output produced and total emissions generated in FDI mode is greater than that in export mode. Even though there is one more firm abating emission in FDI mode, if the emission tax rate is low or the abatement technology is less efficient, the amount of more emissions abated by one more firm does not surpass that of more emissions generated in FDI mode, leading to a greater total emissions in FDI mode, however, if abatement technology is more efficient and the tax rate is high enough, the former will surpass the latter, resulting in more pollution emitted in the export mode.

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Based on Lemma 6, we summarize main results of the influence of the emission tax rate on the total pollution emitted in the host country in Proposition 3.

Proposition 3.

(i) If a higher emission tax rate does not alter the foreign firm's entry mode, then total emission in the host country will be reduced.

(ii) If a higher emission tax rate drives the FDI foreign firm out of the host country, then the total emission in the host country may be raised.

(iii) If a higher emission tax rate emission tax rate attracts the foreign firm to conduct FDI, then total emission in the host country will be reduced.

The intuition of Proposition 3 can be illustrated in Figure 3 as follows.

(i) is the case of a very high a very low value of G. The intuition is straightforward, no matter which entry mode firm f chooses, a higher tax rate will definitely reduce total output but raise total pollution abated, thus total emission will be reduced.

(ii) can be illustrated by two cases, one is the case of a very low α with a high τ and an intermediate G, and another one is the case of an intermediate α with an intermediate G. They can be elaborated in Figure 3. Figure 3 depicts the total emission curve for the first case which corresponds to $\Delta\Pi(\Delta\Pi_M < G < \Delta\Pi_O)$ in Figure 1. As $t^M > t^\rho$ from Lemma 6 (ii), thus t_2^c will always be greater than t^ρ, but t_1^c may be greater or less than t^ρ depending on the magnitude of G. We can see in Figure 1, when G lies between $\Delta\Pi_M$ and $\Delta\Pi_O$ and close to $\Delta\Pi_M$, both the two critical rates of $\Delta\Pi(\Delta\Pi_M < G < \Delta\Pi_O)$ will be closer to t^M, thus, the total emission curve is like the solid line $kabcdt^F$ in Figure 3, which jumps up from point a to b at t_1^c and drop down from point c to d at t_2^c, If t lies between t' and t_1^c initially, then raising t to be greater than t_1^c will alter the entry mode of firm f and thereby total emission may rise. In other words, when t lies between t_1^c and t'', if the host country raise tax rate to attract FDI, he needs not to worry about the deterioration of environment quality.

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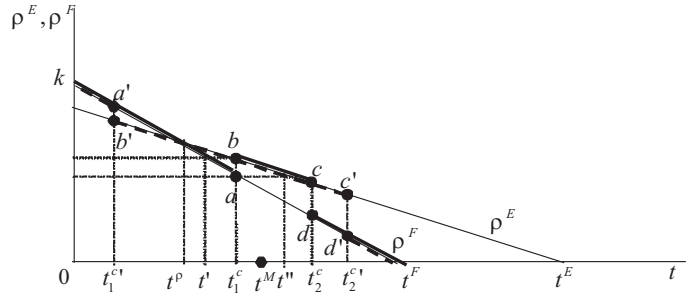


Figure 3: Total emission curve when $0 \leq \alpha \leq \alpha^{\tau}$

Another case is when the abatement technology is not very efficient ($\alpha^H < \alpha < \alpha^{\tau}$), the two total emission curves are similar to those in Figure 3. According to Table 1, if G lies between $\Delta\Pi_C$ and $\Delta\Pi_O$, then raising the tax rate can only change the entry mode from FDI to export. As long as G is close to $\Delta\Pi_C$, the only one critical tax rate such as t_1^c will be greater than t^{ρ}, and the total emission curve is $kabt^E$. Thus, raising t from less than t_1^c may result in a greater total emissions. Alternatively, if G is close to $\Delta\Pi_O$, then the critical tax rate such as $t_1^{c'}$ will be less than t^{ρ} and the total emission line becomes $ka'b't^E$, raising the tax rate will always reduce total emissions.

(iii) is the case of a low α and a high τ with a intermediate high G. Following (ii), because t^M and t^{ρ} are not affected by G, if G is to close to $\Delta\Pi_O$, $\Delta\Pi(\Delta\Pi_M < G < \Delta\Pi_O)$ in Figure 1 moves down and the two critical rate $t_1^{c'}$ and $t_2^{c'}$ are far away from t^M. The corresponding total emission curve in Figure 3 becomes the solid dash line $ka'b'c'd't^F$, thus, raising tax rate to attract FDI reduces total emissions.

We can follow the numerical parameters in subsection 3.3 to check Proposition 3 (ii). When $A = 50$, $n = 3$, $\tau = 12.292$ and $\alpha = 0.099$, we already have $\bar{t}(\alpha) = 0.971$, $\Delta\Pi_O = 99.972$, $\Delta\Pi_C = 100.353$, and $\Delta\Pi_M = 99.04$ at $t^M = 0.444$. At this moment, $\rho^F(t) = (3+1)[(50 - t)/(3+2) - t/0.099]$, $\rho^E(t) = 3[(A - 2t + 12.292)/(3+2) - t/0.099]$ and $t^{\rho} = 0.271$. If $G = 99.2$, the critical rates where the entry mode switches are $t_1^c = 0.331$ and $t_2^c = 0.557$. At $t_1^c = 0.331$, we have $\rho^E = 26.941 > \rho^F = 26.353$, thus, the pollution in host country will jump up

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to $\rho^E (> \rho^F)$ if firm f switches from FDI to export.

4.2 Consumer Surplus in the Host Country

We next examine the influence of emission tax rate on consumer surplus (CS) in the host country. According to market equilibrium, the host country's consumer surplus in the two entry modes are $CS^F = (nq_h^F + q_f^F)^2/2 = [(n+1)(A-t)]^2/[2(n+2)^2]$ and $CS^E = (nq_h^E + q_f^E)^2/2 = [(n+1)A - nt - \tau]^2/2(n+2)^2$, respectively. Thus, we have the following lemma.

Lemma 7.

(i) $(dCS^F/dt) < 0$ and $(dCS^E/dt) < 0$. (ii) Given t, $CS^E - CS^F = ((Q^E + Q^F)(t-\tau)/2(n+2)^2) \gtreqless 0$, if $t \gtreqless \tau$.

Lemma 7 is more obvious, under Cournot competition, consumer surplus is solely dependent on total output of the market which is negatively related to the sum of all firms' total marginal cost. Based on previous analysis and Lemma 7, we have in Proposition 4.

Proposition 4.

(i) If a higher emission tax rate does not change the entry mode, then the consumer surplus in the host country is reduced.

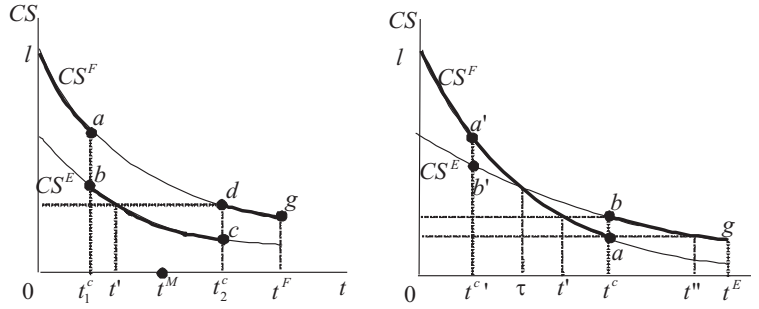
(ii) If a higher emission tax rate does change the entry mode of the foreign firm, then it may raise the consumer surplus of the host country, when

  (a) The abatement technology is efficient and raising the emission tax rate attracts FDI.
  (b) The abatement technology is less efficient and the tax rate is greater than trade cost, whereby raising the tax rate drives the FDI foreign firm out of the host country.

(i) is straightforward in that a higher tax rate reduces output and hence the consumer surplus. Figure 4 illustrates the intuition of (ii). Figure 4a shows case (a) of (ii) where the abatement technology is more efficient ($\alpha < \alpha^H$).[14] The CS curve is line $labcdg$. If $t < t_1^c$, raising t to be between t_1^c and t_2^c will reduce consumer surplus; if $t' < t < t_2^c$, raising t to be greater

[14] This is because $\alpha < \alpha^H$ implies $t^F(\alpha) < \tau$ by Lemma 3.

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a CS curve when $\alpha < \alpha^{\tau}$ **b** CS curve when $\alpha > \alpha^{\tau}$

Figure 4:

than t_2^c may raise or reduce consumer surplus. This is because sum of all firms' total marginal cost changes from $nt + \tau + (n+1)c$ (in export)to $nt_1 + t_1 + (n+1)c$ (in FDI), although $nt_1 > nt$ but $t_1 < \tau$, thus, it may be reduced and lead to a rise of consumer surplus.

Figure 4b shows case (b) of (ii). From Table 1, when $\alpha > \alpha^{\tau}$, a higher tax rate can only drive firm f out of the host country. In Figure 4b, if the critical tax rate $t^{c'} < \tau$, the CS curve is line $la'b'g$, thus a higher tax rate driving out firm f will reduce consumer surplus. Alternatively, if $t^c > \tau$, the CS curve is line $labg$, as $t' < t < t^c$, a higher tax rate driving out firm f may raise or reduce the consumer surplus.

5 Concluding Remarks

We set up a two-country model where a foreign firm chooses FDI or export to compete with n host firms in the host market. By the model, we explore the impact of the host country's emission tax policy on the entry mode of the foreign firm and the associate welfare. The main findings are as follows. A higher emission tax rate causes three effects–the negative emission tax effect and tax avoidance effect and the positive emission abatement effect on the incentive for the foreign firm to FDI. When the trade cost is low, a higher emission tax rate will discourage the foreign firm to FDI. When the trade cost is high and the abatement technology is efficient, a higher emission tax rate may encourage foreign firm to conduct FDI due to the positive emission abatement effect dominating the other two negative effects. When the abatement technology is efficient and trade cost is high, raising the tax

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rate to drive FDI foreign firm out of the host country may result in a rise of total emission in the host country. Furthermore, if a higher emission tax rate changes the foreign firm's entry mode, it may raise the consumer surplus in the host country.

Previous literature studying on the stringency of an emission tax policy on the entry mode of the foreign firm always overlooked the interaction of abatement technological efficiency and trade cost on the incentive for the foreign to conduct FDI. This paper shows that both abatement technological efficiency and trade cost play key roles in determining the relative strength between the positive and the negative incentive caused by a stricter emission tax policy for a foreign firm to FDI. We do not discuss the optimal emission tax rate of the host country for two reasons. One is that, the main purposes of emission tax policy is to control the environmental quality, and recently, the vogue of environmental protection calls for a stricter environmental policy; the other one is that, solving the optimal tax rate for the host country is more complex but gets no more inside. Furthermore, we assume no policy in the foreign country for simplifying the analysis, if we treat τ as trade cost plus emission tax rate of the foreign country, then the foreign firm will abate emissions under the two modes, however, as long as the emission tax rate of the foreign country is kept constant, under plausible parameters, the results of this paper still hold.

Appendix

Proof of Lemma 3

As $t^F(\alpha) = \alpha A/(n+2+\alpha)$ and $t^E(\alpha) = \alpha(A+\tau)/(n+2+2\alpha)$, we have:

$$t^F(\alpha) - t^E(\alpha) = \frac{\alpha[\alpha(A-\tau) - (n+2)\tau]}{(n+2+\alpha)(n+2+2\alpha)},$$

$$t^F(\alpha) - \tau = \frac{\alpha A}{n+2+\alpha} - \tau = \frac{[\alpha(A-\tau) - (n+2)\tau]}{(n+2+\alpha)},$$

$$t^E(\alpha) - \tau = \frac{\alpha(A+\tau)}{n+2+2\alpha} - \tau = \frac{[\alpha(A-\tau) - (n+2)\tau]}{(n+2+2\alpha)}.$$

Thus, denoting $\alpha^\tau \equiv (n+2)\tau/(A-\tau)$, we have: if $\alpha \lesseqgtr \alpha^\tau$, then $t^F \lesseqgtr t^E \lesseqgtr \tau$, thereby, $\vec{t}(\alpha) = t^F(t^E)$.

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Proof of Lemma 4

Reorganizing (12), we have:

$$\frac{\partial \Delta \Pi}{\partial t} = \frac{\left[(n+2)^2 - 2\alpha\left(n^2-1\right)\right]t - 2\alpha(n+1)(A-n\tau)}{\alpha(n+2)^2}. \quad \text{(A1)}$$

(A1) tells that $\partial \Delta \Pi / \partial t|_{t=0} = -2\alpha(n+1)(A-n\tau)/[\alpha(n+2)^2] < 0$, to find out the shape for $\Delta \Pi$, we should observe the sign of $\lim_{t \to \bar{t}(\alpha)^-} \partial \Delta \Pi / \partial t$. By Lemma 3(i), if $\alpha < (>)\alpha^\tau$, then $\bar{t}(\alpha) = t^F(\alpha)(t^E(\alpha))$, thus, we discuss $\alpha < \alpha^\tau$ and $\alpha > \alpha^\tau$ respectively.

(a) $\alpha < \alpha^\tau$

Substituting $t = \bar{t}(\alpha) = t^F(\alpha) = \alpha A/(n+2+\alpha)$ into (A1), we have:

$$\lim_{t \to t^F(\alpha)^-} \frac{\partial \Delta \Pi}{\partial t} = \frac{n\{(n+2)[2(n+1)\tau - A] - 2\alpha(n+1)(A-\tau)\}}{\alpha(n+2+\alpha)(n+2)^2}. \quad \text{(A2)}$$

Because $A - \tau > 0$, from (A2), we know that:

(1) If $2(n+1)\tau - A < 0$, (i.e. $\tau < A/2(n+1)$), then $\lim_{t \to t^F(\alpha)^-} \partial \Delta \Pi / \partial t < 0$ and $\Delta \Pi$ is decreasing on t.

(2) If $2(n+1)\tau - A > 0$, (i.e. $A/2(n+1) < \tau < A/(n+1)$), as α is small (great), then $\lim_{t \to t^F(\alpha)^-} \partial \Delta \Pi / \partial t > (<)0$. Setting (A2) equal to zero, we get $\alpha^H = (n+2)[(2(n+1)\tau - A]/[2(n+1)(A-\tau)]$. Moreover, $\alpha^\tau - \alpha^H = (n+2)A/[2(n+1)(A-\tau)] > 0$, thus, we conclude, if $A/2(n+1) < \tau < A/(n+1)$,

   (i) as $0 < \alpha < \alpha^H$, then $\Delta \Pi$ is "U" shape on $[0, \bar{t}(\alpha)]$. Letting (A1) equal to be zero, we can solve $t^M(\alpha) = 2\alpha(n+1)(A - n\tau)/[(n+2)^2 - 2\alpha(n^2-1)]$ with the minimum $\Delta \Pi_M$.
   (ii) as $\alpha^H < \alpha < \alpha^\tau$, then $\Delta \Pi$ is decreasing on $t \in [0, \bar{t}(\alpha)]$.

(b) $\alpha > \alpha^\tau$

According to Lemma 3(i), if $\alpha > \alpha^\tau$, then $\bar{t}(\alpha) = t^E(\alpha) = \alpha(A+\tau)/(n+2+2\alpha)$, thus, substituting $t = \alpha(A+\tau)/(n+2+2\alpha)$ into (A2), we have:

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$$\lim_{t\to t^E(\alpha)^-}\frac{\partial\Delta\Pi}{\partial t} = -\frac{(n+2)\left[nA-\left(2n^2+3n+2\right)\tau\right]+2\alpha(n+1)^2(A-\tau)}{(n+2)^2(n+2+2\alpha)}. \tag{A3}$$

Because $\alpha > \alpha^\tau$, rearranging (A3), we get:

$$\begin{aligned}\lim_{t\to t^E(\alpha)^-}\frac{\partial\Delta\Pi}{\partial t} &\le -\frac{(n+2)\left[nA-\left(2n^2+3n+2\right)\tau\right]+2\alpha^\tau(n+1)^2(A-\tau)}{(n+2)^2(n+2+2\alpha)}\\ &= -\frac{(n+2)(nA+\tau)}{(n+2)^2(n+2+2\alpha)} < 0,\end{aligned}$$

therefore, we have $\Delta\Pi$ is decreasing on $t \in [0, \bar{t}(\alpha)]$, $\forall\alpha > \alpha^\tau$.

Summarizing (a) and (b) gets Lemma 4.

Proof of Lemma 5

From (10), the difference between $\Delta\Pi(t;\alpha,\tau,0)$ and $\Delta\Pi_O(=\Delta\Pi(0;\alpha,\tau,0))$ is:

$$\begin{aligned}&\Delta\Pi(t;\alpha,\tau,0)-\Delta\Pi(0;\alpha,\tau,0)\\ &\quad= -\frac{t\left\{4\alpha(n+1)(A-n\tau)-t\left[(n+2)^2-2\alpha(n^2-1)\right]\right\}}{2\alpha(n+2)^2}.\end{aligned} \tag{A4}$$

If $\alpha \in (0, \alpha^H)$, then $\alpha < \alpha^\tau$ and $\bar{t}(\alpha) = t^F(\alpha) = \alpha A/(n+2+\alpha)$, substituting $t = \alpha A/(n+2+\alpha)$ into (A4), we have:

$$\Delta\Pi_C - \Delta\Pi_O = -\frac{t^F\{(n+2)[(3n+2)A-4n(n+1)\tau]+2\alpha(n+1)[(n+1)A-2n\tau)]\}}{2(n+2)^2(n+2+\alpha)}. \tag{A5}$$

Because $(n+1)A - 2n\tau > 0$, from (A5), we have:

(1) if $(3n+2)A - 4n(n+1)\tau > 0$ (i.e. $\tau < (3n+2)A/[4n(n+1)]$), then $\Delta\Pi_C < \Delta\Pi_O$.

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(2) if $(3n+2)A - 4n(n+1)\tau < 0$ (i.e. $\tau > (3n+2)A/[4n(n+1)]$), then a small (large) α causes $\Delta\Pi_C > (<)\Delta\Pi_O$. Besides,

(i) when $n \leq 2$, $\tau < A/(n+1) < (3n+2)A/[4n(n+1)]$, thus $\Delta\Pi_C < \Delta\Pi_O$ from (1).

(ii) when $n \geq 3$, $(3n+2)A/[4n(n+1)] < A/(n+1)$, therefore, if $(3n+2)A/[4n(n+1)] < t < A/(n+1)$, by setting (A5) to be zero, we can solve $\alpha^L = (n+2)[4n(n+1)\tau - (3n+2)A]/\{2(n+1)[(n+1)A - 2n\tau]\}$ such that if $\alpha < (>)\alpha^L$, $\Delta\Pi_C > (<)\Delta\Pi_O$. Besides, $\alpha^L - \alpha^H = -(2n+1)(A - n\tau)/\{2(n+1)[(n+1)A - 2n\tau](A-\tau)\} < 0$.

As for (iii), substituting $t = t^E(\alpha^\tau) = \tau$ and $t = \lim_{\alpha\to\infty} t^E(\alpha) = (A+\tau)/2$ into (10), respectively, we have: $\Delta\Pi(t^E(\alpha^\tau); \alpha^\tau, \tau, 0) = \tau^2/2\alpha > 0$ and $\lim_{\alpha\to\infty} \Delta\Pi(t^E(\alpha); \alpha, \tau, 0) = -(n+1)(n+3)(A-\tau)^2/[4(n+2)^2] < 0$; moreover, $d\Delta\Pi(t^E(\alpha); \alpha, \tau, 0)/d\alpha = (\partial\Delta\Pi/\partial t^E)(\partial t^E/\partial\alpha) < 0$, thus, by Intermediate Value Theorem, there exist a $\alpha^U \in (\alpha^\tau, \infty)$ making $\Delta\Pi(t^E(\alpha^U); \alpha^U, \tau, 0) = 0$ and if $\alpha \in (\alpha^\tau, \alpha^U)$, then $\Delta\Pi_C = \Delta\Pi(t^E(\alpha); \alpha, \tau) > 0$; if $\alpha \in (\alpha^U, \infty)$, then $\Delta\Pi_C = \Delta\Pi(t^E(\alpha); \alpha, \tau) < 0$.

Proof of Table 1

To save the space, we only prove the case that $0 < \alpha < \alpha^L$. As $\alpha^L < \alpha^H$, thus, $\alpha < \alpha^L$ and $(3n+2)A/[4n(n+1)] < \tau < A/(n+1)$ assure $\Delta\Pi$ having a minimum $\Delta\Pi_M$ and $\Delta\Pi_C > \Delta\Pi_O$ by Lemma 4(ii) and Lemma 5(ii). Moreover, $\alpha < \alpha^L < \alpha^\tau$ implies $t^M(\alpha) < \bar{t}(\alpha) = t^F(\alpha) < \tau$ which guarantees $\Delta\Pi_M > 0$ from (10). Thus, we have $\Delta\Pi_C > \Delta\Pi_O > \Delta\Pi_M > 0$ and:

(i) if $G < \Delta\Pi_M$: It implies the minimum of $\Delta\Pi - \Delta\Pi_M - G > 0$. Thus, $\Delta\Pi > 0$ for all t.

(ii) if $\Delta\Pi_M < G < \Delta\Pi_O$: It implies $\Delta\Pi_M - G < 0$, and $\Delta\Pi_C - G > \Delta\Pi_O - G > 0$. Because $\Delta\Pi$ is "U" shape on $t \in [0, \bar{t}(\alpha)]$, by Intermediate Value Theorem, there exists $t_1^c \in (0, t^M(\alpha))$ and $t_2^c \in (t^M(\alpha), \bar{t}(\alpha))$ such that $\Delta\Pi(t_1^c; \alpha, \tau, G) = \Delta\Pi(t_2^c; \alpha, \tau, G) = 0$, $\Delta\Pi > 0$ for $0 < t < t_1^c$, $\Delta\Pi < 0$ for $t_1^c < t < t_2^c$, and $\Delta\Pi > 0$ for $t_2^c < t < \bar{t}(\alpha)$.

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(iii) If $\Delta\Pi_O < G < \Delta\Pi_C$: Because $\Delta\Pi$ is decreasing on $t \in [0, t^M(\alpha)]$, $\Delta\Pi_O - G < 0$ assures $\Delta\Pi < 0$ for all $t \in [0, t^M(\alpha)]$. $\Delta\Pi(t^M(\alpha); \alpha, \tau, G) = \Delta\Pi_M - G < 0$ and $\Delta\Pi(\bar{t}(\alpha); \alpha, \tau, G) = \Delta\Pi_C - G > 0$ reveals that there exists a unique $t^c \in [t^M(\alpha), \bar{t}(\alpha)]$ such that $\Delta\Pi(t^c; \alpha, \tau, G) = 0$ and $\Delta\Pi > (<)0$ for $t < (>)t^c$.

(iv) if $G > \Delta\Pi_C$: The maximum of $\Delta\Pi - \Delta\Pi_C - G$ is negative, thus, $\Delta\Pi < 0$ for all t.

Proof of Lemma 6

As $\rho^F(0) - \rho^E(0) = (n+1)A/(n+2) - n(A+\tau)/(n+2) = (A - n\tau)/(n+2) > 0$, therefore, $\rho^F(0) > \rho^E(0)$. Besides, $\rho^E(t) - \rho^F(t) = \{\alpha(n\tau - A) + [(n+2) - (n-1)\alpha]t\}/[(n+2)\alpha]$, as $n\tau - A < 0$, we have:

(a) if $(n+2) - (n-1)\alpha < 0$, then $\rho^E(t) - \rho^F(t) < 0$ for all t.

(b) if$(n+2) - (n-1)\alpha > 0$, then $\rho^E(t) \gtreqless \rho^F(t)$ for $t \gtreqless t^\rho(\alpha) \equiv \alpha(A - n\tau)/[(n+2) - (n-1)\alpha]$. Denoting $\bar{\alpha} \equiv (n+2)/(n-1)$ making $(n+2)-(n-1)\bar{\alpha} = 0$, then if $\alpha \gtreqless \bar{\alpha}$, $(n+2)-(n-1)\alpha \lesseqgtr 0$. Moreover, because of $\bar{\alpha} - \alpha^\tau = (n+2)(A - n\tau)/(A - \tau) > 0$, we have the following results:

(1) if $\alpha > \bar{\alpha}$, then $(n+2) - (n-1)\alpha < 0$, thus $\rho^E(t) < \rho^F(t)$ for all t from (a).

(2) if $\alpha^\tau < \alpha < \bar{\alpha}$, then $(n+2) - (n-1)\alpha > 0$ and $\bar{t}(\alpha) = t^E(\alpha) = \alpha(A+\tau)/(n+2+2\alpha)$. Because $t^E(\alpha) - t^\rho(\alpha) = -\alpha(n+1)[\alpha(A-\tau) - (n+2)\tau]/(n+2+2\alpha)[(n+2) - (n-1)\alpha] < 0$, therefore, $t < t^E(\alpha)$ implies $t < t^\rho(\alpha)$, it assures $\rho^E(t) < \rho^F(t)$ for all t from (b).

(3) if $\alpha < \alpha^\tau$, then $(n+2) - (n-1)\alpha > 0$ and $\bar{t}(\alpha) = t^F(\alpha) = \alpha A/(n+2+\alpha)$. Because $t^F(\alpha) - t^\rho(\alpha) = -\alpha n[\alpha(A-\tau) - (n+2)\tau]/\{(n+2+2\alpha)[(n+2) - (n-1)\alpha]\} > 0$, thus, we have $\rho^E(t) < \rho^F(t)$ for $0 < t < t^\rho(\alpha)$ and $\rho^E(t) > \rho^F(t)$ for $t^\rho(\alpha) < t < \bar{t}(\alpha)$ from (b).

Furthermore, if $\alpha < \alpha^H$, $t^M(\alpha)$ is less than $t^\rho(\alpha)$ because of $t^\rho(\alpha) - t^M(\alpha) = \alpha(A - n\tau)\{1/[n+2-(n-1)\alpha] - 1/[(n+2)^2/2(n+1) - (n-1)\alpha]\} < 0$ and $n + 2 > (n+2)^2/2(n+1)$.

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嚴格的環保政策是否為外人直接投資的障礙?

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本文建立一個兩國模型, 在模型中, 有一外國廠商欲選擇 FDI 或出口模式進入地主國市場, 並與地主國之 *n* 廠商從事 Cournot 競爭。面對地主國實施之污染稅政策, 設廠在地主國之所有廠商皆使用相同污染防治技術。本文發現, 當貿易成本較高, 而且污染的防治技術較有效率時, 提高污染稅率可能使外國廠商到地主國 FDI, 此外, 在某些參數條件下, 提高污染稅讓外國廠商移出地主國反而會造成地主國的環境品質下降, 而且也可能提高地主國之消費者剩餘。因此, 污染稅率之調整與污染防治技術效率及貿易成本的交互作用對外國廠商選擇進入模式及其相關的福利效果具有關鍵性的影響。

關鍵詞: 污染稅, 進入模式, 污染防治, 對外直接投資
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