Environmental Regulation and FDI in the Developing Countries

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Abstract

The pollution haven hypothesis (PHH) states that pollution intensive industries tend to move to the countries with laxer environmental regulation. While a number of theoretical studies support the PHH, the empirical studies found ambiguous or mixed evidence for the PHH. In this paper, we investigate this hypothesis theoretically. We extend the traditional intra-industry trade model by introducing environmental regulation.

The main results are as follows. First, the most important factors when multinational firms consider FDI are market size of the country on which the goods are consumed, and plant specific fixed cost. Second, the more the technology transfer, the larger the market scale and the larger the market share of national firm in the FDI host country. Also, the market scale becomes the largest when both MNFs locate their plant in the developing country.

key words: pollution haven, technology transfer, plant location
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1. Introduction

The pollution haven hypothesis (PHH) states that pollution intensive industries tend to move to the countries with laxer environmental regulation. While a number of theoretical studies support the PHH, the empirical studies found ambiguous or mixed evidence for the PHH.

In the empirical literature, Kirkpatrik and Shimamoto (2008) conclude that their investment does not support the PHH. They insist that it is more important the regulatory framework with certainty and transparency than the level of environmental regulatory measures. Zhang and Fu (2008) examine the PHH with using the provincial data from China, and suggest that FDI refers to locate into the region with laxer environmental regulations. Through the theoretical and empirical analysis, Cole et al. (2006) focus on two main effects on local environmental policymaking, bribery effect and welfare effect, and insist that FDI raises (reduces) local policy stringency when the degree of government corruptibility is relatively low (high). Cole and Elliot (2005) point out that the reason why most theoretical studies support the PHH is that they set in worlds in which the comparative advantage is determined purely by the differences in the stringency of environmental regulations. They pay attention to the fact that most pollution intensive sectors are highly capital intensive, and find that the FDI is influenced by the level of capital endowment relative to the stringency of environmental regulation if comparative advantage is determined by both differences in factor endowment and environmental regulation.

The theoretical analysis has been focused on the plant location of multinational firms (MNFs) in the context of comparative advantage on the production. (Markusen et al. (1995), Ulph and Valentini (1997), Markusen and Venables (1998)). Kayalica and S. Lahiri (2005) find that the FDI host country may apply laxer emission standard under both non-cooperative and cooperative equilibrium when the number of FDI firms are endogenous. While the traditional theoretical literature has been introduced the oligopoly market in the model, some recent literature introduce the monopolistic competition model to emphasize agglomeration effect, especially home market effect. For instance, Zeng and Zhao (2009) try to explain the problem with the industrial agglomeration and the externality of manufacturing pollution on agricultural sector. They introduce two effects that have opposite directions; the demand-reducing effect of pollution that discourages firms to move to the country with laxer environmental regulation, and the cost-reducing effect in manufacturing production that leads to the pollution haven.

We should consider first why the pollution haven phenomenon occurs. To answer this, we should examine the reason why the developing countries try to attract the MNFs into their region. We can consider the merits of attracting MNFs as employment, technology transfer, market expansion, and so on, and the demerits as environmental damage. Thus, we should approach the PHH problem from the standpoint of developing countries.

We pay attention to three factors in this paper: the trade cost (including trade barrier), the degree of environmental regulation and the transfer of abatement technology through FDI in the developing country. At first, we investigate the market structure. The MNFs can build their plant any place where the FDI is allowed. At this time, they consider their profit and the rivals' behavior. The plant location problem has been treated in the intra-industry trade model. We assume that there are two MNFs, and they compete for the production level and plant location. As a result of the location competition, the market structure is determined. Next, we consider the environmental regulation in the developing country as the regulation level of developed country is given.

This paper organized as follows. Section 2 describes the basic model of this paper. In section 3, we analyze the quantity competition in the oligopoly market on which the market consists of two MNFs and one national firm in the developing country. In section 4, we analyze the market structure which is determined by the result of plant location of MNFs. In section 5, we investigate the market scale and market share of each firm under each market structure. In section 6, we examine the environmental regulation of the developing country. Section 7 provides some concluding remarks.

2. Model

We consider the oligopoly model with two countries (north and south) indexed by 1 and 2. There are 2 multinational firms (firm 1 and 2) in country 1 and 1 national firm (firm 3) in country 2. Each of the firms supplies homogeneous goods to the country 2[1]. It takes the firm specific fixed cost, F, to all firms for production behavior. For simplicity, we assume $F=0$. Moreover, firm 1 and 2 can determine their plant location, country 1 or 2. If they decide on the plant location at country 2, a plant

[1] In the traditional intra-industry trade model, the goods are consumed by both countries; however, we ignore the market of the developed country because we focus on the relationship between the environmental regulation of country 2 and plant location of MNFs.

specific fixed cost (fixed cost, hereafter), G is needed. When firm i (i=1,2) locates its plant at country 1 and export the goods to country 2, there is a constant per unit transport cost, s, where the cost can be considered as transport or barriers to trade.

The firms also incur the environmental damage for their production behaviors. The governments of both countries regulate the emission level, $z_j \ (j=1,\ 2)$ respectively. Let e_i as the emission level of firm i, firm i should abate $(e_i - z_j)$. The abatement cost can be defined as the cost in unit of labor. Let the wage rate, w, the abatement cost is given as

$$w_j(e_i - z_j),\ i=1,\ 2,\ 3,\ j=1,\ 2.$$

The case (i, j) = (3, 1) can not be achieved since the national firm of developing country (firm 3) can not locate its plant at foreign countries. We assume the wage rates of both countries are the same $(w_1 = w_2 = w)$ in order to concentrate on the environmental regulation, even though the relatively low labor cost of the developing country is an attractive factor for the MNFs of developed countries.

We consider a two stage game. In the first stage, two MNFs determine their plant location which means that they decide whether to execute FDI. The market structure is determined at this stage. We can consider four cases: (1, 1), (1, 2), (2, 1), (2, 2). For example, (1, 2) means that firm 1 chooses country 1 and firm 2 chooses country 2 as their plant location. As we show in the appendix 1, since the case that {(0, 0), (0, 1), (0, 2), (1, 0), (2, 0)} can not be the Nash equilibrium, we ignore these cases. All the firms decide on their production level through the Cournot game under the given market structure in the stage 2.

Assuming the marginal production cost is zero, the marginal cost of each firm when the FDI is not occurred (the case (1, 1)), is given as

$$\begin{aligned} c_1 &= c_2 = w(s + e_1 - z_1), \\ c_3 &= w(e_2 - z_2) \end{aligned} \tag{1}$$

When one of the MNFs decides on the FDI and locates its plant to country 2, the abatement technology is transferred to the national firm of country 2 (firm 3). When firm k (k =1, 2) undertakes FDI, the marginal cost of each firms is given by

$$d_k = w(e_1 - z_2),\ k = 1, 2$$
$$d_3 = w(\alpha e_2 - z_2),\ \ e_1/e_2 \le \alpha \le 1 \tag{2}$$

α is the parameter of the degree of abatement technology transfer. It means that there is no technology transfer if α =1, and full transfer if $\alpha = e_1/e_2$. Firm *k* will receive the environmental regulation of country 2 because its plant is located in that country. If the regulation is laxer than country 1, the marginal cost becomes lower through FDI.

A lot of factors are taken into account when MNFs undertake FDI: transport cost, fixed cost, environmental regulation, rival firm's behavior, etc. Relatively high transport cost or low fixed cost gives the motivation for undertaking FDI. In the context of environmental regulation, the pollution haven hypothesis suggests that environmental regulation may cause polluting industries to be relocated in countries with relatively lower pollution standard.

3. Output level: stage 2

The game in this model is solved by backward induction in the usual fashion. We first solve for profit maximization problem under each location patterns. Assume that firm 1 and 2 are symmetric, the case of (1, 2) and (2, 1) bring the same result. For simplicity, we introduce the linear inverse demand functions as

$$p_{ij} = a - b(x_{1ij} + x_{2ij} + x_{3ij}), \tag{3}$$

where, $(i, j) = (1,0),\ (1,1),\ (1,2),\ (0,2),\ (2,2)$, and the first subscript refers firm *k*, (*k* = 1, 2, 3) . Of course, x_{210} and x_{102} becomes zero since they exit from the market. Then, we can define the profit function of each firm as

$$\pi_{k11} = (p_{11} - c_1)x_{k11},\quad k = 1, 2$$
$$\pi_{311} = (p_{11} - c_3)x_{311} \tag{4}$$

If firm 1 or 2 let the plant location to the country 2, its production cost is changed and the cost of firm 3 also is changed because of technology transfer. The cost function of each firm when FDI is achieved is indicated at Eq. (2). From the F.O.C. of profit maximization, we can get the following five patterns of Cournot-Nash Equilibriums.

$$
\begin{aligned}
x_{110} &= \frac{a-2c_1+c_3}{3b} \\
x_{210} &= 0 \\
x_{310} &= \frac{a+c_1-2c_3}{3b}
\end{aligned} \tag{5}
$$

$$
\begin{aligned}
x_{111} = x_{211} &= \frac{a-2c_1+c_3}{4b} \\
x_{311} &= \frac{a+2c_1-3c_3}{4b}
\end{aligned} \tag{6}
$$

$$
\begin{aligned}
x_{102} &= 0 \\
x_{202} &= \frac{a-2d_2+d_3}{3b} \\
x_{302} &= \frac{a+d_2-2d_3}{3b}
\end{aligned} \tag{7}
$$

$$
\begin{aligned}
x_{112} &= \frac{a-3c_1+d_2+d_3}{4b} \\
x_{212} &= \frac{a+c_1-3d_2+d_3}{4b} \\
x_{312} &= \frac{a+c_1+d_2-3d_3}{4b}
\end{aligned} \tag{8}
$$

$$
\begin{aligned}
x_{122} = x_{222} &= \frac{a-2d_2+d_3}{4b} \\
x_{322} &= \frac{a+2d_2-3d_3}{4b}
\end{aligned} \tag{9}
$$

Note that the marginal costs of the firms are different according to the market structure.

4. Market structure: stage 1

In the stage 1, both firms 1 and 2 compete for the plant location problem. We obtain all the possible equilibriums in the previous section. The game in this stage can be summarized in table 1.

Table 1 General form of the location game

		firm 2		
		0	1	2
firm1	0	0, 0	0, $\pi_{201}(=\pi_{110})$	0, $\pi_{202}(=\pi_{120})$
	1	$\pi_{201}(=\pi_{110})$, 0	π_{111}, π_{211}	π_{112}, π_{212}
	2	$\pi_{202}(=\pi_{120})$, 0	$\pi_{121}(=\pi_{212})$, $\pi_{221}(=\pi_{112})$	π_{122}, π_{222}

note) *Strategy 0: does not build the plant anywhere*

Strategy 1: The plant location is in country 1

Strategy 2: The plant location is in country 2

Table 1 indicates that there are multiple Nash equilibriums in this game on which depend the variables like $\{s, G, e_i, z_i, \alpha;\ i = 1,2\}$. Assuming $\pi \geq 0$, strategy 0 is dominated by the other strategies for both firms. So we just consider a 2×2 game.

The trade off between transport cost (*s*) and fixed cost (*G*) has been traditionally pointed out in the literature for international economics. However, the most important factors in this model are market size (*a*) and fixed cost (*G*) and abatement technology transfer (α). If no technology transfer has occurred (α=1), the pay offs in table 1 becomes as follows.

$$\pi_{110} - \pi_{202} = \frac{4}{9b}\left[(a - 2e_1 + e_2 + z_1 - s)(z_1 - z_2 - s)\right] + G \tag{10}$$

$$\pi_{211} - \pi_{212} = \frac{3}{8b}\left[(a - 2e_1 + e_2 + 2z_1 - z_2 - 2s)(z_1 - z_2 - s)\right] + G \tag{11}$$

$$\pi_{112} - \pi_{122} = \pi_{112} - \pi_{222} = \frac{3}{16b}\left[(a - 2e_1 + e_2 + z_2)(z_1 - z_2 - s)\right] + G \tag{12}$$

If *G* is extremely high, Eqs. (10) - (11) becomes positive. It means that strategy 1 becomes dominate strategy, thus the Nash equilibrium is (1, 1). The intuition is straightforward. The higher the fixed cost, the lower motivation of FDI for the MNFs as long as the reduction of abatement cost or transport cost is not sufficiently large. On the other hand, $z_1 - z_2 - s < 0$ because that the environmental regulation in the developing country (z_2) is not as stringent as that of a developed country (z_1). So it is not strange to assume $z_1 \leq z_2$. Therefore, if the market size (*a*) is sufficiently large, Eqs. (10) - (12) becomes negative. And strategy 2 is the dominant strategy in this case.

If technology transfer has occurred $(\alpha < 1)$, the results are more complicated. To obtain some insight into the patterns of market structure, we use some examples.

Table 2 Examples[2]

		Nash Equilibrium
Case 1	G = 5, α = 0.8	(1, 1)
Case 2	G = 3, α = 0.8	(1, 2), (2, 1)
Case 3	G = 1, α = 0.8	(2, 2)
Case 4	G = 1, α = 1	(2, 2)
Case 5	G = 3, α = 0.8, $z_2 = z_1$ = 0.2	(1, 2), (2, 1)
Case 6	G = 3, α = e_1 / e_2	(1, 2), (2, 1)

If a MNF chooses its plant location at country 2 (undertake FDI), it can save the transport cost and the abatement cost when the level of environmental regulation in country 2 is laxer than country 1. On the other hand, it is not certain whether the total cost will rise or not because of the fixed cost. Moreover, since the abatement technology is transferred to the firm 3, it leads to the productivity improvement of firm 3. This kind of improvement will change the market shares of the firms in the market. The MNFs should take into account the trade off relationship between these factors when they choose FDI.

When the fixed cost is high (case 1), firm i (i=1, 2) chooses FDI if firm j (j=2, 1) exits from the market, but there is no reason why they choose exit. Thus, both firms will not choose FDI because the profit of the firm on which undertakes FDI becomes lower than that when it chooses location 1. When the fixed cost is low (case 3), both firms will choose FDI, since strategy 2 has become the dominant strategy for both firms. It means that MNFs can raise their profit through the FDI regardless of the rivals' choice when the fixed cost is sufficiently low. As a result, all the MNFs choose the FDI.

When the fixed cost is in the middle level (case 2), only one firm chooses FDI. If one of the MNFs chooses FDI from the state the market structure is (1, 1), it can then obtain more profit because it can expand the market share. If the rival firm, however, chooses FDI too, the expanded market share is not sufficient to cover the fixed cost. Thus, their profits have decreased comparing with (1, 1). As a result, (1,

2 For details, see the Appendix 1.

2) or (2, 1) becomes Nash Equilibrium.

We summarize the results of this section in proposition.

Proposition 1

1. When the plant specific fixed cost is sufficiently high, strategy 1 is the dominant strategy for both MNFs.

2. When the market size is sufficiently large, strategy 2 is the dominant strategy for both MNFs regardless of the transport and abatement cost.

5. Market scale and market share

Here, we should pay attention to the change of market share of firm 3 since technology transfer is an important factor for the FDI host countries. Refer ε_{11} to the market share of firm 3 when the market structure is (1, 1), we can obtain the followings from Eqs. (1), (2) and Eqs. (5) – (9),

$$\frac{\varepsilon_{12}}{\varepsilon_{22}} = \frac{B\{A-(z_1-z_2-s)\}}{A\{B+4(z_1-z_2-s)\}} > 1 \qquad (13)$$

$$\frac{\varepsilon_{11}}{\varepsilon_{22}} = \frac{B\{A-3(1-\alpha)e_2-2(z_1-z_2-s)\}}{A\{B-(1-\alpha)e_2+2(z_1-z_2-s)\}} \qquad (14)$$

$$A = a+2e_1+z_2-3\alpha e_2,$$

$$B = 3a-2e_1-\alpha e_2+3z_2$$

Since the environmental regulation in the developing countries is generally not as severe as that of developed countries, it is natural to assume $z_1-z_2-s<0$. Eq. (13) shows this. As for the firm 3, the market structure (1, 2) or (2, 1) is preferable to (2, 2). Comparing ε_{11} and ε_{22} is a little more complicated. If technology transfer has not occurred (α =1), we can obtain $\varepsilon_{11}/\varepsilon_{22}>1$ easily. Without technology transfer, the FDI is not preferable as for firm 3 because its market share is decreased.

The market scale in equilibrium can be defined as

$$X_{ij} = \sum_{k=1}^{3} x_{kij}, \quad i=1,2, \quad j=1,2.$$

Following the definition, we can compare the market scales in each market structure.

$$X_{11} - X_{12} = \frac{-(1-\alpha)e_2 - 2(z_1 - z_2 - s)}{4b} \quad (15)$$

$$X_{11} - X_{22} = \frac{-(1-\alpha)e_2 + 2(z_1 - z_2 - s)}{4b} < 0 \quad (16)$$

$$X_{12} - X_{22} = \frac{z_1 - z_2 - s}{b} < 0 \quad (17)$$

From Eqs. (15)-(17), we can find that the market scale on (2, 2) is the largest. The sign of Eq. (15) is ambiguous because of the technology transfer. If $\alpha = 1$, Eq. (15) becomes positive. That means market scale on (1, 1) is larger than that of (1, 2).

We summarize the relationship between technology transfer and market share of firm 3 in table 3.

Table 3 The market share and technology transfer[3]

	$\alpha = 1$	$\alpha = 0.8$	$\alpha = e_1/e_2$
ε_{11}	0.3803	0.3803	0.3803
ε_{22}	0.3243	0.3315	0.3333
ε_{12}	0.375	0.3827	0.3846
X_{11}	7.1	7.1	7.1
X_{12}	6.8	6.82	6.825
X_{22}	7.4	7.42	7.425

The numerical analysis of table 3 supports the results of Eqs. (15) – (17). When the technology is fully transferred $(\alpha = e_1/e_2)$, the technology level of developing countries becomes the same as the developed countries. The market scale and market share of firm 3 under each market structure becomes the largest in this case.

We summarize the results of this section in proposition.

Proposition 2

1. The market scale becomes the largest when the market structure is (2, 2).

2. If the level of the abatement technology transfer is high, the market scale is expanded regardless of the market structure.

3. When the abatement technology transfer has not occurred, the market share of

[3] The parameter values of table 3 are followed by appendix 1.

firm 3 under (1, 1) becomes larger than that under (1, 2) and (2, 2). However, the technology is fully transferred, the market share of firm 3 under (2, 2) becomes the largest.

6. Environmental regulation in the developing countries

In this chapter, we investigate the effects of environmental regulation in the country 2 on the market structure. While the laxer regulation is attractive for the MNFs because they can reduce the abatement cost, the national firms of the country 2 also reduce their abatement cost by the technology transfer when the FDI is executed. The government of country 2 should take into account the merits and demerits of the FDI when it determines the environmental regulation.

Appendix 2 suggests the conditions for market structure is changed. If $z_2 > Q_1/6$, the market structure is changed from (1, 1) to (1, 2) or (2, 1). Moreover, if $z_2 > Q_1/6$ *and* $z_2 > Q_2/6$, the market structure is changed to (2, 2)[4]. Table 4 shows the thresholds of z_2 for the market structure has changed. If the fixed cost is low (G=1) and the MNFs determine their plant location at country 2, the government of country 2 can impose more stringent environmental regulation than country 1. As we obtain −0.45 as a numerical analysis, it becomes zero since $0 \leq z_i \leq 1\ (i = 1, 2)$. For MNFs, low fixed cost is more attractive than the increase of abatement cost at this time[5]. When the fixed cost is high (G=5), the government should mitigate the regulation level if it want to attract FDI.

Table 4: The market structure and environmental regulation

z_2(*when* $z_1 = 0.2$)	G = 1	G = 3	G =5
$\pi_{211} = \pi_{212}$	0	0.15	0.82
$\pi_{112} = \pi_{122}$	0	0.78	1

Except G, several factors affect the threshold value of z_2. If the degree of the abatement technology transfer is not high (high α) or the transport cost is high (high s), z_2 becomes low. It means that more stringent regulation is possible for the

4 See the appendix 2 about Q_1 and Q_2.

5 z=0 means that the government does not permit emission at all. If the government permit full emission, it becomes that z=1.

government of country 2 since the incentive for FDI strengthens. On the other hand, if the abatement technology of MNFs is not high (e_1) or the regulation of country 1 is not severe (z_1), the regulation level of country 2 should be mitigated when it wants to attract FDI. This means that z_2 becomes high. Table 5 shows the results of the comparative statistics.

Table 5: Comparative statistics

$\partial z_2/\partial v$	α	e_1	e_2	z_1	s
$\pi_{211}=\pi_{212}$	—	+	+	+	—
$\pi_{112}=\pi_{122}$	—	+	—	+	—

Next, we consider the social welfare problem. The social welfare of the country 2 can be the standard on which the government decides the regulation level. Since the profits of MNFs are repatriated to the country 1, the social welfare of country 2 is consumer's surplus plus the profit of national firm (firm 3), minus environmental damage.

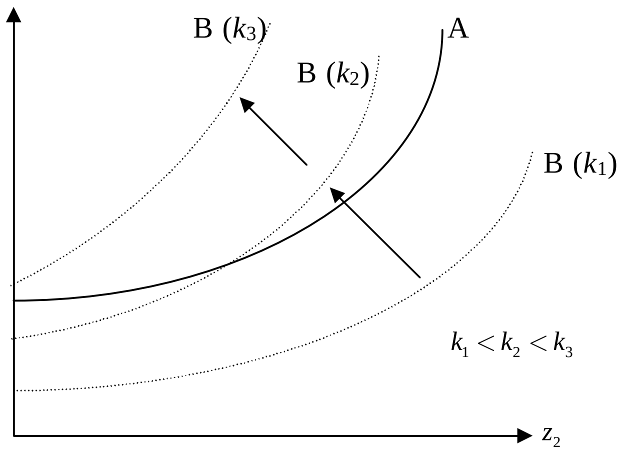
In general, even in the countries which try to attract FDI, they disapprove the pollution that accompanies production. We assume the environmental damage function to be linear (Kayalica and Lahiri (2005), for instance). Therefore, the welfare function is given as

$$W_{ij}=\frac{1}{2}b\left(\sum_{l=1}^{3}x_{lij}\right)^2+\pi_{3ij}-kD_{ij}z_2,\quad i=1,2,\quad j=1,2 \tag{18}$$

where $D_{11}=x_{311},\ D_{12}=x_{212}+x_{312},\ D_{22}=x_{122}+x_{222}+x_{322}$. k refers to the parameter of damage. Let the first two terms of Eq. (18) be as A_{ij} and the third term as B_{ij}. The social welfare is the difference A and B. The shape of A and B with respect to z_2 is upward slope like Fig. 1[6]. Since the environmental damage does not affect the firms' production and location behavior, the magnitude of k changes the social welfare level only. If k is small ($k=k_1$ in Fig. 1), A is larger than B. And the slope of A is steeper than that of B. So the social welfare becomes upward slope, and the welfare maximization regulation level is e_2 *or* αe_2. On the other hand, if k is large ($k=k_3$ in Fig. 1), the welfare maximization regulation level becomes zero. As seen at table 4, it is possible to attract FDI in this case as long as the fixed cost is sufficiently low.

[6] For details, see the appendix 3.

Fig. 1: Social welfare and environmental regulation



In fig. 1, the slope of B becomes steeper as k grows. Therefore, the regulation level that maximizes the social welfare becomes corner solution when k is high $(z_2 = 0)$ or low $(z_2 = e_2 \ or \ \alpha e_2)$. If $k = k_2$, the inner solution is exist. However it is not certain whether the solution is larger than z_1 or not.

The main result of this section is that the important factor is not the decrease of cost by the mitigation of environmental regulation but the fixed cost of FDI host countries when the MNFs decide FDI. This result is similar to Levinson and Taylor (2008). "*Explanations for the failure to find a pollution haven effect often point to the small fraction of costs represented by pollution abatement. Although it is possible that more stringent environmental regulations have a small effect on firms' costs and international competitiveness, it seems unlikely that more stringent regulations would have no effect whatsoever.*" (Levinson and Taylor (2008)). On the other hand, Abe and Zhao (2005) examine how the international differences in abatement technology and emission tax affect FDI and derive the optimal emission tax to attract FDI or joint venture, which depends on the level of its abatement technology. However, they concentrate not the technology transfer but only in the differences of technology.

We summarize the results of this section in proposition.

Proposition 3

1. *If the environmental damage is too small, the social welfare is maximized when the government does not regulate the emission.* $(z_2 = e_2 \ or \ \alpha e_2)$.
2. *If the environmental damage is too large, the social welfare is maximized when the emission of the firms in the country is prohibited completely.* $(z_2 = 0)$. *In this*

case, it is possible for the country 2 to attract FDI if the fixed cost is low.

7. Concluding remarks

While a number of theoretical studies support the PHH, the empirical studies found ambiguous or mixed evidence for the PHH.

In this paper, we investigate this hypothesis theoretically. We extend the traditional intra industry trade model by introducing environmental regulation.

The main results are as follows. First, the most important factors when MNFs consider FDI are market size of the country on which the goods are consumed, and plant specific fixed cost. The more the technology transfer, the larger the market scale and the larger the market share of national firm in the FDI host country. Also, the market scale becomes the largest when the market structure is (2, 2).

In general, it is widely believed that the tougher environmental regulation encourages the 'industrial flight'. Especially, the developing countries will not impose stringent environmental regulation for the fear of this problem. This paper, however, suggests a different proposal. As Levinson and Taylor (2008) have pointed out, the environmental regulation is not the main factor that affects the plant location choice of MNFs. The market size or fixed cost of FDI host countries is more important than the regulation for the MNFs. According to the circumstance, the market scale is expanded and the profits of the firms become higher by FDI even though the environmental regulation in the FDI host country is stringent.

For the developing countries, it is more important to make the circumstance that the MNFs can easily invest in their countries rather than mitigate environmental regulations. If the developing countries only repeat the mitigation competition of environmental regulation without this kind of effort, the economic condition of every country might deteriorate further. Zhang and Fu (2008) support this point through their empirical evidence. They insist that the negative effect of environmental stringency on FDI can be offset by the improvement of some factors that are attractive to FDI, for example the quality of infrastructure.

In this paper, we have investigated only the market and policies of the developing countries. The intra-industry trade assumes that both countries consume the same goods. The developing countries also export their goods to the developed countries. Furthermore, the developed countries might respond to policies of the developing countries. It should be interesting to examine how the market structure and policies of both countries are changed in this case. Further research should investigate these problems.

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Appendix 1: basic examples

$a = 20,\ b = 2,\ w = 1,\ s = 1,\ e_1 = 0.6,\ e_2 = 0.8$, $z_1 = 0.2$, $z_2 = 0.4$

Case 1: *G* =5, α =0.8, *Nash Equilibrium* (*NE*) = (1, 1)

		Firm 2		
		0	**1**	**2**
Firm1	**0**	0, 0	0, 17.01	0, 17.09
	1	17.01, 0	9.57, 9.57	9.99, 8.62
	2	17.09, 0	8.62, 9.99	7.43, 7.43

Case 2: *G* =3, α =0.8, *NE* = (1, 2), (2, 1)

		Firm 2		
		0	**1**	**2**
Firm1	**0**	0, 0	0, 17.01	0, 19.09
	1	17.01, 0	9.57, 9.57	9.99, 10.62
	2	19.09, 0	10.62, 9.99	9.43, 9.43

Case 3: *G* =1, α =0.8, *NE* = (2, 2)

		Firm 2		
		0	**1**	**2**
Firm1	**0**	0, 0	0, 17.01	0, 21.09
	1	17.01, 0	9.57, 9.57	9.99, 12.62
	2	21.09, 0	12.62, 9.99	11.43, 11.43

Case 4: *G* =1, α =1, *NE* = (2, 2)

		Firm 2		
		0	**1**	**2**
Firm1	**0**	0, 0	0, 17.01	0, 21.45
	1	17.01, 0	9.57, 9.57	10.18, 12.84
	2	21.45, 0	12.84, 10.18	11.63, 11.63

Case 5: G =3, α =0.8, $z_2 = z_1 = 0.2$, NE = (1, 2), (2, 1)

	Firm 2			
Firm1		**0**	**1**	**2**
	0	0, 0	0, 17.6	0, 18.43
	1	17.6, 0	9.9, 9.9	10.21, 10.03
	2	18.43, 0	10.03, 10.21	9.05, 9.05

Case 6: G =3, α $= e_1/e_2$, NE = (1, 2), (2, 1)

	Firm 2			
Firm1		**0**	**1**	**2**
	0	0, 0	0, 17.6	0, 18.34
	1	17.6, 0	9.9, 9.9	10.17, 9.98
	2	18.34, 0	9.98, 10.17	9, 12

Case 7: G = 1, z_1 =0, z_2 =1, NE = (2, 2)

	Firm 2			
Firm1		**0**	**1**	**2**
	0	0, 0	0, 15.31	0, 22.21
	1	15.31, 0	8.61, 8.61	9.22, 13.61
	2	22.21, 0	13.61, 9.22	12.06, 12.06

Case 8: G = 3, z_1 =0, z_2 =1, NE = (2, 2)

	Firm 2			
Firm1		**0**	**1**	**2**
	0	0, 0	0, 15.31	0, 20.21
	1	15.31, 0	8.61, 8.61	9.22, 11.61
	2	20.21, 0	11.61, 9.22	10.06, 10.06

Case 9: G = 5, z_1 =0, z_2 =1, NE = (1, 2), (2, 1)

	Firm 2			
Firm1		**0**	**1**	**2**
	0	0, 0	0, 15.31	0, 18.21
	1	15.31, 0	8.61, 8.61	9.22, 9.61
	2	18.21, 0	9.61, 9.22	8.06, 8.06

Appendix 2: The conditions for change of plant location

1. z_2 **on which satisfies** $\pi_{211} = \pi_{212}$.

$$z_2 = \frac{1}{6}Q_1 = \frac{1}{6}\left(q_1 - \sqrt{q_2 + q_3 + q_4 + q_5}\right),$$

where

$$q_1 = 3a - 6e_1 + e_2 + 9z_1 + 2\alpha e_2 - 9s,$$
$$q_2 = 9a^2 + 36e_1^2 - 5e_2^2 - 96bG - 6e_1 z_1 + 9z_1^2 + 4\alpha e_2^2 + 24\alpha e_1 z_1,$$
$$q_3 = 10\alpha^2 e_2^2 - 12e_1(3z_1 - e_2 + 4\alpha e_2 - 3s),$$
$$q_4 = 6se_2 - 18sz_1 - 24\alpha se_2 + 9s^2,$$
$$q_5 = -6a(6e_1 + e_2 - 3z_1 - 4\alpha e_2 + 3s)$$

2. z_2 **on which satisfies** $\pi_{112} = \pi_{122}$.

$$z_2 = \frac{1}{6}Q_2 = \frac{1}{6}\left(q_6 + \sqrt{q_7 + q_8}\right),$$

where

$$q_6 = -3(a - 2e_1 - z_1 + \alpha e_2 + s),$$
$$q_7 = 12(16bG + 3(a - 3e_1 + \alpha e_2)(z_1 - s)),$$
$$q_8 = 9\left(a - 2e_1 - z_1 + \alpha e_2 + s\right)^2$$

Appendix 3: The social welfare maximization regulation level

$$\frac{dA_{11}}{dz_2} = \frac{1}{16}\left[9a + 10(e_1 - z_1) - 19(e_2 - z_2) + 10s\right]$$
$$\frac{dB_{11}}{dz_2} = \frac{k}{4b}\left[a + 2(e_1 - z_1) - 3(e_2 - z_2) + 3z_2 + 2s\right]$$

$$\frac{d^2 A_{11}}{dz_2^2} = \frac{19}{16b}, \quad \frac{d^2 B_{11}}{dz_2^2} = \frac{3k}{2b}$$

$$\frac{dA_{12}}{dz_2} = \frac{1}{16}\left[4a + 16(e_1 - z_1) - 20(e_2 - z_2) - z_1 + z_2 + 17s\right]$$
$$\frac{dB_{11}}{dz_2} = \frac{k}{4b}\left[2a + z_1 - 2(\alpha e_2 - z_2) - s\right]$$

$$\frac{d^2 A_{12}}{dz_2^2} = \frac{21}{16b}, \quad \frac{d^2 B_{12}}{dz_2^2} = \frac{k}{2b}$$

$$\frac{dA_{22}}{dz_2} = \frac{1}{16}\left[11a - 2e_1 - 9(\alpha e_2 - z_2) + 2z_2\right]$$

$$\frac{dB_{11}}{dz_2} = \frac{k}{4b}\left[3a - 2e_1 - \alpha e_2 + 6z_2\right]$$

$$\frac{d^2 A_{22}}{dz_2^2} = \frac{11}{16b}, \quad \frac{d^2 B_{22}}{dz_2^2} = \frac{3k}{2b}$$