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OPTIMAL ENVIRONMENTAL REGULATION ON INTERNATIONAL JOINT VENTURES IN DEVELOPING COUNTRIES

Abstract:

This paper examines how environmental regulation affects the FDI strategies of parent firms in developing countries (the South) and developed countries (the North) when there are differences in the abatement technology and R&D efficiency between these countries. If there are more lenient regulations, it is more attractive to form a JV in the South. However, southern governments opt for lenient regulation when the abatement technology of the North, while not good, is still superior to that of the South. Furthermore, the welfare of the developing country is optimal when forming a domestic JV. This paper focused on FDI strategies in terms of the welfare of the South, with a view to being able to provide better policy modeling for the developing countries.

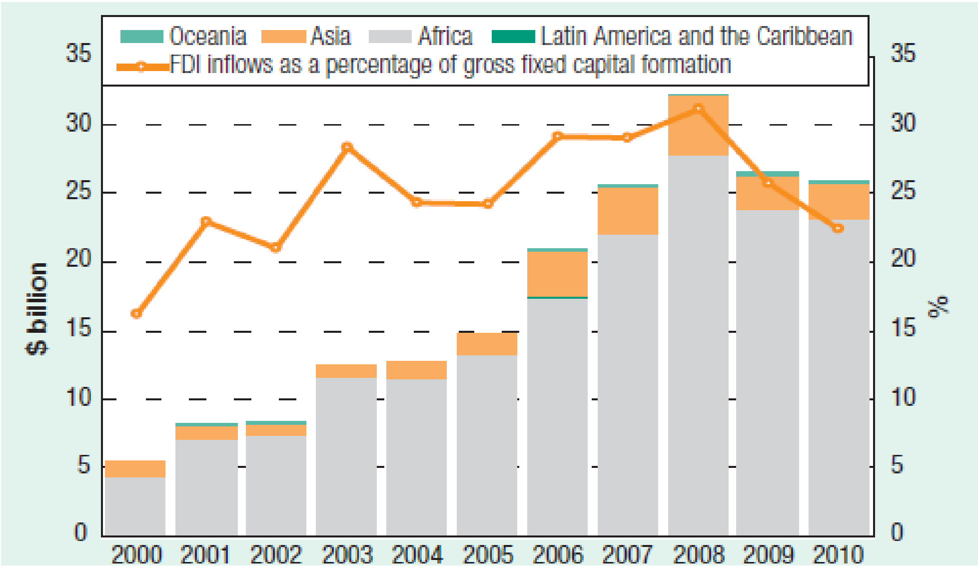
Keywords:

Emission standard; R&D; Developing country; Environmental regulation

JEL Classification: F18, F23, Q56

1. Introduction

When living in a world in which there are increasing differences between developed and developing countries, Foreign Direct Investment (FDI) is a major contributor to the capital formation of developing countries. As shown in figure 1, FDI for developing nations is a significant source of capital formation, especially in least-developed countries (LDCs). FDI is obviously not only a supporter of their capital formation but also provides technology and management knowledge. It is particularly important for LDCs to develop advanced technology.



Source: World Investment Report 2011 p.74

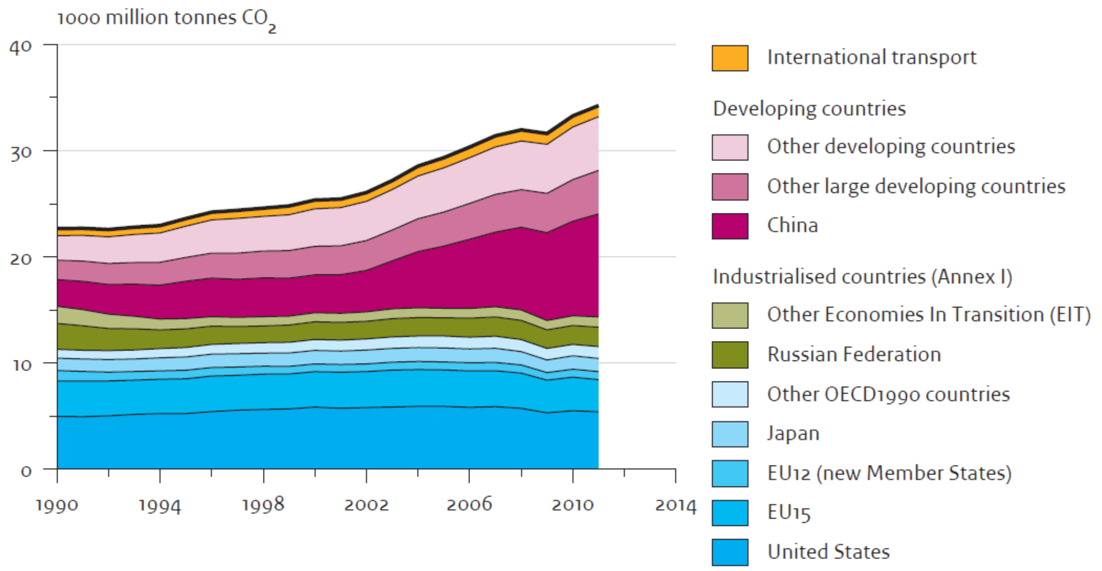
[Figure 1] FDI inflows, 2000-2010

However, one can no longer ignore the environmental issues of FDI. If a government adopts lenient policies, the country may become a pollution haven because polluting industries are concentrated in lenient policy areas. If there is strict policy, on the other hand, there is no incentive to drive FDI, which implements advanced abatement technology. Therefore, developing countries experience a dilemma when choosing between competitiveness and environmental protection when developing environmental regulation strategy.

It is natural that production results in pollution of the local environment. Thus, governmental environmental regulations not only protect the environment but also bring about limitations on production. It is certain that environmental regulations are necessary but governments cannot only rely on strict regulation to protect the environment. Firms must also reduce their outputs by adopting environmental policies that lead to reducing their emissions that pollute the environment.

It is true that emission abatement technologies in developed countries are better than those in developing countries. As shown in figure 2, the CO_2emission per region from fossil fuel use and cement production is different between countries. As European Commission Joint Research Centre & PBL Netherlands Environmental Assessment Agency (2012), although all developing countries has increased their emissions on average by 6%, CO_2emission from China has increased by 9% and those from India has increased by 6% in 2011. Those increases from China and India have significantly responsibility of the largest increase in global emission of 1.0 billion tonnes in 2011.

There are many reasons for this, but it is primarily due to international differences in emission abatement technologies between developed and developing countries. Considering that emissions in China are significantly increasing, as shown in figure 2, the problem of emissions has recently become more significant in developing countries.



Source: EDGAR 4.2(1970-2008); IEA, 2011; USGS, 2012; WSA, 2012; NOAA, 2012. European Commission Joint Research Centre & PBL Netherlands Environmental Assessment Agency (2012)

[Figure 2] Global CO2 emissions per region from fossil fuel use and cement production

In addition, there is much more emissions per capita in developing countries than developed countries from the Table 1. The developed countries such as EU27 reduce their emissions although the population increases. However, there are huge increase of emissions in the developing countries such as China and India. Table 1 shows that the change in per capita CO_2 emissions for 1990-2011 and of population for a numbers of countries such as United States, EU27, Japan, China, India and South Korea. As European Commission Joint Research Centre & PBL Netherlands Environmental Assessment Agency (2012) reported 9700 million tonnes of CO_2 in 2011 and a 227% increase in CO_2/capita emissions for 1990-2011 in China. There is a change in $CO_2$for 1990-2011 in 287% and a change in population for 1990-2011 in 15% in China. In addition, there is a 198% increase in CO2 change and a 30% change in population for 1990-2011 in India. In contrast, 3790 million tonnes of CO_2 in 2011 and a 18% decrease in CO_2/capita emissions for 1990-2011 in EU27. There is a change in $CO_2$for 1990-2011 in -12% and a change in population for 1990-2011 in 6% in EU27.

[Table 1] CO_2 emissions in 2011(million tonnes CO_2) and CO_2/capita emissions, 1990-2011(tonne CO_2/person)

Country	Emissions 2011	Per capita emissions				Change 1990-2011	Change 1990-2011 in%	Change in CO_2 1990-2011 in%	Change in population 1990-2011 in%
		1990	2000	2010	2011				
United States	5420	19.7	20.8	17.8	17.3	-2.4	-12%	9%	19%
EU27	3790	9.2	8.4	7.8	7.5	-1.7	-18%	-12%	6%
Japan	1240	9.5	10.1	10	9.8	0.3	3%	7%	3%
China	9700	2.2	2.8	6.6	7.2	5	227%	287%	15%
India	1970	0.8	1.0	1.5	1.6	0.8	100%	198%	30%
South Korea	610	5.9	9.7	12.2	12.4	6.5	110%	141%	11%

Source: European Commission Joint Research Centre & PBL Netherlands Environmental Assessment Agency (2012)

Due to the low level of the abatement technology in developing countries, the governments of those countries cannot choose strict regulation. If a government adopts strict regulations, national firms will have lower competitiveness. If a government adopts more lenient regulations, this can minimize the disadvantage for national firms but local pollution could become a serious threat.

The Clean Development Mechanism (CDM) is one of the 'flexible mechanisms' within the Kyoto Protocol. There are three flexible mechanisms: international emissions trading (IET), joint implementation (JI), and the clean development mechanism (CDM). These all aim at a reduction in greenhouse gas emissions.[1]

The countries that have responsibility for emission reduction under the Kyoto Protocol (i.e. developed countries) must invest their technology and money in countries without emissions targets (i.e. developing countries). This helps the developed countries to meet their emission reduction targets by allowing them to purchase CERs (certified emission reductions) through CDM projects. Therefore, given increasing concerns about emission pollutions, developed countries have more incentives to invest in developing countries. From this point of view, it is necessary to consider what the optimal strategy of developing countries should be.

There are diverse factors which affect on FDI location decisions. However, it is certain that proper emission standards can be a solution that leads to investment in developing countries by developed countries. The most important contribution from FDI is that ESTs (environmentally sound technologies) are transferred from the developed countries to the developing countries. Thus developing nations may be able to reduce their emissions through the advanced abatement technology provided by the developed country. The government of the developing country can thereby not only raise their competitiveness in the international market but also maintain a clean environment.

There are many methods of environmental regulation but in this paper, only emission standard setting is considered. The model focuses on emission pollution, for which emission standards are the maximum permitted emission level fixed by government for environmental protection. For example, pollution producers pay an

[1] 'What is the CDM?', 2011.07.26, www.guardian.co.uk

emission tax for their total emissions. However, in emission standardization, the government permits emissions up to the emission standard level. Then, only the amount over the standard level is under regulation and the pollution producer needs to pay for exceeding the standard. Therefore, a high emission standard means lenient environmental regulation while a low emission standard means strict environmental regulation. In Korea, there has been emission taxation since 1st September, 1983. The emission taxation consists of 'basic taxation' and 'excess taxation'. It is necessary to pay both the basic tax and the excess tax for sulfur oxides and dust. However, for other pollutants a firm only needs to pay the excess tax depending on the degree to which they exceed the emission standard.[2]

There are several papers that have studied FDI between two countries which have different environmental policies. Rauscher (1995, 1997) examine FDI location using an expanding international capital movement model. This work observed the location decision of a monopoly between N numbers of countries that each has differential environmental policies. In addition, Barrett (1994) and Kennedy (1994) explored the environmental regulation strategy of governments and the effect on firm FDI location decisions. Barrett (1994) considered the differences between Cournot and Bertrand competitions. In addition, transboundary pollution was considered by Kennedy (1994). Ulph and Valentini (1997) analyzed location choices between international oligopoly markets. This paper derived location decision strategy under consideration of the relations between upstream-firms and downstream-firms, which means inter-sectoral linkages.

However, Abe and Zhao (2005) examined not only firm location choice but also endogenous international joint ventures (IJV). Therefore, Abe and Zhao (2005) has differences with previous studies. The authors considered that optimal emission tax depends on the emission abatement technology of the developing countries involved. They point out that IJVs are formed when there are optimal emission taxes. They also postulated that deregulation of the minimum share increases the welfare of the developing countries under a JV. It is a noteworthy that this study ignored the fact that the technology of parent firms can be improved over time. In their model, abatement technologies were given at the outset and then never changed, although the total emission amount was changed by the level of technology. Developing countries also only concentrated on forming FDI or IJV by implementing an attractive environmental policy in the model of Abe and Zhao (2005).

However, in reality, firms of developing countries can conduct Research and Development (R&D) to develop their abatement technologies. Countries perform R&D depending on GDP. It is true that R&D in the real world is not only concentrated on emission abatement technology.

Therefore, this study highlights the fact that both developing and developed countries do not limit themselves by on-going development of their technologies through R&D. However, for simplicity, the model of this paper focuses on the environmental technology industry and abatement technology. Reducing emissions pollution through R&D and R&D costs may affect optimal environmental policy, which in turn maximizes the welfare of developing countries. In addition, this paper apply emission standard as a tool of environmental regulation. These are the most different points compared with previous studies.

This paper examines how environmental regulation affects the FDI strategies of parent firms in developing and developed countries when there are between-country

[2] See Kim, Hyun-dong and Whang, Yun-gi (2010), pp.242-243

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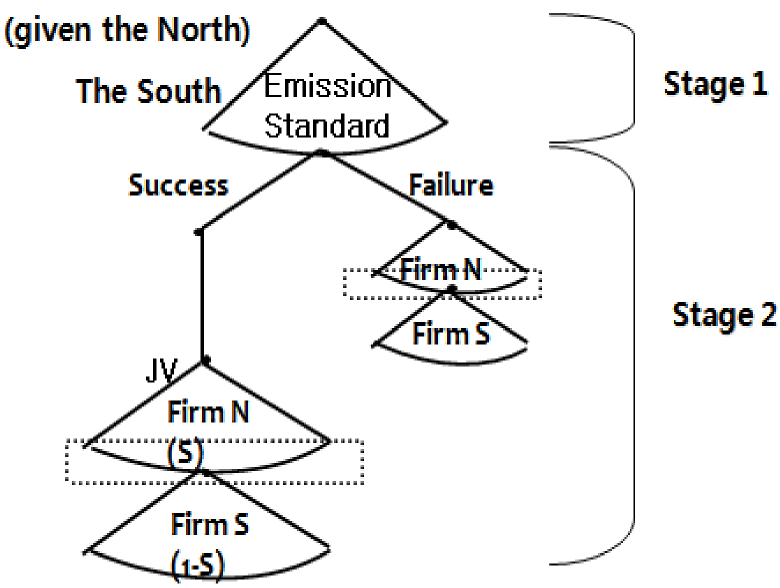
differences in abatement technology and R&D efficiency. In addition, the paper considers the optimal emission standard for each case, assuming that an emission standard is an effective way to solve the regulation dilemma for developed countries. Finally, how R&D affects FDI strategies and developing country welfare is considered. However, the core focus is on determining what level of emission standard is optimal under various situations, dependent on formation of JV or FDI in the developing country. In addition, the optimal welfare of the developing country is considered through analysis of findings.

The rest of the paper is organized as follows: Section two introduces the basic model of emission standards and FDI strategy. Section three presents the threat point whereat bargaining breaks down. Section four describes the endogenous choices between the formation of the international JV and full-ownership FDI. Section five analyzes the optimal emission standard for the South under the full-ownership FDI and IJV. Concluding remarks and summaries are then given in Section six.

2. The basic model

This paper uses a two-country model with a developed country (the North) and a developing country (the South). Both countries have their own environmental policies. Each country has a parent firm: firm N is located in the North and firm S is located in the South. In the model, it is assumed that all types of firms pollute as they produce their homogenous outputs but the focus is situated on industries sensitive to local environmental policies, such as the chemical industry. However, it is assumed that the pollution damage from each firm is different due to different abatement technologies. Firm S has worse abatement technology than firm N. Thus firm S emits more local pollution per unit of output than firm N. R&D technology is consistent with abatement technology, meaning that the relative R&D effectiveness of firm N is larger than that of firm S. Thus Firm S needs to invest more in R&D than firm N. There is no cross-border effect of pollution in this model. All outputs are only consumed in a third country.



[Figure 3] Two-stage game tree

We assume that there is a two-stage game as shown in figure 3 above. In stage one, the South determines their emission standard level. The differences of both abatement technology and R&D efficiency are given for both countries. The South can choose their emission standard level to maximize their welfare, given the North's emission standard level. In stage two, the two parent firms N and S decide whether to form a JV or not. Two firms bargain to form an international JV and they bargain over location, outputs, R&D amount and shares of the JV. If bargaining succeeds, both firms begin the production as a JV. If bargaining breaks down, both firms produce their goods separately.

There are three possible scenarios vis-à-vis the location and the type of firm: (i) each firm chooses to produce independently in their home countries, (ii) both firms are located in the South but choose to produce independently, or (iii) both firms produce together as JV in the South.

To examine the model over time, the two stage game model is solved using backwards induction: the second stage of the game is analyzed first, in which bargaining is either successful or unsuccessful. Then the first stage, in which the South determines their emission standard level, is investigated.

1. The threat point

If bargaining breaks down, both firms produce goods independently and they choose to locate in either country. This is the threat point. At the threat point, both firms compete as either a domestic Cournot or an international Cournot[3]: (i) an International Cournot is Case 1, wherein each firm produces in their home country independently, and (ii) a Domestic Cournot is Case 2, wherein both firms are located in the South but choose to produce independently.

The emission tax structure, considering location, abatement technologies and R&D efficiency, has an effect on firms' output levels. If both firms have incentive to produce positive outputs, it is a duopoly. If one firm produces positive output while the other produces zero output, it is a monopoly.

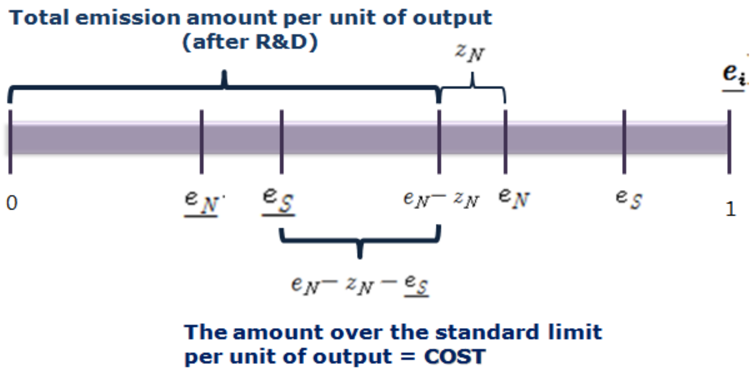
The profit function of the parent firm *j* which is located in country *i* can be formulated as:

$$\pi_j(x_N, x_S, i) = p(x_N + x_S)x_j - w_i a x_j - \left(e_j - z_j - \underline{e_i}\right)x_j - \frac{\gamma_j}{2}z_j^2 \tag{1}$$

where w_i is the wage cost and $\underline{e_i}$ is the emission standard level per unit of output in country *i*. Also, x_j is the output of firm *j* and a is unit labor requirement per unit of output of firm *j*. If e_j is indicated as emission per unit of output of firm *j*, then it can be stated that $e_N \leq e_S$ because the abatement technology owned by the firm N is more efficient than the firm S. In addition, each firm improves their abatement technology through R&D. $\frac{1}{\gamma_j}$ is the relative effectiveness of R&D of firm *j*, z_j is the emission-reduction through R&D and $(\frac{\gamma_j}{2})z_j^2$ is the R&D cost of firm *j*. It is assumed that $\frac{1}{\gamma_N} > \frac{1}{\gamma_S}$ because the R&D efficiency of firm N is better than that of firm S. The inverse demand

[3] See Celik and Orbay (2011), p.1711.

function is considered to be linear in this model:
$p(x_N + x_S) = \beta - \alpha(x_N + x_S),\ \beta > 0, \alpha > 0.$



[Figure 4] The Emission Standard

It was already assumed that pollution producers pay an emission tax but that only the amount over the standard level is under regulation. For example, if firm N produces in the South, then firm N needs to pay their emission tax as $e_N - z_N - \underline{e_S}$ per unit of their output, as shown in figure 4. It is a sort of cost for firm N to produce in the South. Therefore, a higher emission standard represents lenient regulation in this model.

We focus on the difference in environmental policy between two countries. Thus, for simplicity, wages are normalized so that $w_N = w_S \equiv 0$. Also we only concentrate on $\underline{e_S} > \underline{e_N}$.

1.1 International Cournot: Case 1

In this section, we consider Case 1, an international Cournot, in which firm N is located in the North and firm S is located in the South.

We assume $\underline{e_S} > \underline{e_N}$ because the South determines its emission standard level, depending on that of the North. In this case, firm N can choose to stay in its home country (the North) or to move to the South. The notable point here is that each firm can improve their abatement technology by R&D. If firm N stays in the North, it only reduces its total emission amount through R&D. However, if firm N moves to the South, not only does it reduce its total emission amount through R&D but also has a higher emission standard level than it would if staying in the North. In other words, the relatively higher emission standard means a relaxation of environmental policy restriction. Thus, it is certain that firm N will prefer to move to the South. For simplicity, we assume that there is no moving cost involved in this model.

1.2 Domestic Cournot: Case 2

In Case 2, the domestic Cournot, both firms are located in the South. We assume that $\underline{e_S} > \underline{e_N}$, which means the North has much stricter environmental policies than the South. Thus firm N moves to the South which has more flexible emission regulations so that it can gain more profit.

There is a cost difference of parent firm depending on firm location because of wage costs and emission standard levels. $(w_N - w_S)a + \left(\underline{e_S} - \underline{e_N}\right)$ is the cost difference when the firm is located in between the North and the South. The reason for this is that the total unit costs of firm N which is located in country *i* is $w_i a - e_N + z_N + \underline{e_i}$. However, because of wage normalization, we can assume that the emission standard level only affects the decision of a firm's location. Thus, the South chooses the higher emission standard level, compared to the North, so as to make both firms have an incentive to locate in the South.

Under a duopoly in the South condition, the profit maximization problems of firm N and S are formulated as Eq. (2a) and (2b), respectively.

$$\pi_N(x_N, x_S, i) = p(x_N + x_S)x_N - \left(e_N - z_N - \underline{e_S}\right)x_N - \frac{\gamma_N}{2}z_N^2 \quad (2a)$$
$$\pi_S(x_N, x_S, i) = p(x_N + x_S)x_S - \left(e_S - z_S - \underline{e_S}\right)x_S - \frac{\gamma_S}{2}z_S^2 \quad (2b)$$

The outputs for case 2 are shown in Eq. (3a) and (3b), according to both Eq. (2a) and (2b).

$$x_N^c = \frac{\underline{e_S}+\beta-2e_N+e_S+2z_N-z_S}{3\alpha} \quad (3a)$$
$$x_S^c = \frac{\underline{e_S}+\beta+e_N-2e_S-z_N+2z_S}{3\alpha} \quad (3b)$$

Thus, if Eq. (3a) and (3b) are combined with Eq. (2a) and (2b), the threat point payoffs under domestic Cournot are formulated as follows:

$$\pi_N^c = \alpha(x_N^c)^2 - \frac{\gamma_N}{2}z_N^2 \quad (4a)$$
$$= \frac{(\underline{e_S}+\beta-2e_N+e_S+2z_N-z_S)^2}{9\alpha} - \frac{\gamma_N}{2}z_N^2 \equiv \pi_N^c\left(\underline{e_S}, e_S\right)$$
$$\pi_S^c = \alpha(x_S^c)^2 - \frac{\gamma_S}{2}z_S^2 \quad (4b)$$
$$= \frac{(\underline{e_S}+\beta+e_N-2e_S-z_N+2z_S)^2}{9\alpha} - \frac{\gamma_S}{2}z_S^2 \equiv \pi_N^c\left(\underline{e_S}, e_S\right)$$

Accordingly, we obtain the optimal R&D levels for both firms as:

$$Z_N^c = \frac{4(-4\left(\underline{e_S}+\beta-e_N\right)+3\alpha\left(\underline{e_S}+\beta-2e_N+e_S\right)\gamma_S)}{16-24\alpha\gamma_S+3\alpha\gamma_N(-8+9\alpha\gamma_S)} \quad (5a)$$
$$Z_S^c = \frac{4(-4\left(\underline{e_S}+\beta-e_S\right)+3\alpha\left(\underline{e_S}+\beta+e_N-2e_S\right)\gamma_N)}{16-24\alpha\gamma_S+3\alpha\gamma_N(-8+9\alpha\gamma_S)} \quad (5b)$$

Thus, the equilibrium payoffs of both firms with equilibrium outputs and optimal R&D levels are formulated in Eq. (6a) and (6b). Substituting Eq. (5a) and (5b) into Eq. (4a) and (4b), we obtain:

$$\pi_N^c\left(\underline{e_S}, x_N, x_S, z_N, z_S\right) = \frac{\gamma_N(-8+9\alpha\gamma_N)(4\left(\underline{e_S}+\beta-e_N\right)-3\alpha\left(\underline{e_S}+\beta-2e_N+e_S\right)\gamma_S)^2}{(16-24\alpha\gamma_S+3\alpha\gamma_N(-8+9\alpha\gamma_S))^2} \quad (6a)$$

$$\pi_S^C\left(\underline{e_S}, x_N, x_S, z_N, z_S\right) = \frac{\gamma_S(-8+9\alpha\gamma_S)(4(\underline{e_S}+\beta-e_N)-3\alpha(\underline{e_S}+\beta+e_N-2e_S)\gamma_N)^2}{(16-24\alpha\gamma_S+3\alpha\gamma_N(-8+9\alpha\gamma_S))^2} \quad (6b)$$

We can observe from Eq.(3a) and (3b) the relationships between outputs and emission standard levels and between outputs and abatement technology.

$$\frac{\mathrm{d}x_N^C}{\mathrm{d}\underline{e_S}} > 0, \quad \frac{\mathrm{d}x_N^C}{\mathrm{d}e_N} < 0, \quad \frac{\mathrm{d}x_N^C}{\mathrm{d}e_S} > 0 \quad (7a)$$

$$\frac{\mathrm{d}x_S^C}{\mathrm{d}\underline{e_S}} > 0, \quad \frac{\mathrm{d}x_S^C}{\mathrm{d}e_N} > 0, \quad \frac{\mathrm{d}x_S^C}{\mathrm{d}e_S} < 0 \quad (7b)$$

We can observe from Eq. (7a) and (7b) that the outputs of the two firms increase as the emission standard $\underline{e_S}$ increases. In other words, both firm N and S may have higher production in the South if the South government chooses lax environmental regulation. We can also observe that the output of firm N increases as e_S increases, whereas that of firm N decreases. This means that firm N may produce more as either firm S's abatement technology deteriorates or their own abatement technology improves. These results are the same in the optimal output level of firm S.

$$\frac{\mathrm{d}Z_N^C}{\mathrm{d}\underline{e_S}} = \frac{4(-4+3\alpha\gamma_S)}{16-24\alpha\gamma_S+3\alpha\gamma_N(-8+9\alpha\gamma_S)} \quad (8a)$$

$$\frac{\mathrm{d}Z_S^C}{\mathrm{d}\underline{e_S}} = \frac{4(-4+3\alpha\gamma_N)}{16-24\alpha\gamma_S+3\alpha\gamma_N(-8+9\alpha\gamma_S)} \quad (8b)$$

In addition, from Eq. (8a), if $\underline{e_S} < e_N < e_S$ and $\frac{1}{\gamma_N} > \frac{1}{\gamma_S}$, the R&D amount of firm N, Z_N^C decreases as the emission standard $\underline{e_S}$ increases. This means that if the South government chooses loose regulation, firm N has reduced incentive for R&D to reduce their total emissions. This result is the same for firm S. From Eq. (8b), firm S has a lower incentive to reduce their total emissions through R&D if the South government chooses less intensive regulation.[4]

Also, we can observe that both firms have more incentive to conduct R&D as their abatement technology worsens, from Eq. (9a) and (9b).[5]

$$\frac{\mathrm{d}Z_N^C}{\mathrm{d}e_N} = \frac{4(4-6\alpha\gamma_S)}{16-24\alpha\gamma_S+3\alpha\gamma_N(-8+9\alpha\gamma_S)} \quad (9a)$$

$$\frac{\mathrm{d}Z_S^C}{\mathrm{d}e_S} = \frac{4(4-6\alpha\gamma_N)}{16-24\alpha\gamma_S+3\alpha\gamma_N(-8+9\alpha\gamma_S)} \quad (9b)$$

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[4] Unfortunately, at this point a more clear result could not be obtained algebraically. There are three parameters which affect the R&D level. The range of R&D efficiency between two firms and inverse demand function affect whether Eq. (8a) and (8b) become negative or positive. For example, suppose that α=0.01, β=0.5 and γ_N=0.1 for simplicity, Eq. (8b) is negative since $\underline{e_S} < e_N < e_S$, $\frac{1}{\gamma_N} > \frac{1}{\gamma_S}$. Thus, we can only say that market size β and price elasticity α affects the range of R&D level though it is certain that loose regulation ensures the firm has a reduced incentive to reduce their emissions through R&D.

In the other case, suppose α=1, β=100 and γ_N=0.1 for simplicity, Eq. (8b) is negative when γ_S≤0.638 only. Thus, we can only say that firm S may still make greater efforts even though the South government permits loose regulation when firm S has too low a value of R&D efficiency.

[5] The relationship between R&D level and emission amount is unclear because three parameters affect R&D level at once as (9a) and (9b). For example, suppose α=1, β=100 and γ_N=0.1 for simplicity Eq. (9b) is positive when γ_S≤0.638 since $\underline{e_S} < e_N < e_S$, $\frac{1}{\gamma_N} > \frac{1}{\gamma_S}$. Thus, we can only say that firm S will not have an incentive for R&D to reduce their total emissions even though they produce significant emissions when firm S has too low a level of R&D efficiency.

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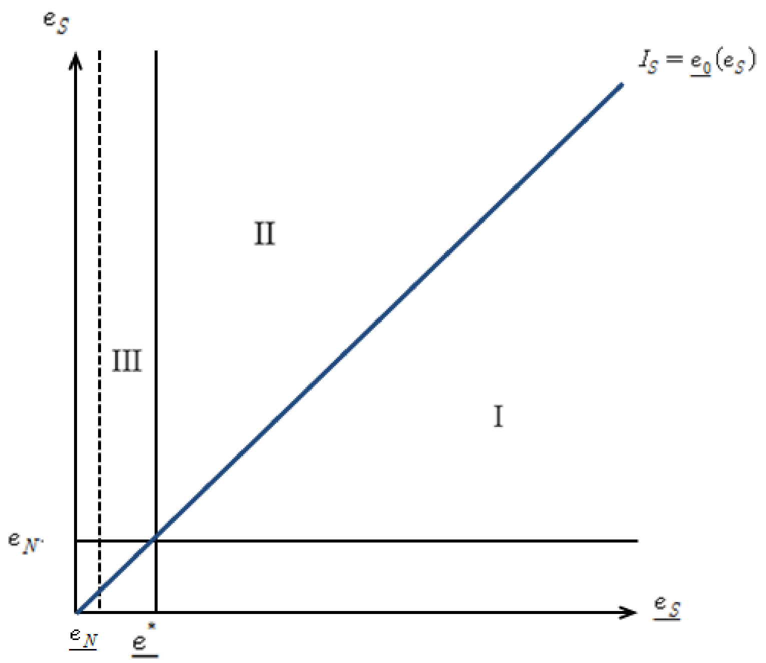
We assumed that $e_S \geq e_N$. Thus, $\pi_N^c(\underline{e_S}, x_N, x_S, z_N, z_S) \geq \pi_S^c(\underline{e_S}, x_N, x_S, z_N, z_S)$ for any $\underline{e_S}$. The emission standard $\underline{e_0}(e_S)$ is the level at which $x_S^c = 0$ such as Eq. (10).

$$\underline{e_0}(e_S) \equiv -\beta - e_N + 2e_S + z_N - 2z_S = \frac{4\beta - 4e_S - 3\alpha\beta\gamma_N - 3\alpha e_N\gamma_N + 6\alpha e_S\gamma_N}{-4 + 3\alpha\gamma_N} \quad (10)$$

We define the threat point payoffs set as $(\pi_N^0, \pi_S^0) = (\pi_N^c, \pi_S^c)$. Also both firms exist in the market only with $\underline{e_S} > \underline{e_0}(e_S)$.

Lemma 1 (The threat point). Suppose that $e_S \geq e_N$ and $\underline{e_S} > \underline{e_N}$. At the threat point of the bargaining game, both firms produce a positive output in the South if $\underline{e_S} > \underline{e_0}(e_S)$.



[Figure 5] Domestic Cournot

Case 2 in which both firms is located in the South and produce independently is illustrated in figure 5[6]. Curve I_S is $\underline{e_0}(e_S)$ as the prohibitive emission standard level at which firm S has no further incentive to produce a positive output. Thus, firm S exists in the market only if $\underline{e_S} > \underline{e_0}(e_S)$. In addition, $\underline{e^*} \equiv \frac{4\beta - 4e_N - 3\alpha\beta\gamma_N + 3\alpha e_N\gamma_N}{-4 + 3\alpha\gamma_N}$ shows the

6 As shown in figure 5, the emission per unit of output for firm S (e_S) increases as the South government determines looser environmental regulation, which means a high value of $\underline{e_S}$. However, this is only completed when $0<\gamma_N<\frac{2}{3\alpha}$. This means that the relationship between firm S and the government of the South is only possible when firm N has a certain level of R&D efficiency. If firm N has significantly inefficient R&D technology, the environmental policy of the South cannot affect strategies of firms.

prohibitive emission standard level at which even monopoly firm N becomes zero profit. This means that neither firm produces anything if $\underline{e_S} < \underline{e}^*$. Then, in area I, both firms produce a positive output at the Cournot equilibrium. In area II, firm S produces zero output and firm N only exists in the market as a monopoly. In area III, both firms produce nothing.

2. The formation of an international JV : Case 3

As we show before, both Cases 1 and 2 are the outcome if bargaining is unsuccessful. In this section, we consider Case 3, in which bargaining is successful. Both firm N and S are then located in the South and they produce together as a JV (Joint Venture). We assume that a JV is formed in which they produce with the advanced abatement technology of firm N at no cost. Thus, the profit function of JV is formulated as Eq. (11) if the JV is located in the South.

$$\begin{aligned}\pi_J &= p(x_N + x_S)x_J - \left(e_J - z_J - \underline{e_S}\right)x_J - \frac{\gamma_J}{2}z_J^2 \\ &= \left(p - e_N + z_J + \underline{e_S}\right)x_J - \frac{\gamma_N}{2}z_J^2\end{aligned} \tag{11}$$

In Eq. (11), x_J is the output of the JV and e_J is emission per unit of output of the JV. A JV executes R&D to improve its abatement technology to reduce total emissions as when two firms produce independently. $\frac{1}{\gamma_J}$ is the relative effectiveness of R&D of the JV, z_J is the emission-reduction from R&D and $(\frac{\gamma_J}{2})z_J^2$ is the R&D cost for the JV.

The noteworthy fact here is the assumption that the JV adopts the advanced technology of firm N without any extra cost and can therefore manage efficient R&D with the better R&D technology from firm N. Thus, the significant differences between this and Cases 2 and 3 are in the output and efficiency of R&D technology. We assume that $x_J = (x_N^c + x_S^c)$ as output, $\frac{1}{\gamma_J} = \frac{1}{\gamma_N}$ as the relative effectiveness of R&D and $e_J = e_N$as the emission per unit of output of the JV. The inverse demand function is considered to be linear: $p(x_N + x_S) = \beta - \alpha(x_N + x_S), \beta > 0, \alpha > 0.$

Defining the share of firm N is *s* and that of firm S is *1-s,* where the JV is formed if $s \in (0,1)$. Then the profit functions of each firm are written as Eq. (12) if the JV is formed.

$$\pi_N^J = s\pi_J,\ \ \pi_S^J = (1-s)\pi_J \tag{12}$$

Nash bargaining is executed for negotiations in this model.

$$V = \left(\pi_N^J - \pi_N^0\right)\left(\pi_S^J - \pi_S^0\right) \tag{13}$$

From the Nash product, π_N^J and π_S^J are the payoffs from forming the JV. Similarly, π_N^0 and π_S^0 are the payoffs at threat point. It is certain that $(\pi_N^J > \pi_N^0, \pi_S^J > \pi_S^0)$ is the equilibrium since $\pi_N^J - \pi_N^0$, $\pi_S^J - \pi_S^0$ are the net gains of firm N and S, respectively.

$(\pi_N^J > \pi_N^0, \pi_S^J > \pi_S^0)$ is the case wherein both firms gain more payoff if the JV is formed, compared with the firms producing independently as duopoly. That is why firm N and S choose to form a JV when bargaining is successful. It is the better choice for the South since it enables production with the advanced abatement technology of firm N if the JV is formed. The JV in case 3 produces fewer emissions than in Case 2.

From maximizing Eq. (13) considering location, the JV's outcome and the share of the JV, we can extrapolate three facts. First of all, with respect to the location, it is certain that the JV is formed in the South. The profit when the JV is located in the South is larger than when in the North since the South has relatively lax regulations. Thus, π_N^J and $\pi_S^J$are larger in the South if $\underline{e_S} > \underline{e_N}$.

$$\frac{\partial \mathrm{V}}{\partial \mathrm{x_J}} = 0 : \frac{\partial \pi_\mathrm{J}}{\partial \mathrm{x_J}} = 0 \quad (14a)$$
$$\frac{\partial V}{\partial s} = 0 : \pi_N^J - \pi_N^0 = \pi_S^J - \pi_S^0 \quad (14b)$$

Secondly, regarding the output and shares, Eq. (14a) and (14b) are suitable. From Eq. (14a), we observe that the firm N and S choose the output level of the JV at a monopoly level to maximize their profits. After that, the two firms divide the JV profit in proportion to the amount of their share *s* and *1-s* as in Eq. (14b).

We assume that the JV adopts the better technology of firm N and produces as much as $x_J = (x_N^c + x_S^c)$. Thus the output and the profit of the JV are same as those of firm N as a monopoly in the South, in Eq. (14a). This is illustrated by the II area of figure 5. In other words, $x_J = x_N^M(\underline{e_S})$ and $\pi_J = \pi_N^M(\underline{e_S})$. Then, the JV's output and profit are:

$$x_N^M = \frac{\underline{e_S}+\beta-e_J+z_J}{2\alpha} = \frac{\underline{e_S}+\beta-e_N+z_J}{2\alpha} \equiv x_N^M(\underline{e_S}) \quad (15)$$
$$\pi_N^M = \alpha(x_N^M)^2 - \frac{\gamma_J}{2} z_J^2 \quad (16)$$
$$= \frac{(\underline{e_S}+\beta-e_J+z_J)^2}{4\alpha} - \frac{\gamma_J}{2} z_J^2 = \frac{(\underline{e_S}+\beta-e_N+z_J)^2}{4\alpha} - \frac{\gamma_N}{2} z_J^2 \equiv \pi_N^M(\underline{e_S})$$

The optimal R&D level of the JV is:

$$z_J = \frac{\underline{e_S}+\beta-e_N}{-1+2\alpha\gamma_N} \equiv z_N^M(\underline{e_S}) \quad (17)$$

The JV which is located in the South may produce more if the South determines a lax environmental regulation, as in Eq. (18). In addition, there is a higher output as they have better abatement technology. If the JV expends more effort on R&D, it can produce more output since they will improve their abatement technologies through R&D.

$$\frac{\mathrm{d}x_J}{\mathrm{d}\underline{e_S}} > 0, \quad \frac{\mathrm{d}x_J}{\mathrm{d}e_N} < 0, \quad \frac{\mathrm{d}x_J}{\mathrm{d}Z_J} > 0 \quad (18)$$

Therefore, the profit of the JV with optimal output and R&D level can be:

$$\pi_J(x_J, z_J) = \frac{\left(\underline{e_S}+\beta-e_N\right)^2 \gamma_N}{4\alpha\gamma_N-2} \equiv \pi_N^M(\underline{e_S}) \quad (19)$$

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Third, two parents firms' share of the JV is satisfied as follows, from Eq. (14b):

$$s = 0.5 + (\pi_N^0 - \pi_S^0)/(2\pi_N^M) \tag{20}$$

As the share of the JV, each firm's profit of the JV is formulated as Eq. (21).[7]

$$\pi_N^J = \left\{\pi_N^M\left(\underline{e_S}\right) + \left(\pi_N^c\left(\underline{e_S}, \mathrm{e_S}\right) - \pi_S^c\left(\underline{e_S}, \mathrm{e_S}\right)\right)\right\}/2 \equiv \pi_N^J(\underline{e_S}, \mathrm{e_S}) \tag{21}$$
$$\pi_S^J = \left\{\pi_N^M\left(\underline{e_S}\right) - \left(\pi_N^c\left(\underline{e_S}, \mathrm{e_S}\right) - \pi_S^c\left(\underline{e_S}, \mathrm{e_S}\right)\right)\right\}/2 \equiv \pi_N^J(\underline{e_S}, \mathrm{e_S})$$

The maximum profit of a JV in the South is larger than the sum of the profits of both firms in a Cournot competition in the South. Then if 0.5≤*s*<1, $\pi_N^M > \pi_N^0 + \pi_S^0 = \pi_N^c + \pi_S^c$ holds.[8] To make sure of this, it is certain that s cannot be less than half because $\pi_N^0 \geq \pi_S^0$; in addition, *1-s*=$\frac{\pi_N^M - (\pi_N^0 - \pi_S^0)}{2\pi_N^M} > \frac{\pi_S^0}{\pi_N^M} \geq 0$*,* leading to *s*<1. From Eq. (20), we also obtain $\pi_N^J - \pi_N^0 = s\pi_J + \pi_N^0 = \frac{\pi_N^M - (\pi_N^0 + \pi_S^0)}{2} > 0$. Thus, the JV is formed with a positive output with the condition $\pi_N^J - \pi_N^0 = \pi_S^J - \pi_S^0 > 0$.

If *s*=1, firm N becomes a monopoly in the market and $\pi_N^M = \pi_N^0$ and π_S^0=0. This means that there is no possibility for a JV and only firm N has a fully owned facility with the whole share of the firm which produces the sum of the two parent firms' outputs. As in Case 2, $\underline{e}^*$is the prohibitive emission standard at which a JV could not exist in the market since the result would be negative profit. Thus, there is no JV with this condition.

Proposition 1 (Forming JV). Suppose that $e_S \geq e_N$, $\underline{e_S} > \underline{e_N}$ and $\underline{e_N} \leq \underline{e}^*$. (i) if $\underline{e_S} > \underline{e_0}(e_S)$, firm N and S produce a positive output in the South and the JV is formed which produces the monopoly level of output; (ii) if $\underline{e}^*$<$\underline{e_S} < \underline{e_0}(e_S)$, firm N undertakes full-ownership FDI in the South and becomes a monopoly; (iii) if $\underline{e_S} \leq \underline{e}^*$, neither firm produces.

[7] The profits of firm N and S receive their profits of the JV such as Eq. (21). See Abe and Zhao (2005), p.229.
[8] See Abe and Zhao (2005), p.228.

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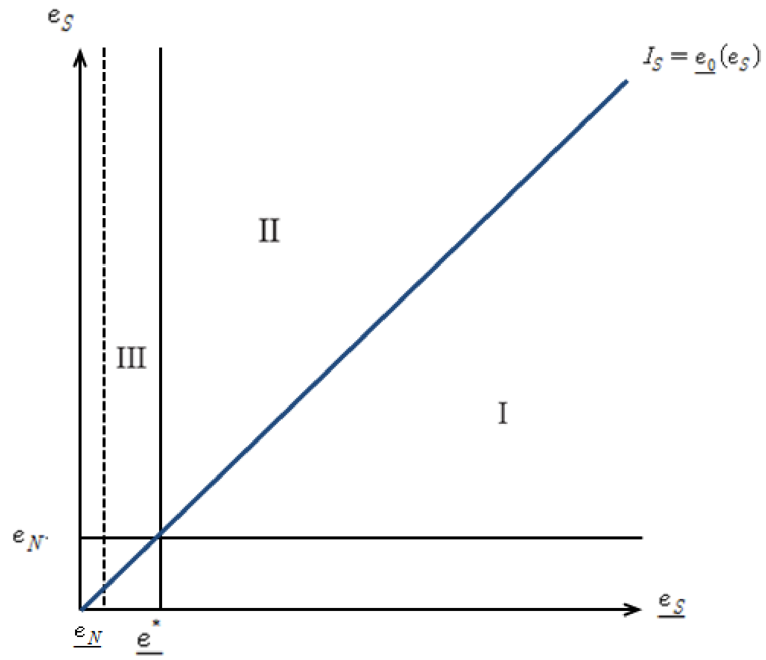

[Figure 6] Formation of JV

Figure 6[9] illustrates a Case 3 in which both firms are located in the South and a JV is formed. As we observed in figure 6, firm S exists in the market only if $\underline{e_S} > \underline{e_0}(e_S)$. In addition, neither firm produces anything if $\underline{e_S} < \underline{e^*}$. Then, in area I (above e_N and to the right of I_S), both firms produce a positive output from forming JV in the South. The critical emission standard level for the formation of the JV is $\underline{e_S} = \underline{e_0}(e_S)$, which leads to $x_S^c = 0$. In area II (above I_S and to the right of $\underline{e^*}$), full-ownership FDI is formed in the South since firm S produce zero output and firm N becomes a monopoly. In area III (to the right of $\underline{e_N}$ and to the left of $\underline{e^*}$), both firms produce nothing.

Proposition 1 indicates that the formation of the JV in the South becomes more difficult as the abatement technology of the South deteriorates. This finding is consistent with the fact that the number of international JVs in least-developed countries (LDCs) is very small, with international JVs much more concentrated in more advanced developing countries such as the Newly Industrialized Countries (NICs)[10].

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[9] In figure 6, the relationship between e_S and $\underline{e_S}$ is only completed when $\frac{1}{2\alpha} < \gamma_N < \frac{2}{3\alpha}$ as figure 5. This means that the relationship between firm S and the government of the South is only possible when firm N has a certain level of R&D efficiency. If firm N is inefficient or too efficient in R&D technology, the environmental policy of the South cannot affect strategies of firms.

[10] See Abe and Zhao (2005), and the United Nations Conference on Trade and Development (UNCTAD) (2002, 2011). According to Abe and Zhao (2005), p. 222, 'the 10 largest host countries in the developing world received three-quarters of the total inflows to developing countries, and the 49 LDCs receive only 2% of them in 2001' from the World Investment Report 2002 (UNCTAD).

In addition, according to the World Investment Report 2011 (UNCTAD), p.74-75, LDCs are assured of forming their capital from FDI. However, FDI flows to LDCs are delayed in recovery and the distribution of FDI flows among LDCs still highly uneven as well. FDI is concentrated in a limited number of resource-rich countries and this concentration keeps increasing. The 10 countries with FDI stocks of more than $5 billion as of 2010, account for two-thirds of the total inward stock. Between that flow, only four mostly natural resources exporting countries-Angola, Equatorial Buinea, Sudan and Zambia-received over half of the total FDI into LDCs.

There is more incentive to determine a higher emission standard to attract JVs when countries have poor abatement technology. Thus, a higher emission standard means an improved bargaining position for firm S in JV negotiations.

3. The optimal emission standard for the South

In figure 3, there is a two-stage game tree, in which the South determines its optimal emission standard level to maximize social welfare, given both the abatement technology and emission standard of the North. We assume that the North decides their emission standard level first, and then the South reacts. There is then no further action in the North. Thus, the South has the advantage of taking action against the other player, the North. It is natural that both parent firms prefer to stay in the South and we already assumed $\underline{e_N} < \underline{e^*}$. Therefore, the emission standard level is the only factor which influences whether to form a JV or full-FDI in the South.

In this section, we draw the optimal emission standard level of the South in two cases: (i) full-ownership FDI in the South, and (ii) joint venture in the South.

3.1 Full-ownership FDI

Full-ownership FDI exists if firm N has a 100 per cent of share of the JV. We already examined a case in which firm S produces zero output while firm N produces positive output, resulting in a monopoly. This is the case when firm N produces in the South as a monopoly.

For simplicity, suppose that consumer surplus is not calculated within welfare effects since we assume that all output is consumed in a third country. Then, the welfare of the country is composed of the tax revenue and the environmental damage. In this model, we assume that the welfare of the South is the only thing under consideration. Thus, we derive only the South's welfare effects and we do not need to consider the profit of Full-ownership FDI, since it belongs entirely to firm N.

The welfare of the South when a full-ownership FDI is formed in the South is derived as:

$$W_S^M\left(\underline{e_S}\right) = \left(e_N - z_J - \underline{e_S}\right)x_N^M - d\left(e_N - z_J\right)x_N^M \tag{22}$$
$$= \frac{\left(\underline{e_S} + \beta - e_N\right)\gamma_N\left(-\beta + d\left(\underline{e_S} + \beta\right) - 2\alpha\left(\underline{e_S} + (-1+d)e_N\right)\gamma_N\right)}{(1-2\alpha\gamma_N)^2}$$

This consists of government tax revenue and environmental damage in the South. In Eq. (22), *d* is the environmental damage per unit of pollution.

It is certain that the South's government chooses an optimal emission standard level to maximize welfare. Then, the optimal emission standard level for the South is:

$$\underline{e_S^M} = \frac{\beta - 2d\beta + de_N + 2\alpha(\beta + (-2+d)e_N)\gamma_N}{2(d - 2\alpha\gamma_N)} \tag{23}$$

The welfare of the South with the optimal emission standard level is satisfied:

$$W_S^M\left(\underline{e_S^M}\right)=\frac{(\beta-e_N d)^2\gamma_N}{4(2\alpha\gamma_N-d)} \tag{24}$$

From Eq. (24), we can examine how other factors affect the welfare of the South.

$$\frac{dW_S^M\left(\underline{e_S^M}\right)}{de_N}=\frac{d(\beta-de_N)\gamma_N}{2(d-2\alpha\gamma_N)},\qquad \frac{dW_S^M\left(\underline{e_S^M}\right)}{d\gamma_N}=-\frac{d(\beta-de_N)^2}{4(d-2\alpha\gamma_N)^2} \tag{25}$$
$$\frac{dW_S^M\left(\underline{e_S^M}\right)}{dd}=\frac{(\beta-de_N)\{de_N(d-6\alpha\gamma_N)+\beta(d+2\alpha\gamma_N)\}}{4(d-2\alpha\gamma_N)^3}$$

A more clear result could not be obtained algebraically. However, we can find that $\frac{dW_S^M\left(\underline{e_S^M}\right)}{de_N}<0$, $\frac{dW_S^M\left(\underline{e_S^M}\right)}{d\gamma_N}<0$ and $\frac{dW_S^M\left(\underline{e_S^M}\right)}{dd}<0$ assuming that $\gamma_N>\frac{1}{2\alpha}$ and 0<d<1.

The welfare of the South under FDI decreases as the R&D efficiency of FDI through production with firm N's technology worsens as well. Considering environmental damage per unit of pollution, the industry which creates more environmental damage reduces the welfare of the South. The welfare of the South under FDI consists of the tax revenue and the environmental damage. Thus, if pollution damage is serious from FDI, it may offset the tax revenue.

Firm N makes positive output if $\underline{e_S^M}>\underline{e^*}$. Also firm N is a monopoly since firm S makes zero output if $\underline{e^*}\le\underline{e_S^M}<\underline{e_0}(e_s)$. Thus, these optimal emission standards and the welfare of the South are appropriate only if $\underline{e^*}\le\underline{e_S^M}<\underline{e_0}(e_s)$ and $\underline{e_S^M}>\underline{e^*}$where the Full-ownership FDI has occurred.

3.2 Joint ventures

A joint venture is formed when both firms N and S produce positive outputs. In other words, firm S under the JV condition has its own share while only firm N has a share under the full-ownership FDI. Thus, the South's welfare effects from JV differ from those of full-FDI. The South's welfare of JV is:

$$W_S^J\left(\underline{e_S},e_S\right)=W_S^M\left(\underline{e_S}\right)+\pi_S^J\left(\underline{e_S},e_S\right) \tag{26}$$

This is composed of the government tax revenue, the environmental damage to the South and firm S's profit from the JV. In other words, Eq. (26) $W_S^J\left(\underline{e_S},e_S\right)$ consists of Eq.(24) $W_S^M\left(\underline{e_S}\right)$ and Eq.(21) $\pi_S^J\left(\underline{e_S},e_S\right)$.

Lemma 2 (Joint ventures). (i) $W_S^J(0,e_S)=W_S^M(0)+\frac{\pi_N^M(0)}{2}<W_S^M\left(\underline{e_S^M}\right)$, for any e_S; (ii) $W_S^J\left(\underline{e_0}(e_s),e_S\right)=W_S^M\left(\underline{e_0}(e_s)\right)$, for any e_S; (iii) $W_S^J\left(\underline{e_S},e_S\right)>W_S^M(\underline{e_S})$, for any $\underline{e_S}\in\left(0,\underline{e_0}(e_s)\right)$.

In Lemma2, first of all, if $\underline{e_S}=0$, both firm N and S receive the same net profit under the Cournot equilibrium. This means that both firm N and S's net share becomes 0.5 . Also the welfare of the South under the JV with any $\underline{e_S}$ is smaller than the maximum welfare under the full-ownership FDI with an optimal emission standard given by Eq. (24). Secondly, if $\underline{e_0} = \underline{e_0}(e_S)$, firm N becomes a monopoly which means the net share of firm N becomes 1 for any e_S. Thirdly, the profit of firm S under the JV is always positive $\pi_S^J\left(\underline{e_S}, e_S\right) > 0$, for any $\underline{e_S} \in \left(0, \underline{e_0}(e_S)\right)$. Thus if the JV is formed, the welfare of the South is better than that under the full-ownership FDI.

In this case, the optimal emission standard level under JV is derived as Eq. (27)[11]. It is derived from differentiating Eq. (26) with respect to $\underline{e_S}$:

$$\underline{e_S^J} = \frac{dW_S^J}{d\underline{e_S}} \equiv \underline{e_S^J}(e_S) \tag{27}$$

The welfare of the South with the optimal emission standard level $W_S^J\left(\underline{e_S^J}(e_S), e_S\right)$ is derived from substituting Eq. (27) into Eq. (26). We can, however, only examine which factors affect on the welfare of the South using Eq. (28).

$$\frac{dW_S^J}{de_J} \leq 0, \quad \frac{dW_S^J}{d\gamma_J} \leq 0, \quad \frac{d\underline{e_S^J}}{de_J} \geq 0 \tag{28}$$

Therefore, welfare in the South under JV decreases if the abatement technology of firm N worsens. Also welfare under JV decreases if the R&D efficiency of firm N worsens. It is certain that the abatement technology of firm N is better than that of firm S but firm N may not be motivated by environmental concerns. However, for the South, it is better to form a JV in their country although it is certain that this will produce more pollution. Thus, the South chooses a high emission standard even though emissions under a JV increase. Loose regulation is the best solution for the South, even though the polluting business will be located in the South through FDI unless the welfare of the South becomes negative.

The optimal emission standard and the corresponding welfare are only valid as long as the JV is sustained. The JV is formed where both parent firms produce

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[11] The optimal emission standard is not derived as more clear result algebraically. However, it is possible to derive from Eq. (26):

$\underline{e_S^J} = (32\gamma_N\left(\beta\left(-16+32d+\alpha\gamma_N(15-96d+2\alpha\gamma_N(31+36d-36\alpha\gamma_N))\right)\right)+e_N\left(-16d+\alpha\gamma_N(65+16d+\right.$
$2\alpha\gamma N-97+30d-36d-2\alpha\gamma N+8-32\beta+eS1-2\alpha\gamma N232+3\alpha\gamma N-32+21\alpha\gamma N+\alpha\gamma N2\beta208-192d+\alpha\gamma N863d-41+9\alpha\gamma N-9-36d+26\alpha\gamma N+3eN64d+\alpha\gamma N-269-40d+2\alpha\gamma N355-114d+129d-19\alpha\gamma N\gamma S-9\alpha-32\beta+2eS1-2\alpha\gamma N216+\alpha\gamma N27\alpha\gamma N-44+\alpha\gamma N\beta352-256d+\alpha\gamma N576d-560+\alpha\gamma N83-324d+162\alpha\gamma N+eN128d-8+\alpha\gamma N-518-32d+\alpha\gamma N1223-414d+546d-13\alpha\gamma N\gamma S2)/(32\gamma N-32d+\alpha\gamma N65+96d+2\alpha\gamma N-97-36d+72\alpha\gamma N-16-16+\alpha\gamma N112-192d+\alpha\gamma N116+504d+9\alpha\gamma N-83-36d+62\alpha\gamma N\gamma S+9\alpha-32+\alpha\gamma N327-8d+\alpha\gamma N-16+576d+\alpha\gamma N-655-324d+486\alpha\gamma N\gamma S2)$

positive outputs such as $\underline{e_N} \leq \underline{e_0}(e_s) < \underline{e_S}$ and $\underline{\mathrm{e}_{\mathrm{S}}^{\mathrm{J}}} > \underline{e^*}$.

3.3 The optimal emission standard

Considering technology transfer, the benefits of full-ownership FDI are about the same as those from the JV. The reason for this is that both full-ownership FDI and the JV use the technology of firm N. In terms of welfare, the JV is obviously a better option since a share of the JV's profits is included as a portion of welfare.

However, the optimal emission standard under the JV shows that the Southern government has to choose more lenient regulation even though the North's technology is also poor. There may be a case in which the North's technology is superior to the South but is also poor. Then, the government has to determine how to lower the barrier of environment regulation appropriately to attract a JV considering both tax revenue and quality environment loss. These losses more than offset the profit gains.

In addition, Abe and Zhao (2005) examined deregulation in relation to the share of the JV improving the quality of the environment. However, this study does not consider it.

4. Conclusions

This paper analyzed how environmental regulation affects the FDI strategies of parent firms in the North and the South given their differences in abatement technology and R&D efficiency. The optimal emission standard level was derived as an environmental regulation of the South under full-ownership FDI and JV conditions. Through modeling which was based on technology differences between the North and the South, it was possible to investigate the different welfare effects for the South depending on the behavior of both parent firms.

Environmental issues affect both developing and developed countries. However, developed countries have more incentive to invest in the developing because of CDMs. This study focused on FDI strategies in terms of the welfare of the South, with a view to being able to provide better policy modeling for the developing countries. Environmental regulation is not necessarily a barrier to being competitive; the solution lies in FDI flows involving the transfer of environmentally sound technologies (ESTs).

It is natural that if more lenient regulations exist, it is more attractive to form a JV in the South. However, the southern government will opt for lenient regulation even if the abatement technology of the North, while not good, is still superior to their own. It is certain that the northern firm has better abatement technology than the southern, although the northern firm may not have perfect ESTs. This is a reason for which developing countries impose lenient regulations to attract JVs. Furthermore, the welfare of the developing country is optimal when forming a JV in their country.

This paper has some limitations. First of all, it assumed the demand, emission and damage functions are linear in the model. Adapting this would not be able to change the basic structure of main findings in this paper but it could affect some points. Also the consumer surplus was not considered, since all outputs were assumed to be consumed in the third country. This is different in the real world, thus, considering consumers is necessary for future studies.

Secondly, only the welfare of the South was examined. In this model, the South determined their action given the North's strategy. It also should be considered what will come next if there is a chance for the North to react after the South has chosen its response.

Thirdly, the emission standard was considered to be an environmental regulation. However, both firms can reduce emissions through R&D. Thus, it might be possible to execute $e_J - Z_J < \underline{e_S}$, while we only have examined the $e_J - Z_J > \underline{e_S}$ case. If firms reduce their emissions in a standardized way, governments may be able to give subsidies to firms so as to encourage them to be more environmentally friendly.

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