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Endogenous International Joint Ventures and the Environment

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Abstract

This paper examines the welfare effects of emission taxes under a choice between an international joint venture (JV) and a full-ownership FDI (Foreign Direct Investment) by parent firms from a developed country (the North) and a developing country (the South), as well as their location and share decisions. If the South has a poor abatement technology, its best policy is to impose a relatively high emission tax to attract a full-ownership FDI. If it has a good abatement technology, the best policy is to impose a relatively low emission tax to attract the JV. Furthermore, deregulation of foreign ownership of the JV improves the quality of the environment.

JEL Classification Number: F2
Keywords: foreign direct investment, international joint ventures, environment, emission tax, ownership regulation

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1. Introduction

There has been widespread concern on the impact of environmental regulations on foreign direct investment (FDI) and international trade. It is hypothesized that tougher environmental regulations in the developed countries could drive polluting industries towards the developing countries with more lenient policies. Such "industrial flight" would lead to further degradation of the environment in the latter countries due to the concentration of dirty industries, the so-called "pollution havens".[1] Developing countries, however, are reluctant to employ stiffer environmental measures in fear of losing their competitiveness, as is, for example, demonstrated by their objection to an inclusion of environmental issues in recent WTO negotiations. Most developing countries only have primitive abatement technologies. Stiffer environmental measures are impossible to be implemented without adequate technology transfer from the developed countries.

Meanwhile, many developing countries have adopted systematic policies such as tax concessions and export processing zones to attract FDI, to foster employment and economic growth. If accompanied by a transfer of environmentally sound technologies (ESTs), FDI could alleviate the dilemma between environmental pollution and competitiveness. One form of FDI involving technology transfer commonly observed is international joint ventures (JVs). Agenda 21 of the United Nations Conference on Environment and Development (1992) states that "Joint ventures should be promoted between suppliers and recipients of technologies," through which, "sound environmental management practices could be transferred and maintained."[2] While expectations are high, the distribution of international JVs is not evenly spread. UNCTAD (2001) states that a rather small group of developing countries, e.g., the Newly Industrialized Countries (NICs), has gained disproportionately more inflow of FDI from inter-firm cooperation than other, least-developed countries (LDCs).[3]

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[1] Empirical findings on this issue are mixed. While Xing and Kolstad (2002), Becker and Henderson (2000), and Levinson and Taylor (2003) find positive support, Jaffe, Peterson, Portney and Stavins (1995), Nordstörm and Vaughan (1999), and Eskeland and Harrison (2003) only identify negligible effects.

[2] See Chapter 34 of Agenda 21, and also Jha and Vossenaar (2002) and Lovei and Gentry (2002), who promote the diffusion of ESTs through business partners or joint ventures.

[3] See Kang and Sakai (2000), and UNCTAD (2000). According to the *World Investment Report 2002* (UNCTAD), 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.

The purpose of this paper is to examine the welfare effects of environmental policies when the choice between an international JV and a full-ownership FDI, and firm location are endogenously determined. We focus on an industry sensitive to environmental policies (e.g., chemicals), and adopt a setup of a developed country (the North) and a developing country (the South). A firm in the South has lower abatement technology than that in the North, and it can exhibit in two types: either a relatively better one as in the NICs, or a very inferior one as in the LDCs. The international JV is formed through bargaining over the profit share and output, as well as the location choice.[4] While under the full ownership FDI, the Northern firm controls 100 percent of the local branch, under the JV it owns only partially the local branch. In either case, the local branch uses the North's better technology. The South may also impose upper limits on foreign ownership.[5] We investigate the conditions for the formation of the JV and the optimal environmental policy of the South.

Our model can shed light in several aspects on the environmental policies in the developing countries, when attracting international JVs or full ownership FDI. Firstly, the larger the difference in the parent firms' abatement technology, the less likely it is for the international JV to be formed. This finding is consistent with the biased distribution of the international JVs in just a few developing countries (e.g., the NICs), as documented by many reports. The intuition is as follows. As both firms produce in the South, they face the same emission tax. However, with better technology, the parent firm in the North pays less tax per unit of output. Thus, the Northern firm has an advantage in the absence of the JV, which translates into a larger share of the profit from the JV if the JV is formed. The larger the difference, the larger the Northern firm's share of the JV profits. Once its share hits 100%, the JV is not formed and the Northern firm engages in full-ownership FDI.

Secondly, the optimal policy for a developing country with a relatively good abatement technology is to set a low emission tax, to induce the formation of the JV in its boundary. On the contrary, that for a country with sufficiently poor abatement technology is to set a relatively higher emission tax, so as to attract a full-ownership FDI. In the second case, attracting a JV (by lowering

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[4] There are other types such as research JVs. Chiou and Hu (2001) examine environmental research JVs.

taxes) instead of a full-ownership FDI degrades the environment and reduces national welfare. The reason the government of the South chooses a low tax when the Southern firm's technology is relatively good is to improve its bargaining position and hence its share of the JV profits (the lower the tax, the lower North's cost advantage at the threat point). However, if the South has very poor technology, then its share of the JV profits will be low, even with a low tax. In this case, the Southern government may prefer to give up on improving its firm's bargaining position and instead focus on reducing emissions and collecting tax revenue. It does this by choosing a higher tax, thereby permitting full-ownership FDI.

Thirdly, we also consider foreign ownership regulation in the South, under which full ownership FDI is not allowed. The optimal policy for the Southern country with sufficiently poor abatement technology is to attract the JV by setting a relatively high emission tax, which can alleviate the pollution vs. competitiveness dilemma. Since the only alternative to a JV is no investment by the North, there is now a real possibility the North's better technology will not be transferred. The parent firm in the South wants the better technology to reduce its tax payment, while the parent firm in the North wants profits by producing in the South. Both parent firms have incentives to form the JV even with a higher emission tax in the South. Thus, the government in the South with poor technology can impose a relatively high emission tax to attract the JV. In addition, deregulation of ownership shares will raise the optimal tax and improve the quality of the environment. This arises because the marginal negative impact of emission tax on the JV profit falls if the regulated share to the local firm is lowered.

Several theoretical papers have examined the relationship between international differences in environmental policies and FDI. Rauscher (1995, 1997) analyzed the issue by extending the standard model of international capital mobility, while Markusen, Morey and Olewiler (1993, 1995), Markusen (1997), and Ulph and Valentini (1997) investigated the firms' location choice under international oligopoly. Barrett (1994) and Kennedy (1994) examine strategic environmental policies, but abstract from incorporating the firms' location choices and FDI. There is no paper like ours, which endogenizes

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[5] We abstract from investigating the policy effects of the North. Nordström and Vaughan (1999) survey the literature on inter-governmental competition, the so-called "race-to-the-bottom" or "race-to-the-top".

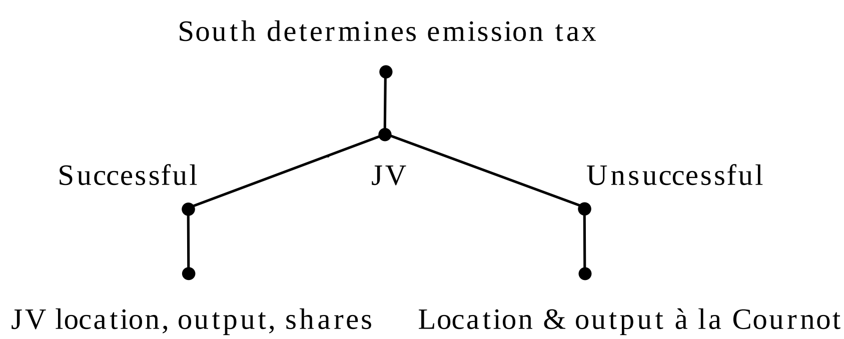
the formation of the international JV incorporating location decisions, and also examines the optimal environmental policy for various technology levels of the South.

The rest of the paper is organized as follows. Section 2 sets up the basic model, incorporating emission tax and FDI. Section 3 describes the properties of the threat point of a bargaining game between the parent firms. Section 4 analyzes the endogenous choices between the formation of the international JV and full-ownership FDI. Section 5 derives some comparative statics results. Section 6 examines the optimal emission tax in the South. Section 7 introduces regulations on foreign ownership. Concluding remarks are given in section 8.

2. The Basic Model

Consider two parent firms *N* and *S* located in two countries the North and South, respectively. Production emits local pollution. Firm *N* has better abatement technology than firm *S*. They bargain to form an international JV, whose production also emits pollution. Both countries have independent environmental policies. Output of the potential JV is only consumed in a third country.

We assume a two-stage game. In stage 1, given the abatement technologies, and the North's emission tax, the South chooses emission tax unilaterally to maximize national welfare; in stage 2, the two parents bargain over location, outputs and their respective shares of the JV. If bargaining is successful, the JV is formed; if bargaining breaks down, both firms can choose to locate in either country and produce independently. A simple game tree can be drawn as follows.



To ensure consistency, we first investigate the second stage of the game, in which bargaining can be successful or unsuccessful.

3. The Threat Point

The threat point is the outcome if bargaining breaks down, then both firms produce independently and compete à la Cournot. Depending on the emission tax structure and abatement technologies, firms may produce positive or zero outputs. A duopoly exists if both produce positive outputs. And a monopoly emerges if the output of one firm is positive while that of the other is zero.

Let the profit of the parent firm in country j that is located in country i be written as

$$\pi_j(x_N, x_S, i) = p(x_N + x_S)x_j - (w_i a + t_i e_j)x_j, \quad i, j = N, S, \tag{1}$$

where w_i and t_i are the wage cost and an emission tax in country *i*, and x_j, a, e_j are respectively the output, unit labor requirement, and emission per unit of output of firm *j*. We assume that firm *S* emits the same or a higher level of pollution per unit of output than firm *N*, i.e., $e_S \geq e_N$.[6] Outputs are consumed only in a third country. And the inverse demand function, $p(x_N + x_S)$, is assumed to be linear for simplicity: $p(x_N + x_S) = \beta - \alpha(x_N + x_S), \ \beta > 0, \ \alpha > 0$.

The total unit costs (including wages costs and pollution tax costs) of firm *N* is $w_i a + t_i e_N$ if it is located in country *i*. The cost difference between locating in the North and the South is given by $(w_N - w_S)a + (t_N - t_S)e_N$. Similar expressions can be defined for firm *S*. Because we do not analyze the effects of wage difference in the two countries, for the rest of the analysis, wages are normalized so that $w_N = w_S \equiv 0$. Thus, the unit cost difference for either firm purely depends on the tax rate differential between the two countries.[7] We focus on $t_N > t_S$, i.e., both firms choose to locate in the South.

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[6] Abatement technologies are assumed to be exogenous. For endogenous abatement activities, see Copeland (1996), Copeland and Taylor (1994, 1995) and Ludema and Wooton (1994).

[7] If the wage is lower in the South than in the North, ceteris paribus, then both firms tend to locate in the South.

Under duopoly, by maximizing (1) with respect to x_j, $j = N, S$, we obtain the outputs at the threat point when both firms are located in the South:

$$x_N^C = \{\beta + (e_S - 2e_N)t_S\}/(3\alpha), \qquad x_S^C = \{\beta + (e_N - 2e_S)t_S\}/(3\alpha). \tag{2}$$

Accordingly, the respective threat-point payoffs are[8]

$$\pi_N^C = \alpha(x_N^C)^2 = \{\beta + (e_S - 2e_N)t_S\}^2 / 9\alpha \equiv \pi_N^C(t_S, e_S), \tag{3a}$$

$$\pi_S^C = \alpha(x_S^C)^2 = \{\beta + (e_N - 2e_S)t_S\}^2 / 9\alpha \equiv \pi_S^C(t_S, e_S). \tag{3b}$$

Notice that $\pi_N^C(t_S, e_S) \geq \pi_S^C(t_S, e_S)$ for any t_S since we have assumed $e_S \geq e_N$.

Define $t_0(e_S)$ as the level of emission tax at which $x_S^C = 0$,

$$t_0(e_S) \equiv \beta/(2e_S - e_N), \tag{4}$$

i.e., $\pi_S^C(t_0(e_S), e_S) = 0$. We need $t_S < t_0(e_S)$ for both firms to produce a positive output at the Cournot equilibrium. Denote the set of payoffs at the threat point as (π_N^0, π_S^0), then $(\pi_N^0, \pi_S^0) = (\pi_N^C, \pi_S^C)$, (see also Brander and Spencer, 1985). These are summarized below:

Lemma 1 (the threat point): *Suppose that* $e_S \geq e_N$ *and* $t_S < t_N$. *At the threat point of the bargaining game, both firms produce a positive output in the South if* $t_S < t_0(e_s)$.

Figure 1 illustrates the case where production occurs in the South. Curve I_S shows $t_0(e_S)$. Then, if the combination is in area I (above e_N and below I_S), both firms produce a positive output at the Cournot equilibrium. In area II, firm S does not produce and firm N becomes a monopoly. And $\overline{t} \equiv \beta / e_N$ is the prohibitive emission tax at which monopoly firm *N* just makes zero profits. Thus in area III, neither firm produces anything.

4. The Formation of the International JV

The JV is formed if bargaining is successful. The two firms negotiate over the location, output and each firm's share of the JV. We assume that the JV fully adopts the better technology of firm *N* for free.[9] A JV located in country *i* has the following profit function

$$\pi_J = (p - e_N t_i) x_J \,. \tag{5}$$

Suppose firm *N*'s share of the JV is s, while that of firm *S* is $1-s$. Then if the JV is formed, the profits of the two firms become, respectively:

$$\pi_N^J = s\pi_J \,, \qquad \pi_S^J = (1-s)\pi_J \,. \tag{6}$$

The parent firms have incentives to form the JV if $s \in (0,1)$.

We adopt Nash bargaining to model the negotiations. The Nash product can be written as [10]

$$V = (\pi_N^J - \pi_N^0)(\pi_S^J - \pi_S^0) \,, \tag{7}$$

where π_N^0 and π_S^0 are the payoffs at the threat point, determined in section 3. The expressions $\pi_N^J - \pi_N^0$ and $\pi_S^J - \pi_S^0$ are the respective net gains of firms *N* and *S* from the bargaining game. The equilibrium is found by maximizing (7) with respect to the location (i.e., country i), x_J and *s*.

Regarding location, the parent firms choose the South if $t_S < t_N$, because π_N^J and π_S^J are larger in the country with the lower emission tax. And with respect to the output and the shares, for an interior solution, the following first order conditions must be satisfied

$$\partial V / \partial x_J = 0: \quad \partial \pi_J / \partial x_J = 0 \,, \tag{8a}$$

$$\partial V / \partial s = 0: \quad \pi_S^J - \pi_S^0 = \pi_N^J - \pi_N^0 \,. \tag{8b}$$

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[8] Since we do not change β and e_N, we will omit them in the solution functions for the rest of this paper.

[9] In an earlier version of the paper, we assumed that technology transfer is also negotiated, and that firm *S* must pay a cost of for *N*'s better technology if the JV is formed. The qualitative results remain the same. Full technology transfer to the JV also supports the fact that multinationals tend to adopt better ESTs. See Nordstrom and Vaughan (1999), p.5, and Bhagwati (2002), p.59.

[10] More general forms such as $V = (\pi_N^J - \pi_N^0)^\gamma (\pi_S^J - \pi_S^0)^{1-\gamma}$ can be adopted, where γ represents the relative bargaining power of firm *N*. See for example Abe and Zhao (2000).

They imply that the two firms first maximize the JV profits by choosing the monopoly level of output as in (8a), and then divide the net realized rents equally by choosing the share, *s*, as in (8b).

From (8a), the output and the profit of the JV are identical to those when firm *N* becomes a monopoly in the South, i.e., $x_J = x_N^M(t_S)$ and $\pi_J = \pi_N^M(t_S)$, where

$$x_N^M = (\beta - t_S e_N)/(2\alpha) \equiv x_N^M(t_S), \quad (9)$$

$$\pi_N^M = \alpha(x_N^M)^2 = (\beta - t_S e_N)^2/(4\alpha) \equiv \pi_N^M(t_S). \quad (10)$$

And from (8b), we also obtain firm *N*'s share

$$s = 0.5 + (\pi_N^0 - \pi_S^0)/(2\pi_N^M). \quad (11)$$

We now prove that the net gain in condition (8b) is positive and the JV is formed. First note that the possible maximum profit of the JV (equal to that of a monopoly by *N*), is larger than the sum of the profits both parent firms can earn by playing Cournot competition. Then $\pi_N^M > \pi_N^0 + \pi_S^0 = \pi_N^C + \pi_S^C$ holds (see also Wong and Leung, 2002, in the absence of environmental issues), giving $0.5 \le s < 1$. To see this, note that s cannot be less than half because $\pi_N^0 \ge \pi_S^0$; In addition, $1 - s = \{\pi_N^M - (\pi_N^0 - \pi_S^0)\}/2\pi_N^M > \pi_S^0/\pi_N^M \ge 0$, leading to $s < 1$. We also obtain $\pi_N^J - \pi_N^0 = s\pi_J - \pi_N^0 = \{\pi_N^M - (\pi_N^0 + \pi_S^0)\}/2 > 0$ by using (11). It follows that $\pi_N^J - \pi_N^0 = \pi_S^J - \pi_S^0 > 0$, which is the condition for the JV to be formed with a positive output.

If firm *N* becomes a monopoly, then $\pi_N^0 = \pi_N^M$ and $\pi_S^0 = 0$. Condition (11) then implies $s = 1$, i.e., firm *N* fully owns the facility, and there is no incentive for the JV to be formed. Furthermore, when the emission tax in the South is higher than the prohibitive emission tax, $\bar{t}$, the JV could not earn positive profits even if it were formed. Thus, both parent firms have no incentive to do so.

We now summarize the above, when the tax rate in the North is above the prohibitive level.[11]

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[11] In an earlier version of the paper, we also analyze the so-called "not-in-my-backyard" (NIMBY). If the North has a fairly low emission tax and the environmental damage is large, the optimal policy for the South is NIMBY. It includes two cases. First, with possible location and a low emission tax in the North, the South with a relatively good abatement technology must reduce the emission tax substantially to induce the JV. But it causes a reduction

Proposition 1: *Suppose that* $e_S \geq e_N$, $t_S < t_N$ **,** *and* $t_N \geq \bar{t}$. (i) *If* $t_S < t_0(e_S)$, *the JV is formed in the South, producing the monopoly level of output;* (ii) *if* $t_0(e_S) \leq t_S < \bar{t}$, *firm N undertakes full-ownership FDI in the South and becomes a monopoly*; (iii) *if* $t_S \geq \bar{t}$, *neither firm produces at all*.

In Figure 1, area I (above e_N and to the left of I_S) illustrates the combination of t_S and e_S under which the JV is formed in the South. In area II (above I_S and to the left of $\bar{t}$), firm *N* undertakes full-ownership FDI and becomes a monopoly in the South. In area III (to the right of $\bar{t}$ and to the left of t_N), neither firm produces at all. Proposition 1 gives the critical emission tax for the formation of the JV. It is $t_S = t_0(e_S)$, which leads to $x_S^C = 0$.

Proposition 1 implies that the formation of the JV in the South becomes more difficult (easier) if the South's abatement technology becomes poorer (better). This finding is consistent with the fact that the number of international JVs in the LDCs is very small, and that international JVs are concentrated in relatively developed developing countries such as the NICs. Countries with poor abatement technology must reduce the emission tax to attract JVs. Thus, the oft-cited "environmental dumping" result of Barret (1994) does not evaporate when JV's are introduced. Instead, the incentive to lower environmental taxes remains as a means of improving the Southern firm's bargaining position in the JV negotiations.

5. Comparative Statics Analysis

In this section, we derive some comparative statics results respectively on the full-ownership FDI and the international JV. First, from (9) and (10), a reduction in the emission tax increases the

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in tax revenue and an increase in the environmental damage. If the South let the JV locate in the North, the tax revenue is lost but better environment is preserved. The latter effect is larger than the former when the emission tax in the North is sufficiently low. Secondly, if the South has a substantially low abatement technology, attracting the JV or the full-ownership FDI causes serious environmental damages. The optimal policy is to let firm *N* stay in the North.

output and the profit of the monopoly firm, and intensifies pollution. The effects are the same on the JV or the full-FDI, since they both produce the monopoly output when chosen.

Next, we look into the effects on the JV shares of a tax change. Since $(\pi_N^0, \pi_S^0) = (\pi_N^C, \pi_S^C)$, substituting (3a), (3b), and (9) into (11), we obtain

$$ds/dt_S = (e_S - e_N)(\beta - e_S t_S)\beta x_N^M / 6\alpha(\pi_N^M)^2 . \qquad (12)$$

From Proposition 1, the highest emission tax the South can impose to induce the JV is smaller than $t_0(e_S) \equiv \beta/(2e_S - e_N)$. Also, $\beta - e_S t_S > \beta - e_S t_0(e_S) = \beta(e_S - e_N)/(2e_S - e_N) \geq 0$ for $t_S < t_0(e_S)$. Thus, from (12), if $e_S > e_N$, a reduction in the emission tax reduces firm *N*'s share of the JV but increases firm *S*'s shar**e**. If $e_S = e_N$, it does not change the JV shares.

Intuitively, in view of (6) and (8b'), a reduction in the emission tax affects the shares of the JV through two channels when $e_S > e_N$. First, it increases the profit of firm *S* more than that of firm *N* at the threat point. In order to have an equal gain from the threat point, firm *S*'s share of the JV must increase; second, it increases the total realized profits of the JV. Given that the share of firm *N* must be larger than that of firm *S*, firm *N* gains more than firm *S*. To keep the net gains equal for both parties from the threat point, the share of firm *N* must be reduced. Put together, a reduction in the emission tax reduces the share of firm *N* and increases that of firm *S*.

The profits the parent firms receive depend on their shares and the profits of the JV. Substituting (11) into (6) yields

$$\pi_N^J = \{\pi_N^M(t_S) + (\pi_N^C(t_S, e_S) - \pi_S^C(t_S, e_S))\}/2 \equiv \pi_N^J(t_S, e_S) , \qquad (13a)$$

$$\pi_S^J = \{\pi_N^M(t_S) - (\pi_N^C(t_S, e_S) - \pi_S^C(t_S, e_S))\}/2 \equiv \pi_S^J(t_S, e_S) . \qquad (13b)$$

Substituting (3a), (3b) and (10) into (13a) and (13b), and differentiating yields respectively

$$\partial\pi_N^J / \partial t_S = [\{7(e_N)^2 - 4(e_S)^2\}t_S + (4e_S - 7e_N)\beta]/(12\alpha) , \qquad (14a)$$

$$\partial\pi_S^J / \partial t_S = [\{4(e_S)^2 - (e_N)^2\}t_S + (e_N - 4e_S)\beta]/(12\alpha) . \qquad (14b)$$

The sign of $d\pi_S^J / dt_S$ is always non-positive while that of $d\pi_N^J / dt_S$ is ambiguous. To see this, evaluating $d\pi_S^J / dt_S$ at $t_S = t_0(e_S)$ to obtain $d\pi_S^J / dt_S = (e_N - e_S)\beta / 6\alpha \le 0$. In order for the JV to be formed, we must have $t_S < t_0(e_S)$. Eq. (14b) thus implies that $d\pi_S^J / dt_S$ is negative under the JV if $e_S \ge e_N$.

The observations above give rise to

Proposition 2: *Suppose that the South reduces the emission tax.* (i) *Under the full-ownership FDI, output and profits increase;* (ii) *Under the international JV, its output and profits increase. The JV share to firm S increases if $e_S > e_N$ and does not change if $e_S = e_N$, but its profit always increases. The JV share to firm N decreases if $e_S > e_N$ and does not change if $e_S = e_N$, but its profit may increase or decrease.*

Next we derive the effects of technology differences on the parents' respective profits from the JV. Differentiating (13a) and (13b) with respect to e_S to obtain

$$\partial\pi_N^J / \partial e_S = -(\partial\pi_S^J / \partial e_S) = t_S(\beta - e_S t_S)/(3\alpha) \ge 0, \tag{15}$$

where the last equality holds only for $t_S = 0$. Otherwise, strict inequality holds because $\beta - e_S t_S > 0$ for $t_S < t_0(e_S)$, which is the condition for the JV to be formed. Thus, we establish

Proposition 3: *Given a positive emission tax, the larger the difference in the parents' abatement technologies, the more (less) firm N (S) benefits from the JV. If there is no emission tax, then the difference does not affect profit distribution.*

This result arises because if the difference in the abatement technology increases, the threat point becomes more advantageous to firm *N*. It follows that firm *N* obtains a larger net share of the JV, which increases its profit, while firm *S* obtains a lower profit because its net share falls.

6. The Optimal Emission Tax for the South

In the first stage, South chooses the emission tax to maximize national welfare, given the abatement technologies and the emission tax in North. We assume that North does not take any action against the emission tax chosen in South. We still assume $t_N > \overline{t}$, so that production can occur only in South. Whether JV or full-FDI arises depends on the emission tax, as shown in Proposition 1. We derive the optimal taxes respectively for both cases.

6.1 Full-Ownership FDI

In this case, firm *N* is a monopoly in the South. Because consumption is in a third country, the South's welfare consists of the tax revenue and the environmental damage.

$$W_S^M(t_S) = (t_S - d)e_N x_N^M = (t_S - d)e_N(\beta - e_N t_S)/(2\alpha), \tag{16}$$

where *d* is the environmental damage per unit of pollution emission. The government chooses t_S to maximize (16), which yields the optimal tax rate as:

$$t_S^M = (\beta + e_N d)/(2e_N). \tag{17}$$

And the corresponding welfare level is:

$$W_S^M(t_S^M) = (\beta - e_N d)^2/(8\alpha). \tag{18}$$

The optimal tax and the corresponding welfare are valid as long as firm *N* undertakes a full-ownership FDI, i.e., $t_0(e_S) \le t_S^M < \overline{t}$. If $t_S^M < t_0(e_S)$, the optimal tax under the full-ownership FDI becomes $t_0(e_S)$. Also, we must have $t_S^M < \overline{t}$, or equivalently $\beta > e_N d$ for the firm to produce a positive output at the optimal emission tax, which we assume true in the following analysis.

6.2 Joint Ventures

Under the JV, the South's welfare consists of the tax revenue, the pollution damage, and firm *S*'s share of the JV profits, which can be written as

$$W_S^J(t_S, e_S) = W_S^M(t_S) + \pi_S^J(t_S, e_S), \tag{19}$$

where $W_S^M(t_S)$ and $\pi_S^J(t_S, e_S)$ are respectively given by (16) and (13b). Eq. (19) differs from (16) in that firm *S* obtains a fraction $1-s$ of the JV profits, and it has the following properties.

Lemma 3: (i) $W_S^J(0, e_S) = W_S^M(0) + \pi_N^M(0)/2 < W_S^M(t_S^M)$, *for any* e_S; (ii) $W_S^J(t_0(e_S), e_S) = W_S^M(t_0(e_S))$, *for any* e_S; (iii) $W_S^J(t_S, e_S) > W_S^M(t_S)$, *for any* $t_S \in (0, t_0(e_S))$.

The intuition is as follows. Firstly, if t_S =0, the net share of firm *N* becomes 0.5 for any e_S, since both parent firms obtain the same net profit at the Cournot equilibrium (see (8b')). We also have $W_S^M(0) + \pi_N^M(0)/2 = \beta(\beta - 4e_N d)/(8\alpha)$, which is smaller than the maximum welfare under the full-ownership FDI given by (18). Secondly, if $t_S = t_0(e_S)$, the net share of firm *N* becomes 1 for any e_S, since it becomes a monopoly firm at the threat point. Thirdly, if the JV is formed, the profit of firm *S* from the JV is always positive, i.e., $\pi_S^J(t_S, e_S)$ >0 for any $t_S \in (0, t_0(e_S))$.

Differentiating (19) with respect to t_S, we obtain the optimal emission tax under the JV:

$$t_S^J = -\{(7e_N - 4e_S)\beta + 6(e_N)^2 d\}/\{4(e_S)^2 - 13(e_N)^2\} \equiv t_S^J(e_S). \qquad (20)$$

In (20), t_s^J is obtained as an interior solution, i.e., $t_S^J(e_S) \in (0, t_0(e_S))$. However, it could be a corner solution, which is either 0 or just below $t_0(e_S)$. Given (20), South's corresponding welfare is

$$W_S^J(t_S^J(e_S), e_S) = W_S^M(t_S^J(e_S)) + \pi_S^J(t_S^J(e_S), e_S). \qquad (21)$$

Using the envelope theorem and Proposition 3, we derive

$$dW_S^J / de_S = \partial \pi_S^J / \partial e_S \le 0, \qquad (22)$$

where equality holds if and only if $t_S^J(e_S)$ =0. Therefore, the maximum welfare of the South under the JV decreases if its abatement technology deteriorates.

6.3 The Optimal Emission Tax

When maximizing welfare, the South takes into consideration the parent firms' decisions. Whether full-ownership FDI or the JV is chosen depends on e_S and t_S, as is shown in Proposition 1. We compare the welfare under the full-ownership FDI and under the JV, and the optimal emission tax for the South is the one yielding the higher welfare.

Let us start with the simplest case that $e_S = e_N$, or $t^0(e_S) = \overline{t}$. For any emission tax less than $\overline{t}$, i.e., for any $t_S \in (0, t^0(e_N))$, the JV is always chosen. Then, South's welfare is defined by curve AC in Figure 2(b), and the optimal emission tax becomes $t_S^J(e_N)$. Expression (20) gives the welfare maximizing emission tax: $t_S^J(e_N) = (\beta + 2e_N d)/3e_N$, and $t_S^J(e_N) < t_S^M$.

Under $e_S > e_N$, if $t_S \in (0, t^0(e_S))$, the parent firms form the JV, and South's welfare is given by (19). The maximum welfare is decreasing in e_S unless $t_S^J(e_S) = 0$, as shown in (22). If $t_S \in [t^0(e_S), \overline{t})$, the full-ownership FDI is chosen, and South's welfare is defined by (16). In this case, the maximum welfare is increasing in e_S until e_S reaches e_S^M such that $t_0(e_S^M) = t_S^M$.[12] If e_S is larger than e_S^M, then $t_0(e_S)$ is smaller than t_S^M. The maximum welfare when the full-ownership FDI is chosen is always attained at t_S^M, and is equal to $W_S^M(t_S^M)$ for any $e_S > e_S^M$.

Now, define $\overline{e}_S$ such that $W_S^J(t_S^J(\overline{e}_S), \overline{e}_S) = W_S^M(t_S^M)$. Applying Lemma 3 we can illustrate South's welfare with various abatement technologies and emission taxes. In Figure 2(b), curve AB represents South's welfare under the full-ownership FDI. Curves AC, DC, and EC are its welfare under the JV for $e_S = e_N$, $e_S = e_S^M$, and $e_S = \overline{e}_S$, respectively. South's welfare under the JV for $e_S = \overline{e}_S$ is given by curve CE. For $t_S \in (0, t_0(\overline{e}_S))$, the JV is chosen, and the South's welfare is given by $W_S^J(t_S, \overline{e}_S)$, which reaches maximum at $W_S^J(t_S^J(\overline{e}_S), \overline{e}_S)$ for this range of t_S. For $t_S \in [t_0(\overline{e}_S), \overline{t}]$, the full-ownership FDI is chosen and the welfare is defined by $W_S^M(t_S)$, which is expressed by curve EA.

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[12] The explicit value of e_S^M is $e_N(3\beta + e_N d)/(2\beta + 2e_N d)$. In Figure 2(b), as e_S increases from e_N to e_S^M, the maximum welfare under the full-ownership FDI increases along curve AD.

The maximum welfare is $W_S^M(t_S^M)$ for this range of t_S. Thus, there are two different levels of the emission tax which maximize the welfare of the South for $e_S = \overline{e}_S$.

From (22), for any $e_S \in [e_N, \overline{e}_S)$, the maximum welfare under the JV is larger than that under the full-ownership FDI. On the other hand, for any $e_S > \overline{e}_S$, we have $W_S^J(t_S^J(e_S), e_S) < W_S^M(t_S^M)$. Under the JV, the South's welfare could be maximized at $t_S = 0$ or just below $t_0(e_S)$ rather than $t_S^J(e_S)$. But from lemma 3 (i) and (ii), the welfare level under the JV attained at these emission taxes is lower than the maximized welfare under the full-ownership FDI. Then, the optimal policy for the South is to set $t_S = t_S^M$ and let firm *N* conduct a full-ownership FDI for any $e_S > \overline{e}_S$.

Figure 2(a) illustrates the optimal emission tax depending on the abatement technology of firm *S*. For $e_S \in [e_N, \overline{e}_S]$, the South's welfare is maximized under the JV, and the optimal emission tax is depicted by curve JJ'.[13] For $e_S \geq \overline{e}_S$, the maximum welfare is achieved under the full-ownership FDI and the optimal emission tax is shown by curve MM'.

Summarizing the above, we can state the following proposition regarding the South.

Proposition 4: *Suppose that* $e_S \geq e_N$, $t_S < t_N$**,** *and* $t_N \geq \overline{t}$. (i) *For* $e_S \in [e_N, \overline{e}_S)$, *the optimal policy is to set the emission tax according to (20) to induce the international JV;* (ii) *For* $e_S = \overline{e}_S$, *the optimal taxes under both the JV and the full-ownership FDI yield identical welfare;* (iii) *For* $e_S > \overline{e}_S$, *the optimal policy is to set the tax according to (17) and to let firm N undertake full-ownership FDI.*

Proposition 4 implies that the South gains to set the emission tax low enough to induce the JV when the two countries' difference in abatement technology is small. A relatively lower emission tax brings lower tax revenue and larger pollution damage, but the benefits from attracting the JV and its technology still more than offset the losses. If the difference in the abatement technology is large, the South should leave firm *N* to undertake fully-owned FDI and impose the optimal tax.

Suppose the South manipulates the emission tax to induce the JV, even if technology difference is very large. The prohibitive level of emission tax for the JV to be established is $t_0(e_S)$. In addition, since $t_0(e_S)$ is decreasing in e_S, we have $t_S^M = t_0(e_S^M) > t_0(\overline{e}_S) > t_0(e_S)$ for any $e_S > \overline{e}_S$. An emission tax lower than t_S^M must be imposed to induce the JV. Therefore, we obtain

Corollary 1: *Suppose that $e_S \geq e_N$, $t_S < t_N$, $t_N \geq \overline{t}$, and the South has a sufficiently low abatement technology such that $e_S > \overline{e}_S$. To induce the JV in the South, the emission tax must be set lower than $t_0(e_S)$, which is below the optimal level. As a consequence, the volume of emission becomes larger.*

This corollary implies that precautions must be taken when encouraging the South to form international JVs instead of full-ownership FDI. Giving incentives to form the JV is not beneficial to a country with sufficiently inferior abatement technology in terms of welfare and the environment. It reduces the tax revenue and degrades the environment, although the South could receive the better technology of the North. In terms of technology transfer for the environment, full-ownership FDI is just as good as the JV, because they use the same technology. When welfare is also considered, the JV could be better because the South has a share of the profits. However, Corollary 1 shows that if the South's technology is sufficiently poor, the Southern government must lower the tax by so much to attract the JV that both tax revenue and quality environment are lost. And these losses more than offset the profit gains.

7. Joint Ventures with Regulated Shares

Many developing countries impose legal limits on foreign ownership. Applied to our model, the South may require that firm *S* owns a minimum share of the JV, which we examine in this section. We provide a case showing that deregulation improves the quality of the environment, especially for the LDCs with poor abatement technology.

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[13] The optimal tax may be increasing in e_s for some interval of e_s (though not illustrated by curve JJ').

7.1 The Threat Point

Firm *N* cannot undertake full-ownership FDI in the South due to the legal limit on foreign ownership, even if $t_S < t_N$. If bargaining breaks down under the minimum share regulation, firm *S* produces in the South, but firm *N* must produce in the North, or exit the market. Specifically, four possible cases arise. The simplest of them is enough to illustrate our point, which we consider now. That is, firm *N* exits the market and firm *S* becomes a monopoly at the threat point. This arises if the tax rate in the North is too high, specifically, $t_N \geq \bar{t}$. [14]

The profit of monopoly firm *S* at the threat point is, for $t_S < \beta / e_S \equiv t_1(e_S)$,

$$\pi_S^M(t_S, e_S) = (\beta - t_S e_S)^2 / 4\alpha . \tag{23}$$

The combination of both parent firms' profits is $(\pi_N^1, \pi_S^1) = (0, \pi_S^M(t_S, e_S))$. If $t_S \geq t_1(e_S)$, then firm *S* does not produce at all and $(\pi_N^1, \pi_S^1) = (0, 0)$. In figure 3(a), dotted curve I_M indicates $t_S = t_1(e_S)$.

7.2 The Formation of a Regulated Joint Venture

Suppose that the South sets the minimum share of the JV to the local firm at $1 - \bar{s}$, with $\bar{s} > 0$. The regulated share may or may not be binding. If the regulated share is just binding or not binding, we must have $\pi_S^J - \pi_S^1 = \pi_N^J - \pi_N^1$ as is similarly shown by (8b). The share is expressed by

$$s(t_S, e_S) \equiv 0.5 - \pi_S^M(t_S, e_S) / 2\pi_N^M(t_S), \tag{24}$$

for $t_S < t_1(e_S)$, and $s(t_S, e_S) = 0.5$ for $t_S \geq t_1(e_S)$. If the share is binding, we must have

$\pi_S^J - \pi_S^1 > \pi_N^J - \pi_N^1$ at $\bar{s} < s(t_S, e_S)$. [15]

Then the net gains for them from the threat point are positive unless $s(t_S, e_S) = 0$, since we have $\pi_S^J - \pi_S^1 \geq \pi_N^J - \pi_N^1 = \min\{s(t_S, e_S), \bar{s}\}\pi^J \geq 0$. In figure 3(a), the JV is formed in areas I and II.

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[14] The three other possible cases are: (i). Neither parent firms produce at all; (ii). Firm *N* becomes a monopoly in the North; (iii). Duopoly: *N* and *S* produce positive outputs in the North and South, respectively.

[15] The maximum value of the non-binding share is 0.5. We assume that the regulated share is smaller than 0.5 so that the regulation can be effective.

The JV is not formed in area III where the profit of the JV cannot be positive, or on line e_N , or on the vertical axis.[16]

The first-order condition for the JV output under regulation is

$$\{(1-\overline{s})(\pi_N^J - \pi_N^1) + \overline{s}(\pi_S^J - \pi_S^1)\}(\partial \pi_J / \partial x_J) = 0, \qquad (25)$$

which says that $\partial \pi_J / \partial x_J = 0$ even if the share of the JV is regulated, i.e., the JV output is the same as that of a monopoly by firm *N*.

7.3 The Optimal Emission Tax under the Regulated JV

The welfare and optimal tax depend on whether the minimum share is binding or not binding. Let us define $\tilde{t}_S(e_S, \overline{s})$ such that $s(\tilde{t}_S, e_S) = \overline{s}$. This is the tax at which the minimum share is just binding. From (24), we obtain $\tilde{t}_S(e_S, \overline{s}) = \{1-(1-2\overline{s})^{0.5}\}\beta / \{e_S - (1-2\overline{s})^{0.5} e_N\}$. In figure 3(a), curve I_R corresponds to $t_S = \tilde{t}_S(e_S, \overline{s})$.[17]

When $t_S > \tilde{t}_S(e_S, \overline{s})$, or the minimum share is binding, South's welfare under the regulated JV is defined as

$$W_S^R(t_S, \overline{s}) = W_S^M(t_S) + (1-\overline{s})\pi_N^M(t_S). \qquad (26)$$

And the emission tax maximizing (26) is given by

$$t_S^R = (\overline{s}\beta + e_N d)/(\overline{s}+1)e_N . \qquad (27)$$

If $\overline{s}$ were binding for all emission tax levels, then South's welfare would be represented by curve AB in figure 3(b).

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[16] If $t_S = 0$ or $e_N = e_S$, we obtain $\pi_S^M(t_S, e_S) = \pi_N^M(t_S)$. Then, $s(t_S, e_S)$ becomes zero, and firm S cannot earn additional gains even if the JV is formed.

[17] Curve I_R lies left of the dotted curve I_M for any $e_S > e_N$.

When $t_S \le \tilde{t}_S(e_S, \overline{s})$, $\overline{s}$ becomes just binding or not binding at all, and in (26), $\overline{s}$ is replaced with $s(t_S, e_S)$. Note that we have (i) $W_S^R(t_S, \overline{s}) = W_S^R(t_S, s(t_S, e_S))$ if $\overline{s}$ is just binding, and (ii) $W_S^R(t_S, \overline{s}) < W_S^R(t_S, s(t_S, e_S))$ if $\overline{s}$ is not binding. Suppose, for example, that $e_S = e_S^R$ in figure 3(b). Then $\overline{s}$ is just binding at $t_S = t_S^R$ and is not binding for $t_S < t_S^R$. Thus, South's welfare can be drawn as ADC. Note that for $t_S \in [\overline{t}, t_N)$, the South's welfare is equal to zero since bargaining breaks down and firm *S* does not produce at all.

Now define $\tilde{e}_S$ such that the maximum welfare under a non-binding $\overline{s}$ is equal to that under a binding $\overline{s}$, i.e. $W_S^J(t_S^J(\tilde{e}_S), \tilde{e}_S) = W_S^R(t_S^R, \overline{s})$. In figure 3(b), when $e_S = \tilde{e}_S$, $\overline{s}$ is just binding at $t_S = \tilde{t}_S$, the same level of maximum welfare is attained both at $t_S^J(\tilde{e}_S)$ and t_S^R. We showed in section 6 that the maximum welfare without regulation is decreasing in e_S. Thus the maximum welfare is attained with a non-binding $\overline{s}$ for any $e_S < \tilde{e}_S$, and the optimal tax schedule is given by curve JJ' in figure 3(a). If $e_S > \tilde{e}_S$, the maximum welfare is attained at t_S^R with a binding $\overline{s}$, and the optimal tax schedule is given by RR'.

We now sum up the results so far in this section.

Proposition 5: *Suppose that* $e_S \ge e_N$, $t_S < t_N$, $t_N \ge \overline{t}$, *and the minimum JV share to firm S is set at* $1-\overline{s}$. (i) *For* $e_S \in [e_N, \tilde{e}_S]$, *the South's optimal policy is to set the emission tax according to (20) to induce the JV with a non-binding* $\overline{s}$. (ii) *For* $e_S \ge \tilde{e}_S$, *the optimal tax is set at* $t_S = t_S^R$ *to induce the JV with a binding* $\overline{s}$.

To see the implications of Proposition 5, consider the hypothetical case in which the formation of international JVs is impossible, and only the local firm in the South produces a positive output. Straightforward calculations show that the optimal tax is equal to the marginal damage, d. This optimal tax is valid as long as the local firm produces a positive output, so that either $d < \beta / e_S$ or

$e_S < \beta / d$ holds. In addition, $\tilde{e}_S$ becomes smaller if the minimum share to the local firm, $1-\overline{s}$, becomes higher.[18] Then, there exists $e_S \in (\tilde{e}_S, \beta / d)$ such that, for the developing countries with abatement technologies within this interval, the optimal tax without the possibility of any JV is d, while the optimal tax is t_S^R when the JV is formed. The South can impose a higher emission tax under the JV than in the absence of the JV because we have $t_S^R - d = \overline{s}(\beta - e_N d)/(\overline{s}+1)e_N > 0$.

Since the local firm has inferior abatement technology, the emission tax brings a relatively heavier burden to the local firm than to the foreign firm in the absence of the JV, which makes the Southern government hesitate to charge a higher tax. If the South attracts the JV, the local firm becomes more competitive in the sense that the JV employs the superior abatement technology of the North. Then, the Southern government can charge a higher emission tax on the JV. In this sense, attracting international JVs in the South can alleviate its dilemma between environmental pollution and competitiveness.

Next, we look into the effects of regulation intensity on the optimal emission tax and the emission level. Differentiating t_S^R in (27), we obtain

$$dt_S^R / d\overline{s} = (\beta - e_N d)e_N / \{(\overline{s}+1)e_N\}^2 > 0, \qquad (28)$$

The inequality in (28) stems from our assumption that $\beta > e_N d$. An increase in $\overline{s}$, or deregulation, reduces the profit share of the JV to firm S, and the negative impact of raising the emission tax on firm S's profit becomes smaller. As a result, the optimal tax becomes larger. Together with Proposition 5, we can establish

Proposition 6: *Suppose that $e_S \geq e_N$, $t_S < t_N$, $t_N \geq \overline{t}$, and South's minimum share is $1-\overline{s}$. If $e_S \geq \tilde{e}_S$, deregulation on the share of the JV raises the optimal emission tax, and reduces emission.*

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[18] This can be verified because curve I_R in figure 3(a) shifts to the left unless $e_S = e_N$ when $1-\overline{s}$ becomes larger.

Proposition 6 follows from proposition 5 and implies that deregulation on the share of the JV improves the quality of the environment. The conflict of competitiveness and environmental quality cannot be resolved by regulation of foreign investment, but rather by its deregulation, for the developing countries with poor abatement technology.

8. Concluding Remarks

We have examined how international differences in abatement technology and emission tax affect FDI strategies of parent firms in the North and the South. We derived the optimal emission tax for the South, either to attract full FDI or a JV, which depends on the level of its abatement technology. Ownership regulation of the JV has also been investigated in detail. Our results are consistent with several documented reports and empirical evidence, which hopefully can provide some guidance to the developing countries in designing policies to attract FDI, foreign technology and especially in preserving the environment.

We abstracted from some important aspects in order to keep our analysis tractable yet relatively comprehensive. For instance, the demand, emission and damage functions are all assumed to be linear. Modifications of these assumptions may change our main results to some degree, but not the basic features of our analysis.

The following extensions can be considered for future research. Firstly, we have used constant abatement technologies in both parent firms. In particular, the parent firm in the North may be able to upgrade its abatement technology and reduce the environmental cost brought by stiffer environmental policies. Then, the firm faces a decision between staying in the home country with technology improvement and investing in the South with more lenient environmental policies.

Secondly, we have adopted an emission tax to model the international differences in environmental policies. But emission standards are becoming more popular as a regulating tool. Investigating the location decisions and the optimal policy under emission standards complements the analysis in the present paper.

Finally, we have examined only the policies of the South. The North may respond to these policies and choose its own best emission tax. It should be interesting to study the Nash equilibrium of a policy game between the two countries.

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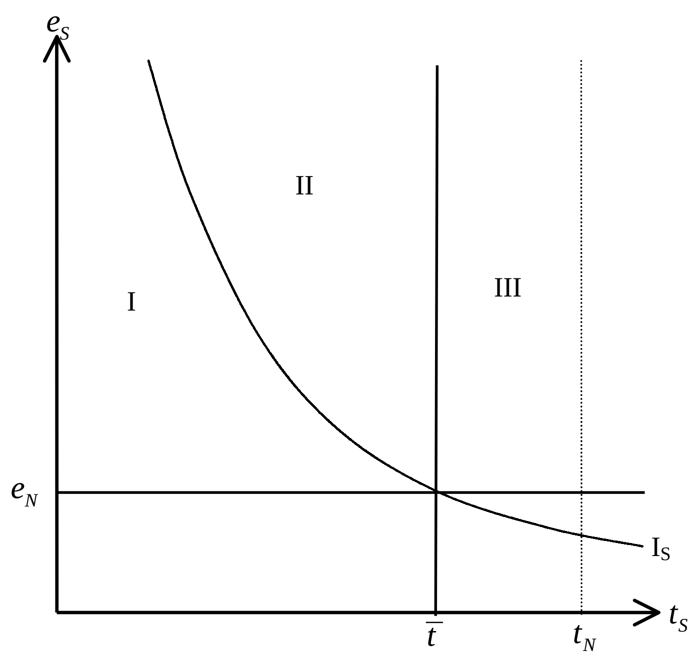
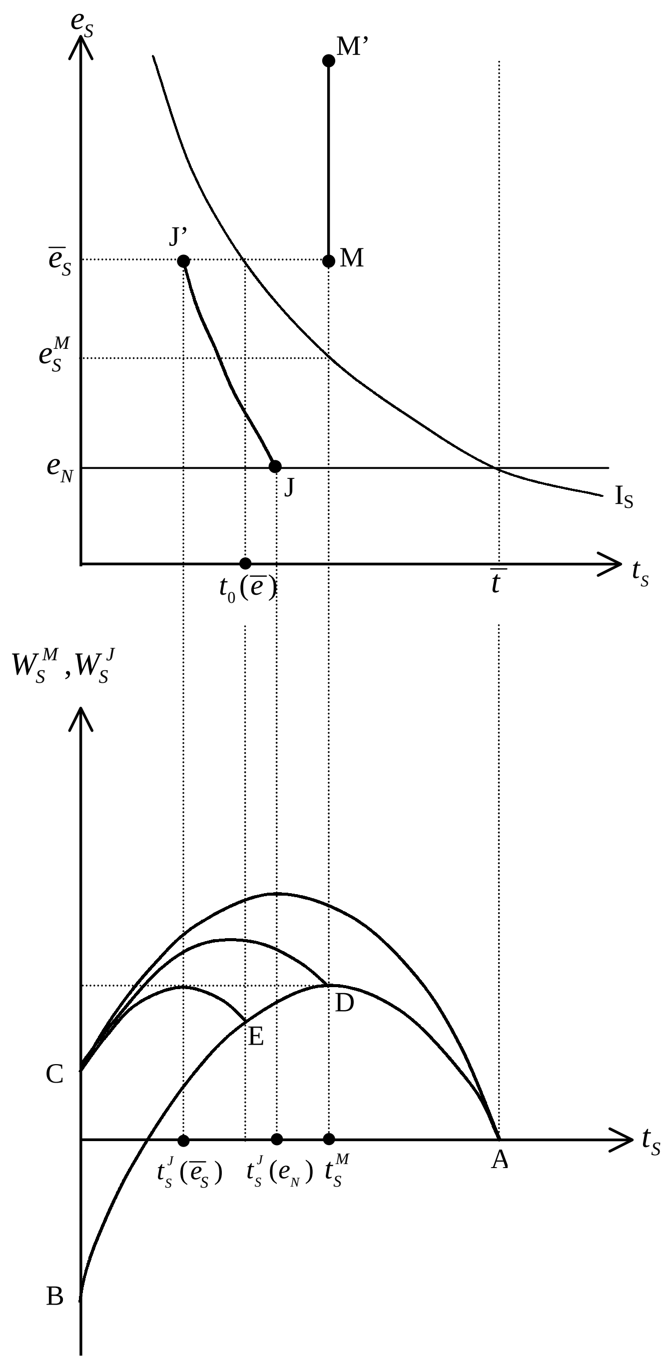


Figure 1

(a)

(b)



e_S
M'
J'
$\bar{e}_S$
M
e_S^M
e_N
J
I_S
$t_0(\bar{e})$
$\bar{t}$
t_S
W_S^M, W_S^J
D
E
C
t_S
A
$t_S^J(\bar{e}_S)$
$t_S^J(e_N)$
t_S^M
B

Figure 2

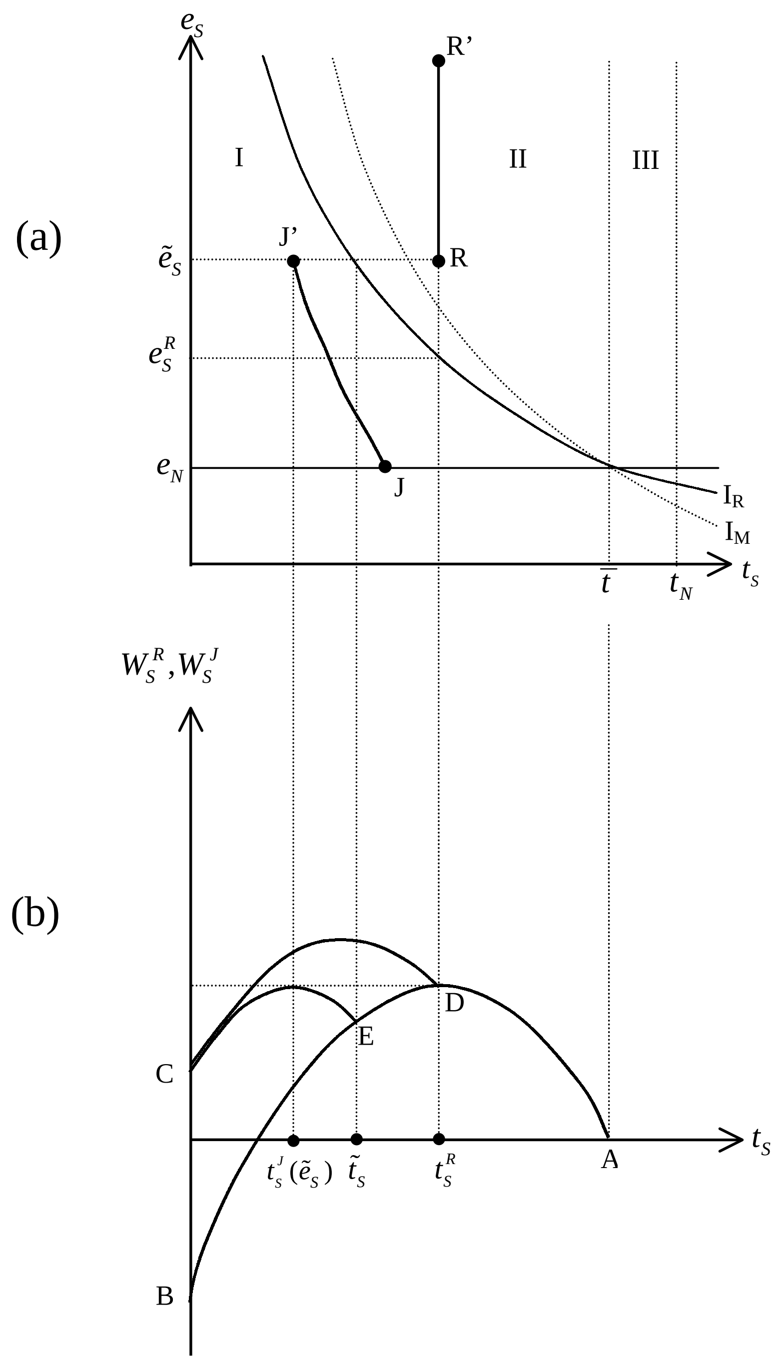

(a)
e_S
R’
I
II
III
J’
$\tilde{e}_S$
R
e_S^R
e_N
J
I_R
I_M
$\bar{t}$
t_N
t_S
(b)
W_S^R, W_S^J
D
E
C
t_S
$t_S^J(\tilde{e}_S)$
$\tilde{t}_S$
t_S^R
A
B

Figure 3