International Agricultural Trade and Policy Center

FOREIGN DIRECT INVESTMENT AND EDUCATION INVESTMENT IN DEVELOPING COUNTRIES

By

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WORKING PAPER SERIES

UNIVERSITY OF FLORIDA

Institute of Food and Agricultural Sciences

INTERNATIONAL AGRICULTURAL TRADE AND POLICY CENTER

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Foreign Direct Investment and Education Investment in Developing Countries

By

Nobuyuki Iwai, Stanley R. Thompson, and Priyodorshi Banerjee[*]

We introduce a model to explain the economic rationale for the observed policy combination of a developing country (hosting foreign direct investment (FDI) through education investment (EDI)) and the interest of a multinational corporation (MNC) in the local labor quality when it contemplates FDI. Information on local labor is the source of a more efficient contract for the MNC with local labor, and the local government can benefit both agents through EDI, FDI, and information sharing. This strategy set is likely to be used by a country in the early stage of economic development. The education level chosen by the local government, however, will be higher than that which maximizes the welfare of local labor. In that sense, the government has the incentive to benefit itself and the MNC at the expense of local labor.

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Foreign Direct Investment and Educational Investment in Developing Countries

1 Introduction

The role of informational asymmetries occupies a central position in the theory of foreign direct investment (FDI). The existing literature has focused on the choice between FDI and licensing to a local firm in an environment where a multinational corporation (MNC) sells in the host-country (local) market (Ethier 1986, Ethier and Markusen 1996, and Horstmann and Markusen 1996). These studies have focused on the advantage of internalizing information about technology and local demand. When considering FDI in developing countries, however, the local market is often of limited importance. MNCs largely use these production centers as an export base to industrialized-country markets, as evidenced by high export-to-local-sales ratios (see the evidence below and also Hayami 2001 and McMilan et al. 1999). As such, two additional considerations absent from the literature are important: information about local labor quality and the role of governments (local or national).[1]

A compelling reason for FDI by an MNC is the availability of relatively cheap skilled labor, making production operations within a developing country profitable for the MNC (Wakasugi 1996). The payoff from investing in a developing country is thus dependent on the quality of the local labor force. Since an MNC typically has imperfect knowledge about the local labor quality, the MNC can gain if the local government shares information about its labor quality.

This paper provides an economic rationale for the observed policy combination whereby developing-country governments host FDI by investing in education and sharing

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[1] This is true, especially for FDI in Southeast Asian countries. See Collins and Bosworth (1996), and Bloom et al. (1998) for evidence on East and Southeast Asian countries' outward oriented economic policy and promotion of education.

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information (OECD 2002[2], United Nations 1999, McMilan et al. 1999). In our benchmark model, the MNC makes FDI in a developing country and offers contracts to local laborers. Precise information on local labor quality will lead to a more efficient contract, which is the source of information rent. Since the local government has superior information about the quality of the labor force, it exploits this advantage by sharing information with the MNC and taxing its profits. Furthermore, the local government has an incentive to use these tax revenues for education investment (EDI) because this raises the value of information and, thus, the profits of the MNC. The point at which the developing-country government starts investing in education we term the "*take-off point.*" The behavior of the *take-off point* is an important contribution of our work.

This paper adds to the literature on the relationship between FDI and local government policy (Horstmann and Markusen 1987, Glass and Saggi 1999, Glass and Saggi 2002). Glass and Saggi (2002) analyze direct subsidies to an MNC by a developing-country government. In their model, the MNC possesses a superior technology compared to the local firms. The local firms can acquire the superior technology by hiring away the MNC workers, but the MNC can prevent this by paying a wage premium. Then the welfare-maximizing government may induce FDI through the direct subsidy aiming either for technology transfer or wage increases. In Glass and Saggi (1999), the impact of government policy is studied in a model which examines how FDI changes the distribution of wages and profits between host and source country with oligopolisitic industries. Horstmann and Markusen (1987) study whether an MNC interested in selling to a foreign market prefers to export, license production or invest

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[2] OECD (2002) emphasizes importance of the role of local government by concluding "The major impact of FDI on human capital appears to have occurred not so much through the efforts of individual MNEs as from government policies designed to attract FDI via enhanced human capital." (p.122)

directly in a reputation based model. The local government has the incentive to induce licensing production because it leads to higher consumer surplus and licensee profit which otherwise accrues to the MNC.

None of these papers address the possibility that the host country government can have private information which is valuable to the MNC or study the information sharing and education investment policies. Further, by making the government one of the players which may either choose to maximize its own net revenue or the welfare of the local labor,[3] we more closely reflect reality in many developing countries, in that the government may place a higher priority on its net revenue over the welfare of local labor. Above all, we are the first to model the relationships among FDI, EDI, and the rents accruing from labor quality information.

The rest of the paper is as follows. In section 2, evidence is presented on the relationship between FDI and EDI in developing countries. We present some evidence showing that, relative to the local output market, the local labor market is more important for FDI in developing countries. Section 3 presents the basic structure of the model. In section 4, the MNC decision problem is analyzed. In section 5, we investigate the policy of a local government that chooses a level of education and a tax rate to maximize its net revenue. In section 6, the welfare effect of the policy is illustrated. We show that the local government policy can benefit both itself and the MNC at the expense of local labor welfare. We also study how government policy will change when the welfare of local labor is considered. Finally, conclusions follow in section 7.

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[3] In section 6, it is shown that the policy which maximizes net revenue and that which maximizes welfare of local labor, is quite different in our model. We further study the case in which the government maximizes the sum of these.

2 Evidence

A positive relationship between FDI and EDI in developing countries is shown in Figure 1. Here we depict the average annual growth rate of FDI inflow and that of public spending on education between 1980 and 2000 for 20 countries.[4] The correlation coefficient between the two annual growth rates is 0.45, one-sided p-value less than 0.025.
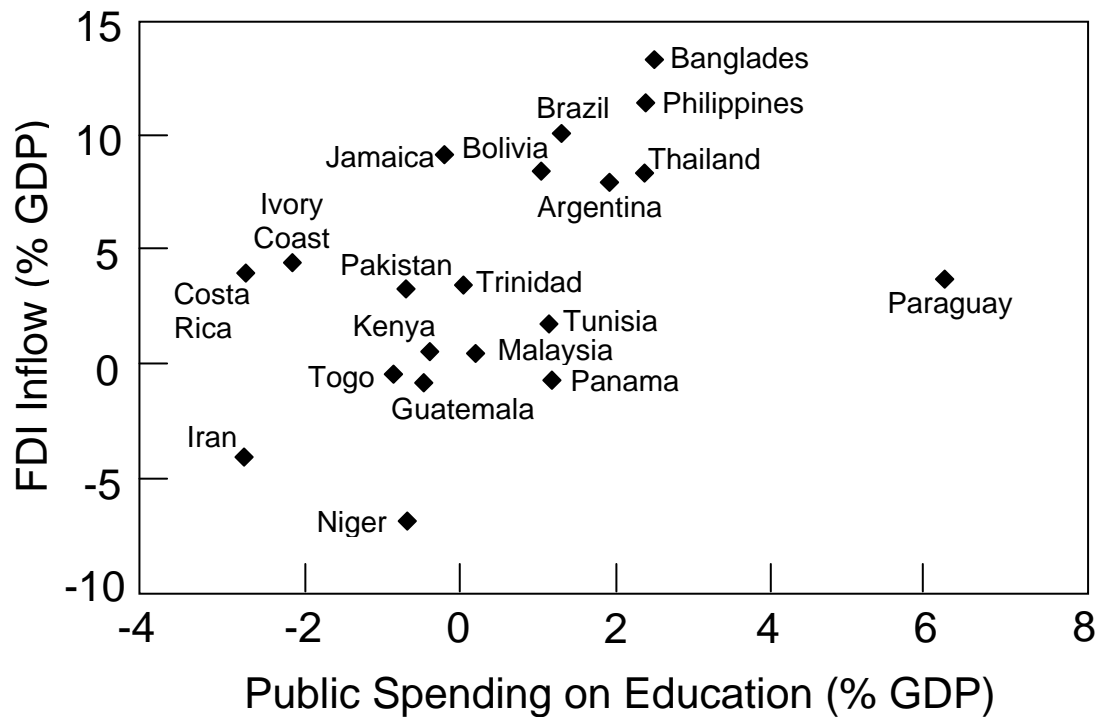

Figure 1. The average annual growth rate of FDI inflow and public spending on education (both as a percent of GDP).

Although not shown, we calculated the average growth rate of secondary school enrollment ratio for the same 20 countries over the same period. The correlation coefficient with this measure of education investment and FDI is 0.33, one-sided p-value less than 0.10. Again, higher EDI tends to host more FDI.

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[4] Per capita GDP in all 20 countries was less than $10,000 in year 2000. FDI inflow data were from UNCTAD (2004). All other data are taken from World Bank (2003).

For many industries, the importance of the local labor market relative to the local output market is dramatic. This is typical in East Asia. In 1995, for instance, 27.4 percent of laborers in the Japanese electrical products industry lived abroad, while for the automobile and nonferrous metal industries these numbers were 32.3 and 36.5 percent, respectively. In turn, FDI can be very important for the local labor market. The share of employment within the electrical products industry held by Japanese firms was 38.8 percent in Singapore, 37.3 percent in Indonesia, 38.0 percent in the Philippines, and 28.2 percent in Malaysia. For the automobile industry the employment shares were 34.3 percent in Indonesia and 30.9 percent in Malaysia.[5]

The data above show that the local labor market is of considerable importance in the context of FDI in developing countries. What about the local-goods market as a source of revenue for the MNC? For Japanese firms within the ASEAN 4 (Indonesia, Thailand, the Philippines and Malaysia), the proportion of exports in total sales in 1996 was 79.0 percent for the electrical products industry, 57.6 percent for the precision machinery industry, and 54.0 percent for the textile industry (Fukao and Amano 1998). For all industries, 18.1 percent of the total exports from the Philippines in 1996 was by Japanese firms. For Malaysia and Thailand, total exports by Japanese firms were 17.7 and 17.3 percent, respectively (MITI 1999). These data suggest that the local output market is a less important revenue source than the export market.

3 Model Description

Information about the quality of local labor plays an important role in our model. The local government has superior information on local labor quality (composition of the

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[5] All of these are data for 1995, cited from Fukao and Amano (1998).

skilled labor) over the MNC seeking to set up a production site in a developing country.[6] Because higher tax revenue flows from higher MNC profits, the local government takes advantage of the MNC's interest in labor quality information by investing in education and revealing it (in another context, the MNC has incentive to inquire about the information). This strategy set (FDI, EDI, and information sharing) makes both agents at least as well off as without it. However, the education level chosen by the local government will be higher than that which maximizes the welfare of local labor. Hence, the local government would increase its own net revenue and the MNC's profit at the expense of local labor.

The sequence of actions in the basic model is as follows. First, the MNC makes its decision to enter based on the probability distribution of labor quality. Without other information it cannot compute the probability of positive EDI, so it enters if expected profit is non-negative. Upon entrance, the local government chooses the level of education, and reveals the information on education and tax rates. Then, the MNC implements a principal-agent contract with local labor. Finally, the local government taxes the profit of the MNC. This sequence is shown as Figure 2.

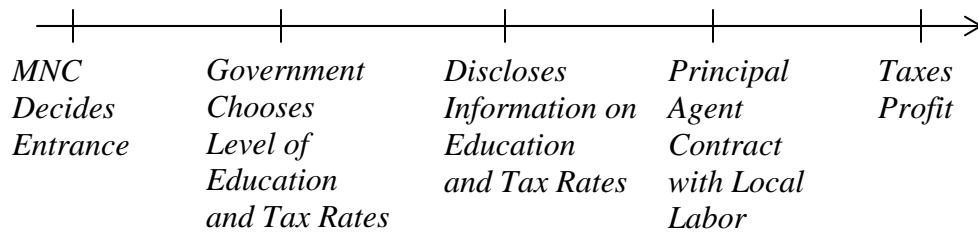| MNC Decides Entrance | Government Chooses Level of Education and Tax Rates | Discloses Information on Education and Tax Rates | Principal Agent Contract with Local Labor | Taxes Profit |

Figure 2. Sequence of actions in the basic model

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[6] We assume that the MNC does not have the option to license the local firm due to the high merit of internalizing technological information.

The local government can contact the potential entrant but will incur costs of search and access. The local government avoids this extra cost if the MNC enters the region without this "before-entrance-contact." However, if the expected MNC profit is negative but the local government still can profitably host FDI, the government will contact the potential entrant even with the extra cost. Then the sequence of actions is changed as in Figure 3; we call this case *"FDI inducing EDI."*
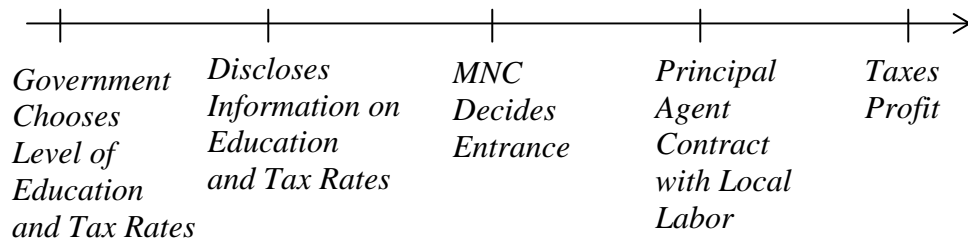
Government Chooses Level of Education and Tax Rates	*Discloses Information on Education and Tax Rates*	*MNC Decides Entrance*	*Principal Agent Contract with Local Labor*	*Taxes Profit*

Figure 3. Sequence of actions when the local government engages in *"FDI inducing EDI."*

4 MNC Decisions

4.1 Principal-Agent Contract

Consider an MNC setting up a factory in a developing country and implementing a principal-agent contract with local labor. We first analyze the case with precise information of labor quality, and then the case with only the probability distribution of labor quality.

The firm sells the product competitively as a price taker in the global market; thus, it can sell as much of the product as it wants at $p = 1$ (price is normalized to one). The firm is owned by shareholders with globally diversified portfolios; the global capital market affords complete hedge against the risk of operation at this developing country site. This

assumption results in risk-neutrality of the firm with respect to profit from this site.[7]

Within the developing country, the labor supply for the specific industry is fixed (also normalized to one).[8]

There are two types of labor (skilled and unskilled). We normalize the reservation utilities for each type of labor to zero. While a laborer knows his own type, outsiders cannot distinguish an individual's laborer type.[9] We can imagine the proportion of skilled labor P ($0 \leq P \leq 1$) to be the indicator of local labor quality. We assume that P is increasing in the level of education. Thus P can also be understood as a measure of the level of education.

In keeping with the terms skilled and unskilled, we assume that skilled labor suffers a lower disutility of effort. If the MNC knew the real value of P, it would implement a screening contract. The principal-agent problem is given by

$$\max_{x_1, x_2, w_1, w_2} P(x_1 - w_1) + (1 - P)(x_2 - w_2) - F$$
$$s.t. \quad w_1 - c_1(x_1) \geq 0$$
$$w_2 - c_2(x_2) \geq 0$$
$$w_1 - c_1(x_1) \geq w_2 - c_1(x_2)$$
$$w_2 - c_2(x_2) \geq w_1 - c_2(x_1),$$

where, $i =$ type of labor (1 if skilled, 2 if unskilled), $x_i \geq 0$ is the production level of labor type i, w_i is the wage of labor type i, c_i is the disutility from working for labor type i, and $F > 0$ is a fixed setup cost for the MNC. The constraints are standard; the first two are the participation constraints guaranteeing each type of labor their reservation utility,

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[7] Ethier (1985) used a similar assumption to have risk-neutrality of a firm. In the following adverse selection type setting, no other agent faces a risk.

[8] Alternatively we can assume that there is an unpaid local resource whose volume is fixed. We can also assume that an internal resource, such as managers sent from the source country, is limited.

[9] We assume laborers cannot engage in ex-ante signaling.

and the next two are the incentive compatibility constraints ensuring that a laborer of type i prefers the contract (x_i, w_i). We impose the following assumption:

Assumption 1: $c_i(x)$ is continuous and twice differentiable for $x \geq 0$. $c_i(0) = 0$, $c_i'(0) = 0$, and for $x > 0$, $0 < c_1(x) < c_2(x)$, $0 < c_1'(x) < c_2'(x)$ and $0 < c_1''(x) < c_2''(x)$.[10]

Solving this problem for a given P leads to the first-order conditions (Mas-Colell et al. 1995),

$$w_1 = c_1(x_1) + w_2 - c_1(x_2), \tag{1}$$

$$w_2 = c_2(x_2), \tag{2}$$

$$c_1'(x_1) = 1, \tag{3}$$

$$c_2'(x_2) = 1 - P + P c_1'(x_2). \tag{4}$$

The MNC's problem yields the optimal strategy vector $(x_1(P)$, $w_1(P)$, $x_2(P)$, $w_2(P))$.[11] Let $\Pi^*(\tilde{P})$ denote optimal profit for the MNC when $P = \tilde{P}$. Further we define

$a_i(\tilde{P}) = x_i(\tilde{P}) - w_i(\tilde{P})$, and $b(\tilde{P}) = x_1(\tilde{P}) - w_1(\tilde{P}) - (x_2(\tilde{P}) - w_2(\tilde{P}))$. $a_i(\tilde{P})$ is the profit from a contract with a laborer of type i, and $b(\tilde{P})$ is the extra profit earned from a contract with a skilled laborer over that with an unskilled laborer. From equations (1)

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[10] These are standard conditions; disutility is increasing and convex in effort, and unskilled labor suffers a larger disutility than skilled labor. The assumption that $c_i(0) = c_i'(0) = 0$ is unnecessary but simplifies calculations.

[11] Equations (1) through (4) express the solutions even for $P=0$ and $P=1$ cases. When $P=0$, they yield $c_2'(x_2) = 1$, $w_2 = c_2(x_2)$. When $P=1$, they yield $c_1'(x_1) = 1$, $w_1 = c_1(x_1)$. These are the identical solutions as in the principal-agent contract with one kind of labor. From Assumption 1, w_i and x_i are continuous.

through (4) and Assumption 1, we have $a_2(\tilde{P}) \geq 0$, $a_2'(\tilde{P}) \leq 0$, $b(\tilde{P}) > 0$ and $b'(\tilde{P}) \geq 0$ (formal proofs are given in Appendix I). Furthermore, we have the following lemma:

Lemma 1: $\Pi^*(\tilde{P})$ is increasing and convex in $\tilde{P}$.

Proof: See Appendix II.

Next, we investigate the case in which MNC does not know the exact value of P. However, the distribution is common knowledge. Let $f(P)$ be the probability density function of P, and let $\bar{P}$ ($0 < \bar{P} < 1$) be the mean of the random variable.[12] Knowing this probability distribution, the MNC seeks to design the contract to maximize expected profit. It is easy to show that the optimal contract involves the same first-order conditions (equations (1) through (4)), but uses $\bar{P}$ instead of P. This means that the MNC sets the target value to $\bar{P}$.

Given the target value, we denote ($x_1(\bar{P})$, $w_1(\bar{P})$, $x_2(\bar{P})$, $w_2(\bar{P})$) as the strategy vector chosen by the firm. This strategy successfully distinguishes skilled from unskilled labor regardless of the real value of P, implying that profits earned from skilled labor and from unskilled labor are fixed. The MNC can compute its profit from this contract for each real value of P. Profit from this strategy can be expressed as

$$\Pi(P, \bar{P}, F) = P[x_1(\bar{P}) - w_1(\bar{P})] + (1 - P)[x_2(\bar{P}) - w_2(\bar{P})] - F$$
$$= a_2(\bar{P}) + b(\bar{P})P - F, \tag{5}$$

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[12] One way of thinking about this is that the MNC is planning to enter a province or state in a developing country. While it may know the probability distribution of the labor quality for the entire country, it is uncertain about the exact labor quality for a particular province.

where $a_2(\cdot)$ and $b(\cdot)$ are previously defined. Equation (5) gives the reservation profit of the MNC when it does not know the real value of P. Since $b(\overline{P}) > 0$, the reservation profit is increasing and linear in P (see Figure 4).[13] If the firm knows the real value of P, the optimal profit is

$$\Pi^*(P, F) = a_2(P) + b(P)P - F. \tag{6}$$

The gain to the firm from knowing the real value of P is therefore the difference between equations (6) and (5). We call this difference information rent and denote it as $R(P, \overline{P})$.

$$R(P, \overline{P}) = [a_2(P) + b(P)P] - [a_2(\overline{P}) + b(\overline{P})P]. \tag{7}$$

From Lemma 1, optimal profit $\Pi^*(P, F)$ is increasing and convex in P. Reservation profit $\Pi(P, \overline{P}, F)$ is increasing and linear in P. These two are equal at $P = \overline{P}$, which means that, if the expected value $\overline{P}$ is equal to the real value P, information rent is zero and, there is no loss of efficiency. At any other point $\Pi^*(P, F) > \Pi(P, \overline{P}, F)$. Reservation profit is shown in Figure 4 as the tangency line at $\overline{P}$ to the optimal profit. The vertical distance between the two is information rent which is shown in Figure 5.[14] Figure 5 also shows that information rent weakly increases for any P larger than, or equal to, $\overline{P}$ as the expected value $\overline{P}$ decreases. Formally, we have

Lemma 2:
$$-\frac{\partial R(P, \overline{P})}{\partial \overline{P}} \geq 0 \quad for \quad P \geq \overline{P}. \tag{8}$$

Proof: See Appendix III.

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[13] $a_2(\overline{P}) - F$ is the intercept and $b(\overline{P})$ is the slope of reservation profit in Figure 4.

[14] In Figure 4, information rent is larger on the right side of $\overline{P}$ than on the left side. But this is just because of the way the figure is drawn. The relative size could be opposite, and it does not affect our analysis.
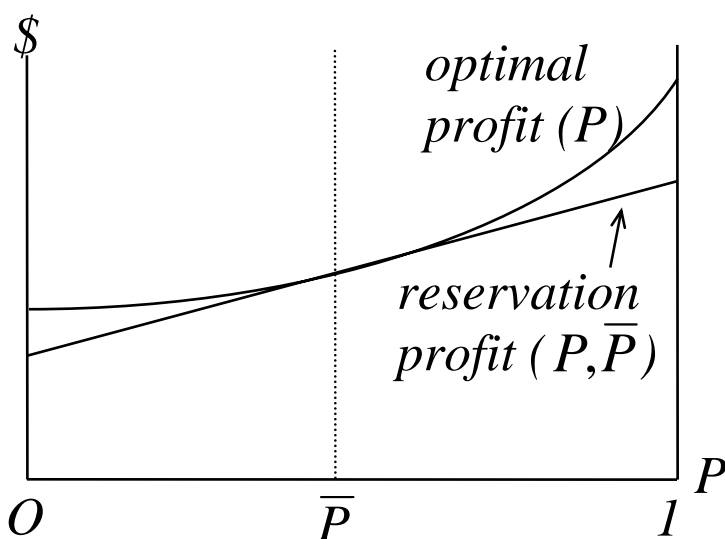
Figure 4. Optimal profit and reservation profit.
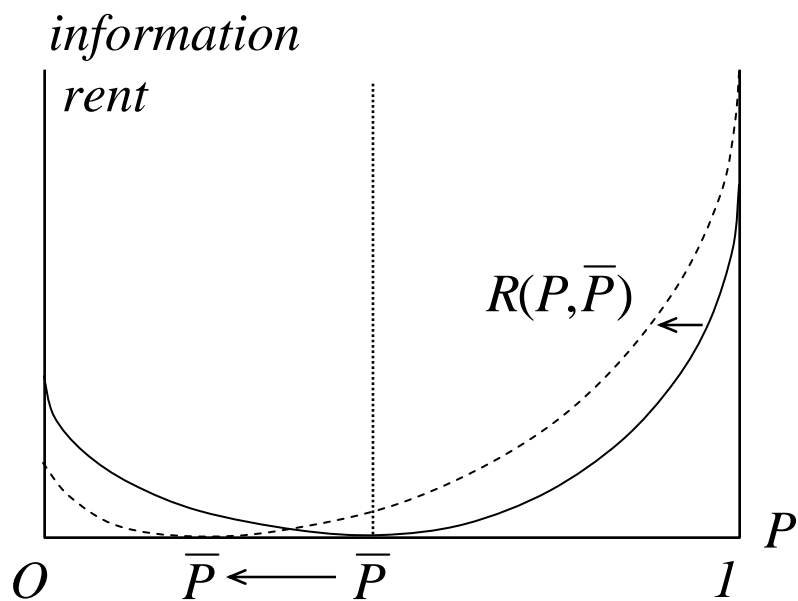

Figure 5. Information rent. Decrease in $\overline{P}$ weakly increases information rent for any level of P larger than, or equal to, $\overline{P}$.

A downward shift of $\overline{P}$ shifts the point of tangency between $\Pi^*(P,F)$ and $\Pi(P,\overline{P},F)$ to the left in Figure 4. This shift weakly increases the information rent at any point to the right of, or on, $\overline{P}$.

4.2 Entrance Decision

The *entry point* of the MNC can now be defined, given that the real level of local labor quality (P) is unknown to the MNC. In this case the entry decision depends on whether or not its expected reservation profit is non-negative.[15] From equation (5) expected reservation profit is given as,

$$E\{\Pi(P,\overline{P},F)\} = a_2(\overline{P}) + b(\overline{P})\overline{P} - F.$$

We can use Lemma 1 to show that the expression above is increasing and convex in $\overline{P}$. In Figure 6, the expected reservation profit for a given F is depicted as an increasing convex curve. Let $\overline{P}_e$ denote the value of $\overline{P}$ which makes expected reservation profit equal to zero.
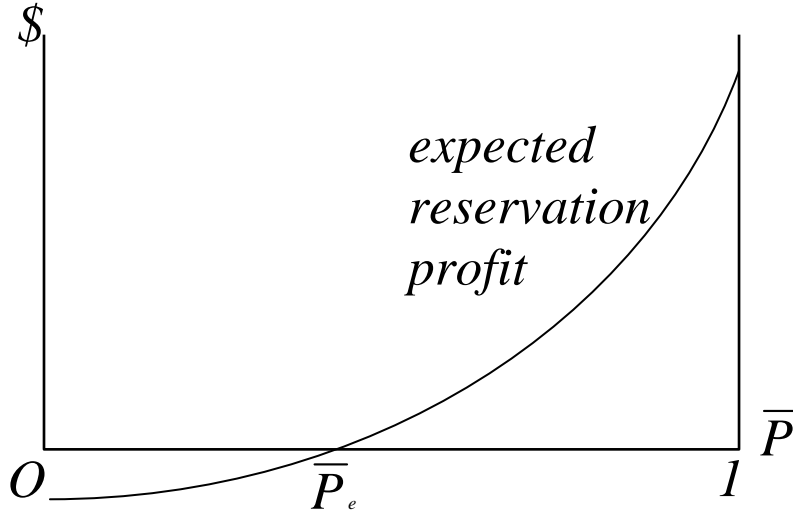
Figure 6. Expected reservation profit. MNC enters the developing country if $\overline{P} \geq \overline{P}_e(F)$, where $\overline{P}'_e(F) > 0$.

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[15] Without any other information than the distribution of labor quality, the MNC cannot compute probability of a positive EDI.

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Any value of $\overline{P}$ greater than $\overline{P}_e$ will yield a positive expected reservation profit. As long as $\overline{P}$ is higher than $\overline{P}_e(F)$ the MNC will enter the developing country. As the setup cost increases, the expected reservation profit decreases; $\overline{P}_e(F)$ shifts to the right, and the range of $\overline{P}$, which allows the MNC to enter, becomes smaller. In summary, the MNC's decision to enter depends on the values of $\overline{P}$ and F in the following way:

Proposition 1: The MNC's incentive to enter is increasing in $\overline{P}$, and decreasing in F. It enters if $\overline{P} \geq \overline{P}_e(F)$, where $\overline{P}'_e(F) > 0$; otherwise, it does not.

Having defined the MNC's entry problem when it is uninformed about the real value of labor quality, we now analyze the local government's information sharing and education investment policy.

5 Local Government Policy

5.1 Education Investment

As shown above, the MNC can gain from knowing the labor quality P (i.e., the true probability that a randomly selected local laborer is skilled). The local government can take advantage of that interest by sharing information with the MNC in exchange for tax revenues. Furthermore, the government can use these revenues to invest in education (EDI).[16] In this section, we shall study the behavior of a government that is assumed solely to care about its own net revenue (i.e., the government is assumed to maximize tax

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[16] Tax revenue is used for educational investment before production. One can think of the government as having access to credit at a zero interest rate. The introduction of a (small) positive interest rate does not change our results qualitatively.

revenues less education cost). In section 6.3 we study the behavior of a government that also cares about the welfare of local labor.[17]

We begin by assuming relatively high expected labor quality and relatively low setup cost, so that the expected reservation profit is positive and the MNC enters without information sharing. However, if expected labor quality is low and setup cost is high, the expected reservation profit is negative. Then the MNC enters only if the government induces it with EDI and information revelation. Such a situation has important welfare implications, and it is investigated as the *"FDI inducing EDI"* discussed in section 6.2.

The optimization problem of the local government, given FDI, takes the following form:

$$\max_{P,t}[t\Pi^*(P,F) - \int_{P_o}^{P} C(P)dP]$$
$$\text{subject to}$$
$$(1-t)\Pi^*(P,F) \geq \Pi(P,\overline{P},F),$$
$$t\Pi^*(P,F) - \int_{P_o}^{P} C(P)dP \geq 0,$$

where, t is the tax rate on the MNC profit, P is the portion of skilled laborer *after* EDI, P_0 is the portion of skilled labor *before* EDI, $C(P)$ is the marginal cost of education, $\Pi^*(P,F)$ is optimal profit of the MNC knowing the real value of P, and $\Pi(P,\overline{P},F)$ is reservation profit for the MNC.

This constrained optimization problem has a double principal-agent structure. The local government is the principal to the MNC, and the MNC is the principal to local labor. Given the principal-agent strategy of the MNC against local labor, the local

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[17] We assume that the only revenue source for the government is taxes from the MNC. We do not look at the possibility of income taxes on local labor. One can think of the developing country in question as a country where it is difficult, either for reasons of low prevalent incomes, or because of administrative difficulties, to levy income taxes.

government chooses the tax rate and the education level to maximize tax revenue less the cost of education. The first constraint guarantees that the *after tax* profit of the MNC is larger than, or equal to, the reservation profit. The second constraint guarantees the local government tax revenue less the cost of education is non-negative.

Also, note that we simply assume that the government tells the MNC the true value of *P*. However, this truth-telling can be made the optimal strategy with the following assumptions often made in persuasion games (Grossman 1981, Milgrom 1981). First, the principal (government) cannot reveal false information. Second, an agent (MNC) has rational expectations about the strategy of the counterpart. In our case, we can show that the government cannot increase its revenue by misleading the MNC to believe the value of *P*, which is higher than the true value. Then, an MNC with rational expectations should expect that the true *P* is the maximum value in the set presented by the government. So, there is no incentive for the government to tell a lie.

From the first constraint, we have

$$\Pi^*(P,F) - \Pi(P,\overline{P},F) - t\Pi^*(P,F) = 0.$$
$$\Rightarrow R(P,\overline{P}) - t\Pi^*(P,F) = 0,$$

where $R(P,\overline{P})$ is the information rent defined earlier, which does not depend on setup cost (*F*). Substitution of this into the objective function and the second constraint results in the following local government optimization problem:

$$\max_{P,t}[R(P,\overline{P}) - \int_{P_0}^{P} C(P)dP] \tag{9}$$

$$\text{s.t. } R(P,\overline{P}) - t\Pi^*(P,F) = 0, \tag{10}$$

$$R(P,\overline{P}) - \int_{P_0}^{P} C(P)dP \geq 0. \tag{11}$$

The local government chooses P so as to maximize the information rent less the cost of education. It then sets the tax rate so that the *after tax* profit of the MNC is equal to reservation profit at P.

From Figure 5, we know that the marginal information rent is negative at any point $P < \overline{P}$, and is positive at any point $P > \overline{P}$. Also, marginal information rent is increasing everywhere. Marginal information rent (MR) and marginal education cost (MC), which is assumed to be constant, are shown in Figure 7. Because MR is increasing everywhere while MC is constant, marginal net revenue for the local government is increasing everywhere.[18]
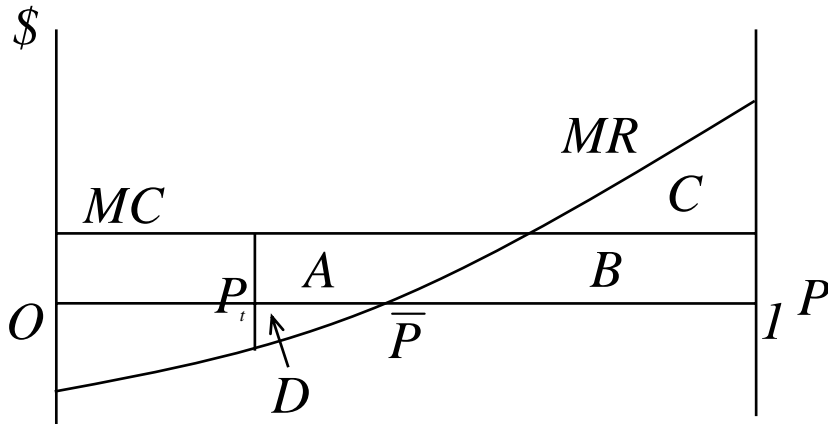

Figure 7. As long as $P_0 < P_t$ there is no incentive for EDI; however, once P_0 equals P_t the government immediately jumps to $P = 1$. This point (P_t) is the *take-off point*.

The conventional maximization rule (MR=MC) does not apply here. Rather, the optimal value of P is 1 or 0, depending on at which point the information rent less the

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[18] The assumption of constant marginal cost (MC) is not essential, but is made for expository simplicity. Changing this assumption does not affect our arguments. Neither of the following two cases changes the arguments at all: decreasing MC or increasing MC, which intersects with MR only once. When increasing MC intersects with MR twice, the second intersection becomes the destination of the jump-process (explained later) instead of $P=1$. As long as MC is positive everywhere, we have the jump-process because MR is negative when P is low.

cost of education is greater. But, since we assume that the initial value of P cannot decrease, either $P=1$ or the initial level P_0 will be chosen.

Suppose that a developing country has the initial value $P_0 = P_t$ so that the area B+C =A+B+D in Figure 7. The area B+C corresponds to the total information rent at $P=1$; A+B corresponds to the total education cost required to reach $P=1$ from P_t, and; D corresponds to the information rent earned by retaining the initial level of education P_t. Thus, the government is indifferent between choosing the initial level P_t and $P=1$. Any local government whose initial P_0 is lower than P_t has no incentive to invest in education because its cost exceeds the rent it can earn. Any local government whose level of initial P_0 is higher than P_t has the incentive to choose $P=1$. As long as $P_0 < P_t$ there is no incentive for EDI; however, once P_0 equals P_t the government immediately jumps to $P=1$. This sudden change is because the marginal net revenue of the government is increasing everywhere, and it has no ability to reduce the value of P. We term this point (P_t) the *take-off point*.

An interesting property of *take-off point* P_t is that it decreases as the expected labor quality $\overline{P}$ decreases. As shown in Figure 5, marginal rent to the right of $\overline{P}$ increases as $\overline{P}$ decreases. Consequently the *take-off point* P_t moves to the left because the cost of reaching $P=1$ from old P_t is now less than rent earned. This means that as the expected labor quality $\overline{P}$ goes down, the local government has the incentive to jump to $P=1$ from a lower level of P_t. This situation is shown in Figure 8 in which the shift of expectation $\overline{P}$ to $\overline{P}'$ causes a leftward shift of MR to MR' and P_t to P_t'.
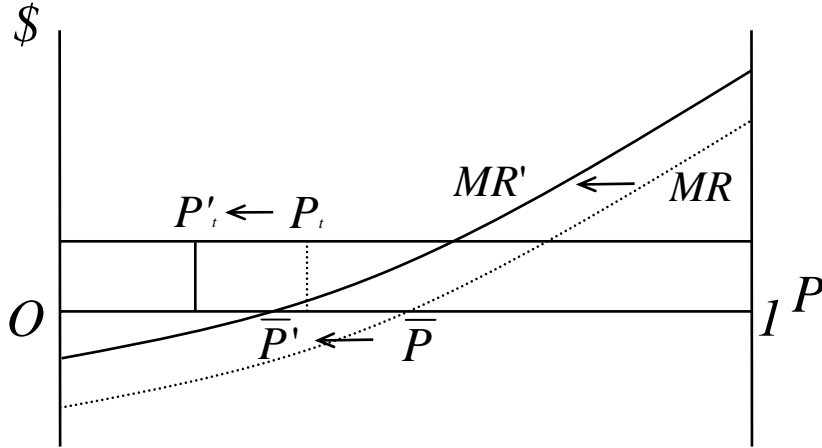
18

Figure 8. The *take-off point* (P_t) decreases as the expected labor quality ($\bar{P}$) decreases.

The *take-off point* is an increasing function of marginal cost ($C(P)$). In Figure 7, an increase in marginal cost will shift MC up without changing MR. Total education cost is now greater than total rent at P_t. So, P_t must move to the right. There will be no incentive to invest in education regardless of the value of P_0 when MC intersects with MR at *P*=1.

Setup cost does not shift the *take-off point*. This is because it neither changes the value of information rent nor the of education cost. But, setup cost does affect the entry decision of the MNC, and it has important welfare implications (investigated in section 6.2). So far, given the principal-agent contract of the MNC, the local government jumps to the maximum level of education at the *take-off point*. The lower the expected level of education and the cost of education, the lower the *take-off point*.

Proposition 2:

The local government has no incentive for EDI when $P_0 < P_t$; however, once P_0 equals P_t it immediately jumps to $P=1$. P_t is increasing in $\overline{P}$ and $C(P)$.

This jump process shows some similarity to the popular multiple equilibria problem of economic development. Considerable literature recognizes the deadlock in the multiple equilibria of developing countries (Murphy et al. 1989, Becker et al. 1990). In Becker et al. (1990), there is little incentive to invest in education during the early stage of economic development so that the economy is trapped in the lower equilibrium. But, our model shows the opposite results are possible.

Suppose that a region within a developing country hosts an MNC, where, the probability distribution of the labor quality within the entire country is known, but the exact labor quality of the region is not known. Then, the host country (or regional) government has an incentive to reach the maximum level of education from the *take-off point*. Besides, the *take-off point* gets lower as the known expected labor quality of the country gets lower.[19] The lower the expectation (country in early stage of economic development) is, the lower is the *take-off point*. This shows the distinct possibility of the jump occurring during the early stage of economic development, and may shed light on considerable differences in economic development among regions within a country.

These remarkable characteristics of our model come from the role of labor quality information. In the early stage of economic development the expected labor quality is low. The higher the real labor quality relative to expected quality, the higher the value of

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[19] Note, however, that expected labor quality has to be at least as high as $\overline{P}_e$ to host FDI. If not, the government has to engage in *"FDI inducing EDI"* which is analyzed in section 6.2.

information. When the value of information transacted between the government and MNC is high, the former can increase its share of the profits, and has a stronger incentive to invest in education.

5.2 Tax Policy

Now we investigate the tax policy of the local government. Repeating equation (10), the tax rate t is adjusted so that the local government can earn information rent. The tax revenue is shown as

$$t\Pi^*(P,F) = \Pi^*(P,F) - \Pi(P,\overline{P},F) \geq 0.$$

This is non-negative because the optimal profit is at least as high as the reservation profit (see section 4.1). If the initial P_0 is located on, or to the right of, the *take-off point* P_t, the local government will increase education level to $P=1$. So the tax revenue is

$$t\Pi^*(P,F) = \Pi^*(1,F) - \Pi(1,\overline{P},F) > 0.$$

This is positive because we assumed $0 < \overline{P} < 1$. If the initial P_0 is located to the left of the *take-off point* P_t, the local government retains the initial level of education with the tax revenue

$$t\Pi^*(P_0,F) = \Pi^*(P_0,F) - \Pi(P_0,\overline{P},F) \geq 0.$$

This is equal to zero when $P_0 = \overline{P}$. With any other value of P_0, the above equation is positive. In summary, tax revenue of the local government is non-negative; it is zero only when $P_0 = \overline{P}$, given $P_0 < P_t$.

6 Welfare Analysis

In this section we investigate the welfare effects of FDI, EDI, and information sharing between the government and the MNC. There are two kinds of welfare gains from this strategy set. The first gain is from EDI and a more efficient local labor contract, given that the MNC enters the country anyway (efficiency gain effect). The second is the welfare gain when the MNC enters the region due to EDI and information sharing, which does not enter without these ("*FDI inducing EDI*" case). We also investigate the policy effects on the welfare of local labor.

6.1 Efficiency Gain Effect

Here we retain the assumption that the MNC enters the region with, or without, information sharing. The optimization problem given in section 5.1 satisfies the incentive compatibility for both the local government and the MNC; the former earns non-negative tax revenue less education cost, and the latter earns after tax profit greater than, or equal to, its reservation profit. So, neither agent has an incentive to deviate from its own strategy, given that of the other (Nash equilibrium). Because the local government has perfect information, it can make a Pareto efficient contract with the MNC. The problem is to determine the situation in which each agent is strictly better off than without this strategy set.

From the tax policy analysis in section 5.2 the local government earns positive tax revenue except when $P_0 = \overline{P}$, given $P_0 < P_t$. Tax revenue is always greater than education cost because the local government can choose zero education cost simply by retaining the initial level. We can conclude that the local government is strictly better off except when $P_0 = \overline{P}$, given $P_0 < P_t$.

Can the MNC increase profits by acquiring information about local labor quality? From equation (10), the after tax MNC profit is always equal to reservation profit at P, so that $(1-t)\Pi^*(P,F) = \Pi(P,\overline{P},F)$. Without information sharing, MNC profit would be the reservation profit for the initial P_0 which is given by $\Pi(P_0,\overline{P},F)$. From equation (5) the reservation profit is a linear increasing function of P, so that $\Pi(P,\overline{P},F) > \Pi(P_0,\overline{P},F)$ if, and only if, $P > P_0$. In other words, the MNC is strictly better off whenever the local government is induced to invest in education (the case in which the initial P_0 is larger than, or equal to, P_t). With positive EDI both agents are strictly better off. We summarize our findings:

Proposition 3:

The strategy set makes both the local government and the MNC at least as well off as without it; the former is strictly better off except when $P_0 = \overline{P}$, given $P_0 < P_t$; and the latter is strictly better off when $P_0 \geq P_t$.

6.2 FDI inducing EDI

From Proposition 1, when the expected labor quality is low, it is less likely for the MNC (without information sharing) to enter the developing country. On the other hand, from Proposition 2, when the expected labor quality is low, it is more likely that the local government will invest in education, given FDI. This inconsistent behavior of the two agents results in failed opportunities for both parties. In the early stage of development (the lower expected labor quality), the local government has a stronger incentive for EDI,

given FDI, but the MNC will likely not want to invest (FDI) in the region. Therefore, the local government has incentive to have EDI, contact and reveal the information to a potential entrant (even with extra cost) that, otherwise, would not enter the region. We call this action of the government "*FDI inducing EDI*."

In order for the *FDI inducing EDI* to be realized three conditions must be met. First, the MNC does not have FDI without information sharing (negative expected reservation profit). Second, the local government can gain by investing in education (EDI), revealing labor quality information to the MNC, and guaranteeing the MNC reservation profit. Third, the MNC provides FDI when informed of the tax rate and the improved labor quality due to EDI (positive reservation profit after EDI).[20] These conditions are given as

$$\Pi(\overline{P},\overline{P},F) < 0 \Leftrightarrow a_2(\overline{P}) + b(\overline{P})\overline{P} - F < 0, \tag{12}$$

$$\Pi^*(1,F) - \Pi(1,\overline{P},F) > (1-P_0)C + A$$
$$\Leftrightarrow a_2(1) + b(1) - [a_2(\overline{P}) + b(\overline{P})] > (1-P_0)C + A, \tag{13}$$

$$\Pi(1,\overline{P},F) > 0 \Leftrightarrow a_2(\overline{P}) + b(\overline{P}) - F > 0, \tag{14}$$

where *A* is the access cost of the local government to a potential entrant. Definitions of $a_2(\cdot)$ and $b(\cdot)$ were previously provided. Combining equations (13) and (14)

$$a_2(1) + b(1) - F - (1-P_0)C - A > a_2(\overline{P}) + b(\overline{P}) - F > 0. \tag{15}$$

The first inequality of equation (15) is more easily satisfied, as the expected education level ($\overline{P}$), the marginal cost of education (*C*), and access cost (*A*) are lower, and the initial level of education (P_0) is higher. Also, the inequality of equation (12) is more

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[20] There are cases in which the local government can induce FDI by simply revealing information. However, we focus on the case with positive EDI because the relation between EDI and FDI is the theme of this paper.

easily satisfied as $\overline{P}$ is lower. Hence, as long as the second inequality of (15) is satisfied, the lower $\overline{P}$ is, the easier the conditions are satisfied.

However, when $\overline{P}$ is too low, a negative reservation profit results for the MNC even after positive EDI. This is because the lower $\overline{P}$ is, the higher is the share taken by the government. The allowable range of $\overline{P}$ depends on the value of setup cost (F). Combining (12) and (15), we have

$$a_2(\overline{P}) + b(\overline{P})\overline{P} < F < a_2(\overline{P}) + b(\overline{P}).$$

First, note that $a_2(\overline{P}) + b(\overline{P})\overline{P}$ is increasing and convex in $\overline{P}$, and $a_2(\overline{P}) + b(\overline{P})$ is non-decreasing in $\overline{P}$.[21] The former is smaller than, or equal to, the latter. The allowable range of F gets greater, as the difference between these, $b(\overline{P}) - b(\overline{P})\overline{P}$, gets greater. This is positive for $\overline{P} < 1$, but is getting smaller when $\overline{P}$ is sufficiently high. It asymptotically approaches zero as $\overline{P}$ approaches one. Hence, *FDI inducting EDI* is more common for the government with relatively low $\overline{P}$.

This claim can be illustrated in much-exaggerated measure by assuming commonly used disutility functions: $c_1(x) = x^\gamma / \gamma$, $c_2(x) = kx^\gamma / \gamma$, where $k>1$ is the productivity difference indicator, and $\gamma > 1$ is the common elasticity of disutility.[22] Then we have

$$b(\overline{P}) - b(\overline{P})\overline{P} = \left\{ \frac{1}{\gamma} \left[\frac{1 - \overline{P}}{k - \overline{P}} \right]^{\frac{\gamma}{\gamma-1}} - \left[\frac{1 - \overline{P}}{k - \overline{P}} \right]^{\frac{1}{\gamma-1}} + 1 - \frac{1}{\gamma} \right\} (1 - \overline{P}),$$

---

[21] Increasing and convexity of $a_2(\overline{P}) + b(\overline{P})\overline{P}$ are directly from Lemma 1. Non-decreasing $a_2(\overline{P}) + b(\overline{P})$ is from $a_2'(\overline{P}) + b'(\overline{P}) = (c_1'(x_2) - c_2'(x_2)) \dfrac{dx_2}{d\overline{P}}$ where $\dfrac{dx_2}{d\overline{P}} \le 0$.

[22] Disutility function for each type cannot have different elasticity because it would violate the conditions of $c_1(x) < c_2(x)$, $0 < c_1'(x) < c_2'(x)$ and $0 < c_1''(x) < c_2''(x)$ for $x > 0$.

Since $k - \bar{P} > 1 - \bar{P} > 0$, we have $0 < \dfrac{1 - \bar{P}}{k - \bar{P}} < 1$. Also from $\gamma > 1$, $1 - \dfrac{1}{\gamma} > 0$. It is easy to

see that the expression in the curly bracket is decreasing in $\dfrac{1 - \bar{P}}{k - \bar{P}}$, so that it approaches

zero as $\dfrac{1 - \bar{P}}{k - \bar{P}}$ approaches one. Therefore, we have

$$\left\{ \frac{1}{\gamma}\left[\frac{1 - \bar{P}}{k - \bar{P}} \right]^{\frac{\gamma}{\gamma - 1}} - \left[\frac{1 - \bar{P}}{k - \bar{P}} \right]^{\frac{1}{\gamma - 1}} + 1 - \frac{1}{\gamma} \right\}(1 - \bar{P}) > 0.$$

The change of allowable range with $\bar{P}$ is given by

$$\frac{\partial [b(\bar{P}) - b(\bar{P})\bar{P}]}{\partial \bar{P}} = \frac{1}{(\gamma - 1)}\left[\frac{k - 1}{k - \bar{P}} \right]^{2}\left[\frac{1 - \bar{P}}{k - \bar{P}} \right]^{\frac{1}{\gamma - 1}} - \left\{ \frac{1}{\gamma}\left[\frac{1 - \bar{P}}{k - \bar{P}} \right]^{\frac{\gamma}{\gamma - 1}} - \left[\frac{1 - \bar{P}}{k - \bar{P}} \right]^{\frac{1}{\gamma - 1}} + 1 - \frac{1}{\gamma} \right\}.$$

Since $0 < \dfrac{k - 1}{k - \bar{P}} < 1$ and $0 < \dfrac{1 - \bar{P}}{k - \bar{P}} < 1$, $\dfrac{1}{(\gamma - 1)}\left[\dfrac{k - 1}{k - \bar{P}} \right]^{2}\left[\dfrac{1 - \bar{P}}{k - \bar{P}} \right]^{\frac{1}{\gamma - 1}}$ is negligible when γ

is sufficiently high. If this is the case, we have $\dfrac{\partial (b - b\bar{P})}{\partial \bar{P}} < 0,$ which means that the

allowable range of F gets larger as $\bar{P}$ gets smaller. We illustrate the case with the

quadratic disutility function ($\gamma = 2$, $k = 2$) in Figure 9. The shaded area in Figure 9 is the

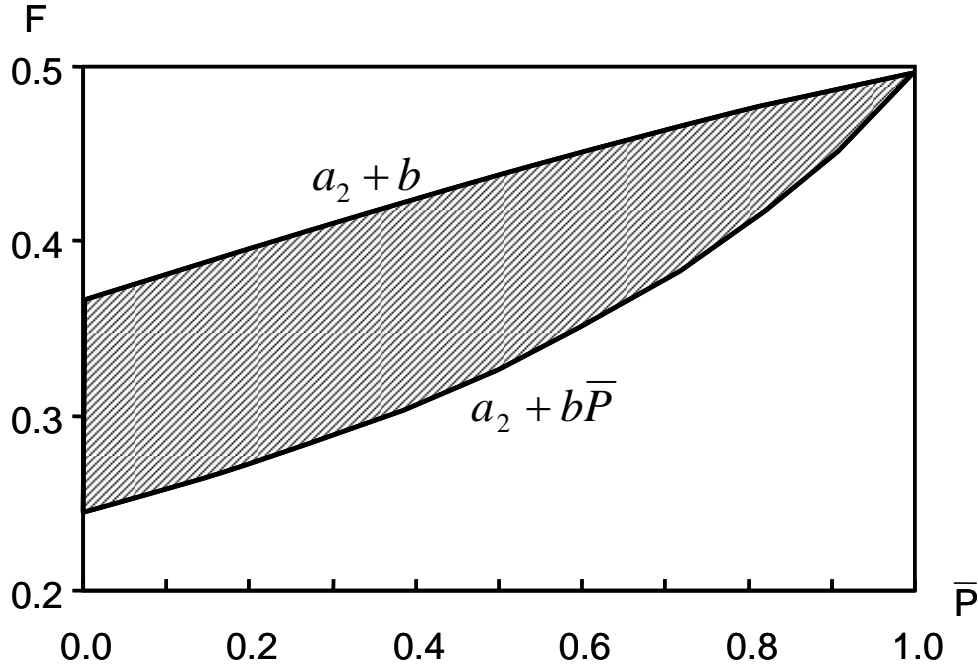allowable range of $\bar{P}$ and F to realize "*FDI inducting EDI.*"

Figure 9. The allowable range of $\overline{P}$ and F with quadratic disutility function.

Note that the allowable range of F is decreasing in $\overline{P}$ everywhere. Also from Figure 9, we can see that the allowable range of $\overline{P}$ is wider when F is relatively low. This comes from the convexity of $a_2(\overline{P}) + b(\overline{P})\overline{P}$.

In summary, the *FDI inducing EDI* is more common when the country is in an early stage of development (low expected labor quality); its initial labor quality is high; and its education cost, access cost, and MNC's setup cost are low.

6.3 Local Labor Welfare

In this section we investigate the effect of the strategy set on local labor welfare. First, we show the case in which the strategy set benefits local labor. Second, we analyze how government policy will change if it tries to maximize the welfare of local labor.

27

When there is neither information sharing nor EDI, the MNC uses $\overline{P}$ as the target value as shown in section 4. The total labor surplus (W_0) without the strategy set depends on the initial and expected labor quality as

$$W_0(P_0, \overline{P}) = P_0[w_1(\overline{P}) - c_1(x_1(\overline{P}))] + (1 - P_0)[w_2(\overline{P}) - c_2(x_1(\overline{P}))].$$

Setting the target value to $\overline{P}$ in equation (2),

$$W_0(P_0, \overline{P}) = P_0[w_1(\overline{P}) - c_1(x_1(\overline{P}))].$$

With the strategy set, the total labor surplus (W) becomes

$$W(P) = P[w_1(P) - c_1(x_1(P))].$$

Again we used equation (2). First, we show that positive EDI is always welfare deteriorating for local labor.

Whenever the local government has positive EDI it has an incentive to go to the maximum level ($P = 1$). If there are only skilled laborers, the MNC's strategy becomes

$$\max_{x_1, w_1}(x_1 - w_1)$$
$$\text{s.t. } w_1 - c_1(x_1) \geq 0$$

$$\Rightarrow \quad FOCs \quad w_1 = c_1(x_1), \ c_1'(x_1) = 1.^{23}$$

This means that skilled labor surplus is zero. Therefore, when there are only skilled laborers, all labor surplus disappears so that $W(1) = 0$. On the other hand, the total labor surplus without the strategy set is positive because skilled labor has a positive surplus with $0 < \overline{P} < 1$.[24] Thus, $W(P) - W_0(P_0, \overline{P}) < 0$ when $P_t \leq P_0$. Therefore, the cases in which the local labor benefits from the strategy set are limited to those without EDI (i.e., $P_t > P_0$).

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[23] The same result is derived by setting $P=1$ in equations (1) through (4).

[24] From Assumption 1 and equations (1) and (2), we can derive $w_1 - c_1(x_1) = w_2 - c_1(x_2) > 0$ if $0 < \overline{P} < 1$.

When the government retains the initial level of labor quality, the total labor surplus with the strategy set becomes

$$W(P_0) = P_0(w_1(P_0) - c_1(x_1(P_0))).$$

Then the difference in total labor surplus between with and without the strategy set now can be expressed as

$$W(P_0) - W_0(P_0, \overline{P}) = P_0[(w_1(P_0) - c_1(x_1(P_0))) - (w_1(\overline{P}) - c_1(x_1(\overline{P})))].$$

From equations (1), (2), and (4) we can derive $(w_1(P) - c_1(x_1(P)))$ is non-increasing in P. This leads us to that $W(P_0) - W_0(P_0, \overline{P}) > 0$ only if $P_0 < \overline{P}$. In conclusion, the strategy set benefits the local labor only if $P_0 < \min\{\overline{P}, P_t\}$. Local labor is worse off in all other cases. This is a very restrictive condition compared to the government and MNC, both of which are always at least as well off as without the strategy set. Besides, both are strictly better off in the case of positive EDI, while the local labor is strictly worse off with a positive EDI.

How will government policy change if it tries to maximize the welfare of the local labor? This optimization problem is the same as shown in section 5, except for the objective function. Now the government's objective is to maximize the total welfare of local labor, so that

$$\max_{P,t}[P(w_1 - c_1(x_1)) + (1 - P)(w_2 - c_2(x_2))] \tag{9'}$$

$$\text{s.t. } R(P, \overline{P}) - t\Pi^*(P, F) = 0, \tag{10'}$$

$$R(P, \overline{P}) - \int_{P_0}^{P} C(P)dP \geq 0. \tag{11'}$$

As previously shown, when there is only one kind of laborer ($P=0$ or 1), all labor surplus disappears. However, when $0<P<1$, the total labor surplus is strictly positive

because skilled labor has a positive surplus. Because the total labor surplus is a continuous function of P, there must be $0<P<1$, which maximizes the total labor surplus. We denote this optimal P as P^*.

First, if the initial level of education is higher than, or equal to, the optimal point P^*, there is no incentive for education investment. Because further education investment will result in reduced welfare of local labor, the government will maintain education at the initial level.

Second, if the initial level of education is lower than P^*, we can define the *take-off point* again. Before the *take-off point*, the government has no incentive for EDI. But, once it reaches the *take-off point*, the government incentive is to jump to P^*. As before, the *take-off point* is increasing in the marginal cost of education and the expected labor quality.

There are some important changes from the net revenue maximizing government. Under the current policy, the government jumps to P^* which is strictly lower than one. Because it jumps to the lower point than before, the budget constraints for education mandate the *take-off point* to be higher than before.[25] So, both the range where the jump process occurs and the distance of the jump are smaller than for net revenue maximizing government.[26] Any value of P greater than P^*, which happens whenever net revenue maximizing government has EDI, damages the welfare of local labor. In that sense, incentives are provided to itself and to the MNC at the expense of local labor. This result is in clear contrast to the conventional belief that skill building in the host country must

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[25] Remember that marginal information rent is increasing everywhere while marginal education cost is constant. Hence, the higher the destination of jump process is, the lower is the *take-off point*.
[26] When the government tries to maximize the sum of labor surplus and net tax revenue, the chosen level of education would be between P^* and 1.

always benefit local labor (United Nations 1999). Finally, we summarize these results as Proposition 4.

Proposition 4: Local labor benefits from the strategy set only if $P_0 < \min\{\overline{P}, P_t\}$. The *take-off point* becomes higher and the distance of the jump becomes shorter when the local government tries to maximize the local labor welfare.

7 Conclusion

We have developed a model explaining the observed policy combination of a developing country (hosting FDI and investing in education) and the interest of the MNC about the quality of the local labor force when it contemplates FDI in a developing country. Information on local labor is the source of a more efficient local labor contract for the MNC. The local government has an incentive to invest in education (EDI) because it increases both its net tax revenue and MNC profit.

The important implication of EDI by the local government is that it suddenly jumps to the maximum level of education when it reaches the *take-off point*. However, the local government does not invest in education before it reaches the *take-off point*. An interesting finding is that the *take-off point* becomes lower as the expectation of education level decreases. This means that a country in an early stage of development has the incentive to take a larger leap, which heretofore has not been considered in existing multiple equilibria models.

The strategy set (FDI, EDI, and information sharing) has two positive welfare effects. First, EDI and information sharing contributes to a more efficient contract between the

MNC and local labor, given the MNC has FDI in the country. Second, with EDI and information sharing, the local government can induce an MNC to have FDI in the country, which otherwise would not occur. This *"FDI inducting EDI"* is more likely to occur for a country in the early stage of economic development.

The strategy set makes both the government and the MNC at least as well off as without it, but it benefits local labor only under very restrictive conditions. Furthermore, when the local government invests in education, it must over-invest to the level that deteriorates the local labor welfare. So, the government has the incentive to benefit itself and the MNC at the expense of local labor. This result is in clear contrast to the conventional belief that skill building in a developing country always benefits local labor.

Appendix I.1

Proof of $a_2(\tilde{P}) \geq 0, b(\tilde{P}) > 0$.

From Assumption 1, equation (2) must pass through the origin ($(x_2, w_2) = (0,0)$).

Equation (2) is shown as the $w_2 = c_2(x_2)$ curve in Figure A. 1. The iso-profit line

($w_2 = x_2 - a_2$) has slope of one and passes through a point on the $w_2 = c_2(x_2)$ curve.

From the incentive compatibility constraints we have $c_2(x_1) - c_2(x_2) \geq c_1(x_1) - c_1(x_2)$.

This, combined with Assumption 1, indicates that $x_1 \geq x_2$. From equation (3), and

$x_1 \geq x_2$, we have

$$1 - c_1'(x_2) \geq 0. \tag{A. I. 1}$$

Substituting this into equation (4) yields

$$1 - c_2'(x_2) \geq 0. \tag{A. I. 2}$$

Hence, slope of the $w_2 = c_2(x_2)$ curve must be less than, or equal to, one at (x_2, w_2). This and Assumption 1 indicate that slope of the $w_2 = c_2(x_2)$ curve is less than one all the way up to (x_2, w_2). Then the w-intercept of the iso-profit line ($w_2 = x_2 - a_2$) is non-positive so that $a_2 \geq 0$.

From participation constraints and equation (1), we have $w_1 - c_1(x_1) = w_2 - c_1(x_2) \geq 0$. This means that a skilled laborer has at least the reservation utility, and is indifferent between (w_1, x_1) and (w_2, x_2). In Figure A.1 we draw the skilled laborer's indifference curve ($w_1 = U_1 + c_1(x_1)$ with a constant $U_1 \geq 0$) passing through (w_2, x_2).

When $x_2 > 0$, the skilled laborer's indifference curve is less steep than that of unskilled laborer at (w_2, x_2) from Assumption 1. From equation (3), the iso-profit line ($w_1 = x_1 - a_1$) is tangent to the indifference curve on (w_1, x_1). From Figure A.1, it is clear that $a_1 > a_2$. This means that $b > 0$. When $x_2 = 0$, we have $c_1'(x_2) = c_2'(x_2) = 0$ from Assumption 1. Then equation (3), which is $c_1'(x_1) = 1$, means that $x_1 > x_2 = 0$. This leads to $a_1 > a_2 = 0$, and $b > 0$.
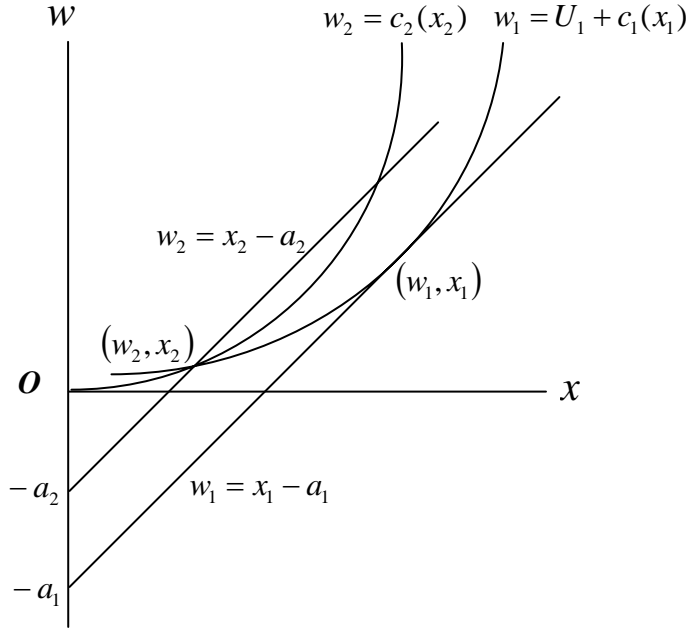
Figure A.1 Indifference curves and iso-profit lines for a given $\tilde{P}$.

Appendix I.2

Proof of $a_2{}'(\tilde{P}) \leq 0, b'(\tilde{P}) \geq 0$.

By definition $a_2(\tilde{P}) = x_2(\tilde{P}) - w_2(\tilde{P})$. Substituting equation (2) yields $a_2(\tilde{P}) = x_2(\tilde{P}) - c_2(x_2(\tilde{P}))$. Differentiating with respect to $\tilde{P}$ yields

$$a_2{}'(\tilde{P}) = (1 - c_2{}'(x_2))\frac{dx_2}{d\tilde{P}}. \tag{A. I. 3}$$

Differentiating equation (4) with respect to $\tilde{P}$ yields

$$\frac{dx_2}{d\tilde{P}} = [c_2{}''(x_2) - \tilde{P}c_1{}''(x_2)]^{-1}[c_1{}'(x_2) - 1].$$

34

From Assumption 1, $c_2''(x_2) - \tilde{P} c_1''(x_2) > 0$. Substituting this and equation (A. I. 1) into

the above yields $\dfrac{dx_2}{d\tilde{P}} \leq 0$. Substituting $\dfrac{dx_2}{d\tilde{P}} \leq 0$ and equation (A. I. 2) into equation (A. I.

3) yields $a_2'(\tilde{P}) \leq 0$.

By definition, $b(\tilde{P}) = x_1(\tilde{P}) - w_1(\tilde{P}) - (x_2(\tilde{P}) - w_2(\tilde{P}))$. Using equations (1) and (2),

$b(\tilde{P}) = x_1(\tilde{P}) - x_2(\tilde{P}) - c_1(x_1(\tilde{P})) + c_1(x_2(\tilde{P}))$. Differentiating with respect to $\tilde{P}$ yields

$$b'(\tilde{P}) = (1 - c_1'(x_1)) \frac{dx_1}{d\tilde{P}} - (1 - c_1'(x_2)) \frac{dx_2}{d\tilde{P}}.$$

Using equation (3), $\dfrac{dx_1}{d\tilde{P}} = 0$. Substituting this into the above equation yields

$$b'(\tilde{P}) = -(1 - c_1'(x_2)) \frac{dx_2}{d\tilde{P}}.$$

Substituting $\dfrac{dx_2}{d\tilde{P}} \leq 0$ and equation (A. I. 1) yields $b'(\tilde{P}) \geq 0$.

Appendix II

Proof of Lemma 1.

First, we show that $\Pi^*(\tilde{P}, F) > \Pi^*(\tilde{P}^t, F)$ for $\tilde{P} > \tilde{P}^t$. Denote $(\tilde{x}_1, \tilde{w}_1, \tilde{x}_2, \tilde{w}_2)$ as the

strategy vector for $\tilde{P}$, and $(\tilde{x}_1^t, \tilde{w}_1^t, \tilde{x}_2^t, \tilde{w}_2^t)$ as the strategy vector for $\tilde{P}^t$. Then, we have

the following relation:

$$\tilde{P}[\tilde{x}_1 - \tilde{w}_1] + (1 - \tilde{P})[\tilde{x}_2 - \tilde{w}_2] \geq \tilde{P}[\tilde{x}_1^t - \tilde{w}_1^t] + (1 - \tilde{P})[\tilde{x}_2^t - \tilde{w}_2^t]$$
$$> \tilde{P}^t[\tilde{x}_1^t - \tilde{w}_1^t] + (1 - \tilde{P}^t)[\tilde{x}_2^t - \tilde{w}_2^t].$$

This means that $\Pi^*(\tilde{P}, F) > \Pi^*(\tilde{P}^t, F)$. The first inequality is from the optimization at $\tilde{P}$, and the second inequality is from the fact that $\tilde{P} > \tilde{P}^t$ and that $\tilde{x}_1^t - \tilde{w}_1^t > \tilde{x}_2^t - \tilde{w}_2^t$ (proof in Appendix I. 1). Now we show that the profit function is convex in $\tilde{P}$.

For $\tilde{P}, \tilde{P}'$, and $\tilde{P}'' = \lambda\tilde{P} + (1-\lambda)\tilde{P}'$ such that $0 \le \lambda \le 1$, let the strategy vectors be $(\tilde{x}_1, \tilde{w}_1, \tilde{x}_2, \tilde{w}_2)$, $(\tilde{x}_1', \tilde{w}_1', \tilde{x}_2', \tilde{w}_2')$ and $(\tilde{x}_1'', \tilde{w}_1'', \tilde{x}_2'', \tilde{w}_2'')$, respectively. We therefore have the following results:

$$\lambda[\tilde{P}(\tilde{x}_1 - \tilde{w}_1) + (1-\tilde{P})(\tilde{x}_2 - \tilde{w}_2)] \ge \lambda[\tilde{P}(\tilde{x}_1'' - \tilde{w}_1'') + (1-\tilde{P})(\tilde{x}_2'' - \tilde{w}_2'')].$$

$$(1-\lambda)[\tilde{P}'(\tilde{x}_1' - \tilde{w}_1') + (1-\tilde{P}')(\tilde{x}_2' - \tilde{w}_2')] \ge (1-\lambda)[\tilde{P}'(\tilde{x}_1'' - \tilde{w}_1'') + (1-\tilde{P}')(\tilde{x}_2'' - \tilde{w}_2'')].$$

Summing up each side of the inequalities, we can compute

$$\lambda\Pi^*(\tilde{P}, F) + (1-\lambda)\Pi^*(\tilde{P}', F) \ge \Pi^*(\lambda\tilde{P} + (1-\lambda)\tilde{P}', F).$$

Therefore, the profit function is convex in $\tilde{P}$.

Appendix III

Proof of Lemma 2.

The effect of a decrease in $\overline{P}$ on information rent is given by

$$-\frac{\partial R(P, \overline{P})}{\partial \overline{P}} = -\frac{\partial\left(\Pi^*(P, F) - \Pi(P, \overline{P}, F)\right)}{\partial \overline{P}} = \frac{\partial\Pi(P, \overline{P}, F)}{\partial \overline{P}}$$
$$= -Pw_1'(\overline{P}) + (1-P)(x_2'(\overline{P}) - w_2'(\overline{P})).$$

In deriving the result above, we used equation (3). Using equations (1) and (2), the above equation is transformed as follows:

$$-\frac{\partial R(P, \overline{P})}{\partial \overline{P}} = -P[c_2'(x_2) - c_1'(x_2)]\frac{dx_2}{d\overline{P}} + (1-P)[1 - c_2'(x_2)]\frac{dx_2}{d\overline{P}}.$$

Using equation (4) we can compute

$$-\frac{\partial R(P,\overline{P})}{\partial \overline{P}} = -(P - \overline{P})(1 - c_1'(x_2))\frac{dx_2}{dP} \geq 0, \quad for \quad P \geq \overline{P}.$$

In deriving the final inequality, we used $1 - c_1'(x_2) \geq 0$ from equation (A. I. 1), and

$\frac{dx_2}{dP} \leq 0$ from Appendix I. 2.

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