Comparative Advantage and Vertical Multinational Enterprises

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Abstract

This paper builds a model of vertical multinational firms with endogenous spillover that explains recent empirical findings. First, vertical multinational firms invest more in low-tech industries than in high-tech industries in skill scarce countries while they invest more in high-tech industries than in low-tech industries in skill abundant countries. Second, the effects of technology transfers are limited only in low-tech sectors in skilled labor scarce economies. To explain these findings, I emphasize industry characteristics as well as country characteristics in a small open general equilibrium framework.

Keywords: Vertical multinational firms, Industry characteristics, Technology spillover, Skilled and unskilled labor, Economic development

JEL Classification: F12, F14, F23, O12, O33

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1 Introduction

There are two widely recognized motives of foreign direct investment (FDI). Horizontal multinational enterprize (MNE) FDI tends to occur between similar factor abundant or similar income level economies. While vertical multinational firms FDI tends to occur between different factor abundant economies. Following Yeaple (2003), I call the first motive *market access motive* and the second *comparative advantage motive*. Although a large body of empirical studies have identified that market access motives dominate the comparative advantage motives, comparative advantage motive is still important for especially developing countries.

The purpose of this paper is to build a theoretical model of *vertical* production networks that explains empirical findings; why less developed countries have little or no spillover effects from FDI, why spillover effects occur only low-tech sectors, and how MNE behaviors or spillover effects are different across industries. Regarding the last question, it is rather surprising that little theoretical attention has been paid to the comparative advantage characteristic of FDI. To explain these questions, I endogenize spillover effects and incorporate industry characteristics into the model.

I start this short introduction with a clarification of concepts on horizontal and vertical production networks and show the evidence for the importance of comparative advantage motives especially in manufacturing sectors of developing countries. I then survey the recent empirical findings on technology spillovers through FDI in vertical production networks.

Vertical vs. Horizontal Production Networks

Horizontal multinational firms have their headquarters in their home country and final assembly plant in both the host and the home countries. On the other hand, vertical multinational firms split their production process into more than two locations. Keeping their headquarters in their home country, vertical multinational firms assemble final products in the host country. For horizontal multinational firms, the trade-off between exporting and producing in the host economy usually arises. On the other hand, vertical multinationals involve trade-off between cost of producing whole process in source country and cost of breaking up the vertical production structure.

The effects of horizontal and vertical multinational firms can be different in many aspects. First, horizontal multinationals are likely to be substituted for international trade while vertical multinationals are complement to trade. Second, horizontal multinationals are likely to occur between countries of similar development levels while vertical multinationals are more likely between countries with different levels of development. Third, horizontal multinationals generally have more job creation effects on host economy than vertical multinationals.

Carr et al. (2003) show that the volume of subsidiary sales or the number of multinational firms for vertical MNE is declining as countries factor endowment structures or levels of development become similar. On the other hand, the number of horizontal multinationals are an increasing function of similarity between countries. This gives simple insights when we consider the effects of MNE on host economy, i.e., we need to distinguish two types of multinationals to identify their effects on the host economy.[1] It means that when we consider the effects of multinationals on host developing economies, we should emphasize vertical multinationals rather than horizontal ones. Although horizontal multinational firms are more important in world capital flows, vertical multinationals are still very important for developing countries especially for their development strategy.

Maskus and Webster (1995) and Yeaple (2003) are two examples that provide evidence of comparative advantage consistent vertical FDI. Hanson, Mataloni and Slaugh-

[1]See Markusen (1995, 2002) for differences between two types of multinationals. Markusen and Maskus (2001) provide a careful argument on this issue both in theoretical and empirical aspects.

ter (2001) state that the vertical FDI is more common than previous studies suggested. Figure 1 shows the relationship between comparative advantage and the FDI inflow for 8 developing Asian countries. The columns in the graph indicate the revealed comparative advantage (RCA)[2] (measured on the left axis) which is a substitute for comparative advantage index while the solid line stands for the share of FDI inflow (measured on the right axis). RCA can be interpreted as a comparative *advantage* if it is greater than one and comparative *disadvantage* if it is less than one. In Figure 1, each graph is arranged by the order of human development index (HDI) ranking of UNDP. It is worthwhile to point out that the education level index, GDP per capita, and HDI ranking are strongly correlated with each other. In low education level or low GDP per capita countries such as Myanmar, Cambodia and Indonesia, it is clear that they have comparative advantages and a higher share of FDI inflow in the low-tech sector.[3] On the other hand, relatively high education and high GDP per capita countries, such as Thailand, Malaysia, Korea and Singapore, have comparative advantages and a higher share of FDI inflow into the high-tech sector. Figure 1 provides the evidence that comparative advantage plays an important role in predicting the share of FDI inflow in manufacturing sectors of developing countries.[4]

Spillover Effects

For developing countries, superior knowledge of production is an especially important

[2]RCA is calculated by the following formula: $RCA_{ij} = (X_{ij}/X_j)/(X_{iw}/X_w)$, where RCA_{ij} is revealed comparative advantage of indystry i of country$j$, X_{ij} is export (to the world) in industry i of country j, X_j is the total exports of country j. X_{iw} is the world exports in industry i and X_w is the total export of the world.

[3]Only exception is China. China has a different trend from other Asian countries; China has a comparative advantage in low-tech sector but has a higher share of FDI inflow in high-tech sector. This indicates that the FDI inflow into China is import-substituting horizontal FDI. Another aspect to be noted about China's FDI is that due to the FDI inflow into Hongkong, it is difficult to distinguish FDI inflow between mainland China and Hong Kong.

[4]Although there are evidently strong correlation between FDI inflow and country's comparative advantage as Figure 1 shows, it does not tell the *causality* between them. However, the causality is not a topic of this paper.

Figure 1

Comparative Advantage and FDI Inflows

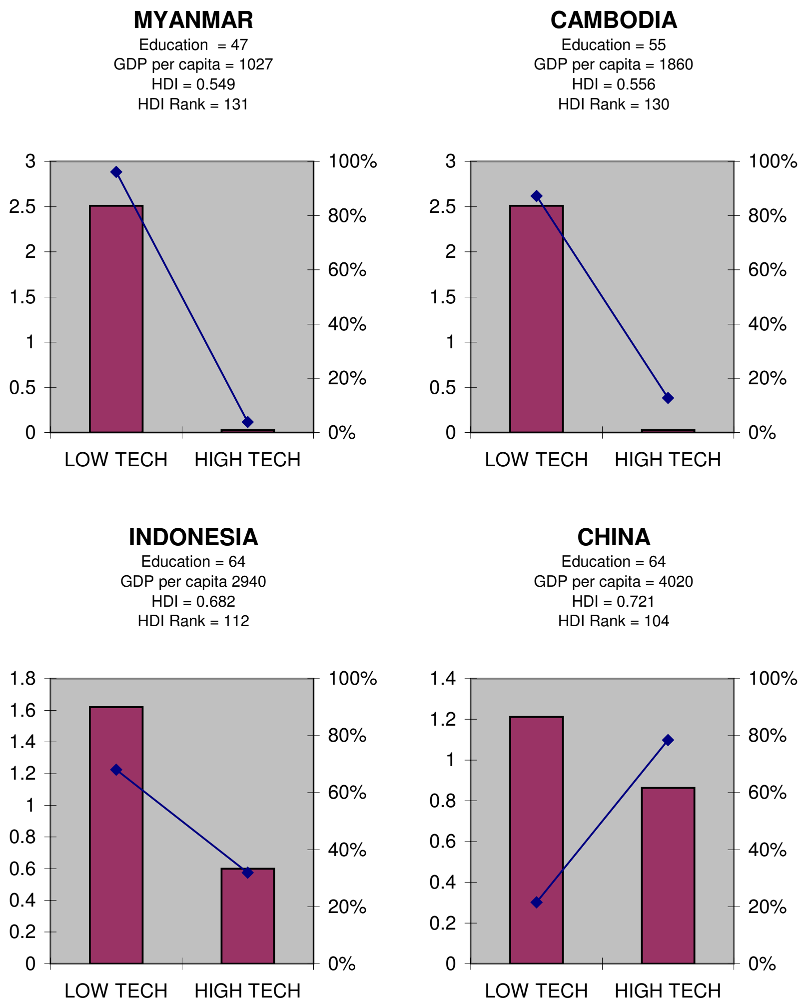
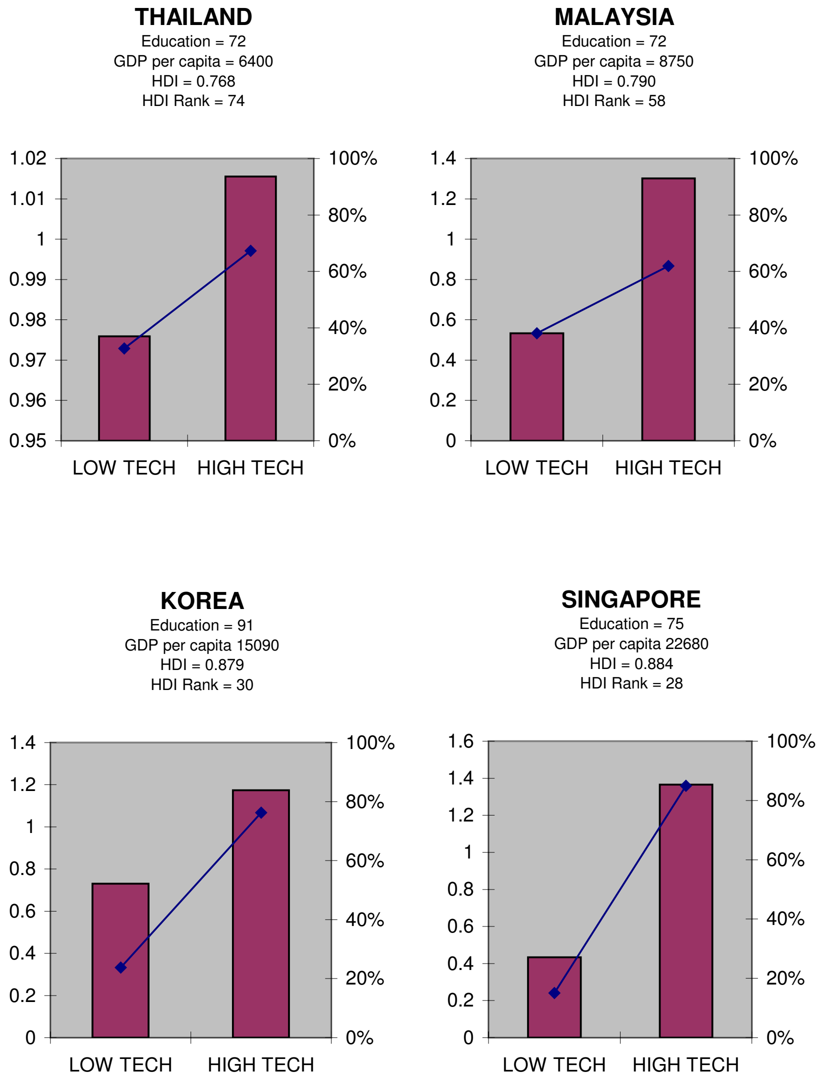


Figure 1 (Cont.)



Notes:

1. Column stands for revealed comparative advantage (RCA) index (measured by left axis) that is defined in the text while solid line the share of foreign direct investment (FDI) inflows (measured by right axis).
2. Low-tech industries include food, beverages, tobacco, textiles, clothing, leather, wood and wood products, publishing, printing, cork, petroleum products, non-metallic mineral products, and metal products. High-tech industries include chemicals and chemical products, rubber and plastic products, machinery and equipment, motor vehicles and other transport equipment, electrical and electric equipments, precision instruments, and pharmaceuticals.
3. Education indicates the combined primary, secondary and tertiary gross enrollment ratio (%) in 2000-2001. GDP per capita is in ppp US dollars in 2001. HDI stands for the human development index value in 2001, which lies between 0 and 1. HDI Rank shows the country ranking by HDI value. The higher HDI ranking means a more human resource developed country.

Sources:

1. FDI data for Cambodia, Indonesia, Malaysia, Myanmar, Singapore and Thailand is obtained from *Statistics of Foreign Direct Investment in ASEAN* (2003), ASEAN Secretariat. These countries' data are 5-year averages between 1993 and 1997.
2. FDI data for China is obtained from Ministry of Commerce of the People's Republic of China. China's FDI inflow data are the average of 2001 and 2002.
3. FDI data for Korea comes from Ministry of Finance and Economy. Cumulative data from 1962 to January 2001 is used for calculation.
4. Export data for the calculation of RCA for all countries except for Cambodia and Myanmar is obtained from the World Bank's dataset, *Trade and Production, 1976-1999*. All are 1999 data.
5. Export data for Cambodia and Myanmar is found in *World Trade Flows, 1980-1997*, compiled by R. Feenstra. 1997 data is used for these two countries.
6. World trade data for the calculation of RCA is found in World Trade Organization, *International Trade Statistics 2003*. Data in 2000 are used for this purpose.
7. Data for education enrollment ratio, GDP per capita, HDI and HDI ranking are found in UNDP *Human Development Reports* (2003).

source of economic development. Since the 1960s, the contents of technological change or spillover has been left as an unexplained residual, although many economists recognized the importance of technological diffusion for economic development.[5] During the same period in which theoretical contributions to technology spillover have been developed, some empirical studies were conducted within the framework of international trade.[6]

In the 1990s the study of technology spillover split along two newly emerging paths. One is a series of micro empirical studies, usually using firm level data, while the other path is interested in empirical tests of the endogenous growth model in Macroeconomics. A series of endogenous growth models, such as Barro and Sala-i-Martin (1995) and Grossman and Helpman (1991), enable us to discuss differences in economic growth rates. Barro and Sala-i-Martin (1995) highlighted human capital as a source of the technology differences across countries. Grossman and Helpman's (1991) model clarified the role of dynamic scale economies and the learning mechanism in the catching-up process.

These two paths provide both macro and micro incentives for empirical studies on technological diffusion across countries or across industries. Empirical studies on international technology spillover can roughly be classified into two groups: those that emphasize the trade channel[7] and those that emphasize the foreign direct investment (FDI) channel. Studies on FDI channel may be further divided into two groups: those

[5] For the early theoretical example, see Nelson and Phelps (1966) and Findlay (1978).

[6] Several early empirical studies on technology diffusion through foreign direct investment (FDI) include Caves (1974), Globerman (1979), and Blomström and Persson (1983). All these studies conclude that FDI has a positive impact of technology transfer on host countries, i.e., Australia (Caves), Canada (Globerman), and Mexico (Blomström and Persson).

[7] Coe and Helpman (1995) analyze the trade among OECD countries and find positive spillovers and Coe, Helpman, and Hoffmaister (1997) find the positive spillovers between developed and developing countries. On the other hand Keller (1998) cast doubt on these positive spillovers. See Keller (2002) for the detailed survey on trade channel. However, recent literature has focused on the mixed effects of trade and FDI on economic growth. See Lichetenberg and van Pottelberghe de la Potterie (1998) and Baldwin et al., (1999), for references.

that use cross-country estimation and those that employ firm-level estimation.[8] Recent literature concerning crosscountry effects of FDI have some novel findings that FDI contributes technology transfer and hence economic growth. The novelty of this is that the result is only true for some host countries. This insight leads us to the idea of a "threshold of development." That is, in order to benefit from FDI, a host country needs to reach a minimum human capital threshold level. On the other hand, the results of firm level estimations are mixed. Despite these results we are able to gain some valuable insights from this literature, as I will review below.

Cross-Country Evidence

Endogenous growth models and dynamic open trade models also spurred empirical studies on international technology spillovers. The FDI channel of technology spillover on cross-country evidence can be divided further into two groups of studies according to the type of equations estimated. If the growth rate of the economy is regressed on the FDI, I call it "indirect estimation." From the theoretical foundations mentioned above, I know FDI inflow affects the productivity of a host country, and then the productivity change affects economic growth. In other words, the impact of FDI captured in such estimation is indirect.

The first group includes Blomström, Lipsey, and Zejan (1992) and Borensztein, Gregorio, and Lee (1998). These two papers have a strong theoretical foundation in human capital endogenous growth models, in which countries with greater initial stocks of human capital experience more rapid rates of introduction of new goods and thereby tend to grow faster (Lucas 1988 and Romer 1990). These studies use the so called "Barro equation," which refers to regressing the growth rate on variables such as initial income level, education level (both primary and secondary), the number of revolutions and coups, the number of assassinations, price fluctuations, and socialist

[8]One may add the third group that uses case studies.

regimes and regional dummies,and so forth.

Blomström et al. (1992) found that FDI has a positive and statistically significant impact on the growth rate in the higher income sample, but not in lower income sample. Since their primary purpose is, however, to investigate conditional convergence, they do not further investigate this phenomenon. Borensztein, Gregorio, and Lee (1998) focus more directly on FDI and economic growth. They concentrate on the estimation of the impact of FDI on economic growth based on the endogenous growth theoretical background.

They found that there must be a threshold level of development according to the human capital accumulation in host developing countries. Thus, FDI contributes to economic growth only when sufficient capability of the advanced technologies is available in the host economy.

In contrast to the indirect estimation of the FDI channel, direct estimation of this channel has the following features: 1. The models are closely related to endogenous growth models, but are relatively free of the specification from the Barro equation. 2. Direct estimation enables us to see the impact of FDI on productivity change in the host country. This is the reason I call this direct.

Xu (2000) investigates the impact of FDI on the host country's productivity by using panel data, which consist of 20 developed and 20 developing countries. Xu's (2000) results clearly show a threshold of human capital level at which FDI benefits productivity. In the developed country sample, the technology transfer effect is positive and statistically significant, but in developing country sample, it is positive but is not significant.

Firm level Evidence

Firm level evidences may roughly be divided into two categories. The first group consists of developed country samples which finds that multinational enterprize (MNE) subsidiaries [9] have positive impacts on the host economy's productivity. This group includes Haskel, et al., (2002) and Veugelers and Cassiman (2003).[10] The second group consists of developing country's samples which has mixed results. This includes Kokko (1994), Haddad and Harrison (1993), Aitken and Harrison (1999), Blomström and Sjöholm (1999), and Blomström et al. (2000).

While the studies with developed country data find the positive spillover effects of FDI, most of the studies analyzing developing countries have failed to find the evidence of positive spillovers. Haddad and Harrison (1993) employ firm-level data of Moroccan manufacturing sector, but they reject the hypothesis that FDI accelerated productivity growth in domestic firms during the second half of the 1980s. However they find that spillover effects are significant for relatively simple technology using sectors and there are no significant transfers of modern technologies. Analyzing Mexican manufacturing industry data Kokko (1994) concludes that the industries where large productivity gaps and large foreign shares occur may explain why spillovers do not exist. Kokko also argues that when foreign affiliates and local firms are in more direct competition with each other, spillover effects are more likely to occur. Aitken and Harrison (1999) find with Venezuelan plant level data that increases in foreign equity participation are correlated with increases in productivity for small plants. However they fail to find the positive spillover effects to other domestic plants. They emphasize the possibility that spillover effects vary across industries. Blomström and Sjöholm (1999) show with Indonesian detailed establishments data that foreign establishments benefit from spillovers. However, breaking down the industry level they find that spilovers are found in only *food, textiles, wood, chemicals,* and *nonmetal products*[11] industries which are

[9] Focussing on the argument of vertical multinationals and technology spillover via subsidiaries, I exclude licensing as one of possible supply modes in this paper. Thus, I use the word "multinational firm" and "FDI" interchangeable.

[10] Haskel et al.(2002) analyze UK and Veugelers and Cassiman (2003) use Belgium firm level data, respectively.

[11] Blomström and Sjöholm (1999), p920, footnote 7

relatively low-tech industries.[12]

Blomström et al. (2000) investigate using Mexican firm level data and conclude that the spillover effect is positive and highly statistically significant in relatively labor intensive industries, but not significant in relatively capital intensive industries.

Cross-country studies identify that the FDI channel exists but for the countries which satisfied a certain human capital requirement, and not for other countries. On the other hand, three points should be noted about firm level evidences. First most of them refer to the possibility or show with clear evidences that spillovers may differ across industries. Second, most of them refer to the host country's absorption capability for technology spillovers as a possible reason for no or little evidences of positive spillovers. Lastly, some evidences show that spilloveres are found only in low-tech industries.

The rest of this paper is organized as follows. Section 2 presents the model of vertical multinational firm and derive the main implications of the model. Section 3 extends the model to endogenous technology spillover model which is the central aim of this paper. Section 4 refers to implications for economic development of host economy. Section 5 concludes the paper.

2 A Model of Vertical Multinationals

Although the importance of technology spillovers from developed to developing countries have been recognized empirically, few theories try to uncover the mechanism of spillovers.[13]

[12] *Chemicals* range widely from fireworks, plastic tubes, pipes, hoses which are relatively unskilled labor intensive goods, to medicaments, perfume which are relatively skilled labor intensive goods. Blomström et al. show that the capital labor ratios of these chemical products are less than the average of total manufacturing in Mexican case, see Table 9.2, p.139.

[13] See Wang and Blomstöm (1992) for survey on the earlier works on this issue. Many of earlier models focus on capital inflow and learning by doing process in dynamic setting

Recent theoretical contributions focus on the equilibrium conditions in which technology spilloves occur. Markusen and Ethier (1996) analyze multinational firms and technology spillover in a product cycle setting. Their main concern is to investigate the decision making of supply modes (exports, licensing contracts, or multinationals), and endogenous determination of wage rate and the number of multinational firms. They assume that licensing contract and multinational subsidiaries are main routes of technology transfer via labor turnover but exporting is not.

Fosfuri et al.(2001) and Glass and Saggi (2002) focus on narrower point of spillover mechanism. Fosfuri et al.(2001) identify the conditions under which technology spillovers occur using two stage multinational firm's decision game, based on the idea that technology spillovers occur through workers mobility. Trained workers in the multinational's subsidiaries establish local rivals firms. Their other concern is to identify why multinationals provide workers higher wages than local firms do and conditions under which this is true. Glass and Saggi (2002) construct two-country one-shot Cournot game but they concentrate on more host government's policy concern.

The model of this paper is different from both the earlier and recent models in many aspects. Since my model is constructed to explain the empirical findings mentioned in the previous section, I do not focus much on the conditions in which technology spillovers occur. Instead I focus more on the idea that the effects of multinational firms vary across industries and the endogenous determination of technology spillover effcts. The framework of my model is more similar to Markusen and Venables (2000) which construct the horizontal multinational firm model with the varieties of final goods in two country general equilibrium, and Zhang and Markusen (1999) where they make the vertical multinational model under the oligopoly in two country general equilibrium. However, these models study neither industry characteristics nor technology spillovers.

Model

The (host) economy is assumed to be a developing and small open economy with two final goods sectors, X and Y, and two factor inputs of productions, skilled and unskilled labor. While Y-sector is characterized as a perfect competition, X-sector is monopolistic competitive market. While Y-sector produces final good Y using both skilled and unskilled labor X-sector produces final good X with two types of machines; one is low-tech and the other is high-tech machines. Since the host country is less developed, I assume this country is relatively abundant in unskilled labor. I further assume that low-tech machines are produced by only unskilled labor and the high-tech machines are produced by only skilled labor. Under this assumption, the host country has a comparative advantage in the production of low-tech machines. Hence multinational firms have incentives to split the production process of good X in which multinational firms produce and bring high-tech machines to the host country and assemble them with low-tech machines produced in the host country. Factors are perfectly mobile within each country but are immobile between countries. However, high-tech machines are tradable with some transfer and adjustment costs.

The distinct feature of my analysis is to allow the model to focus on the effects of the multinational firms on the host economy under the various industry characteristics as well as country characteristics. While the ratio of fixed endowments of skilled to total labor force stands for the country characteristics, the intensiveness of high-tech machines used in the sector determines the industry characteristics.

Preference

There are two final goods, X and Y, and the preference takes the following Cob-Douglas utility form.

$$u = X^{\gamma} Y^{1-\gamma}, \quad X = \left[\sum_{i=1}^{n} X_{di}^{\frac{\epsilon-1}{\epsilon}} + \sum_{j=1}^{m} X_{mj}^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}, \quad \epsilon > 1,$$

where γ is the expenditure share to the good X $(0 < \gamma < 1)$, X_d (X_m) is the differentiated good by local (multinational) firms. ϵ is the elasticity of substitution between X_d and X_m. n (m) is the numbers of domestic (multinational) firms. Economy endows fixed amount of skilled and unskilled labor.[14]

Final Goods Sector

There are two final goods sectors; Y is produced using skilled and unskilled labor showing constant returns to scale technology, and Y is assumed numeraire. Good X is produced by two types of producers; domestic producers and multinational firms. X_d represents each variety produced by domestic producers and X_m is each variety produced by multinationals. Final good Y represents the rest of the economy and is tradable at the fixed world market price. I further assume the trade in good Y is costless. Demand for each final good is as follows;

$$X = \frac{\gamma E}{Q_X}, \quad Y = (1-\gamma)E. \tag{1}$$

where E is total expenditure of the economy which will be defined shortly and Q_X is a composite price index of X which consists of prices of X_d and X_m[15]

$$Q_X = \left[\sum_{i=1}^{n} p_{di}^{1-\epsilon} + \sum_{j=1}^{m} p_{mj}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}, \tag{2}$$

where p_d and p_m represent the prices of domestic and foreign goods respectively.

Given X, domestic firms and multinationals generate the demand for each variety, X_d and X_m

$$X_d = p_d^{-\epsilon} Q_X^{\epsilon} X, \tag{3}$$

$$X_m = p_m^{-\epsilon} Q_X^{\epsilon} X, \tag{4}$$

[14]To save the number of variables, I use X and Y for denoting both demand and supply of final goods.

[15]The derivations of Q_X and demand functions for X_d and X_m are already well-stylized. See Markusen (2002), chapter 6, for details.

Each variety X_d and X_m is produced under monopolistically competitive markets with the following production techniques;

$$X_d = \Psi \min\left\{\frac{Z_L^d}{1-\mu}, \frac{Z_H^d}{\mu}\right\},$$
$$X_m = \min\left\{\frac{Z_L^m}{1-\mu}, \frac{Z_H^m}{\mu}\right\},$$

where Z_i^j, $i = L, H$ and $j = d, m$ is quantity of intermediate goods (machines) used in each final good production. Final good X_d and X_m are produced with two types of machines, low tech- and high-tech machines. Machines are assumed to be tradable. I further assume that multinationals bring (import) Z_H^m from their home country to the host economy and assemble the final goods X_m using low-tech machines which are produced in the host country. A μ indicates the fixed productivity parameter and also indicates the type of industry assumed to lie between 0 and unity. A Ψ is productivity parameter and captures spillover effects from multinational firms in which the activity of multinationals has an externality to local firm production. This productivity parameter contains the quantity of skilled labor who obtain knowledge of new technology and absorptive capability of host economy that will be discussed in next section. In this section Ψ is assumed to be unity, that is, there are no spillover effects.

Technology of Y-sector is assumed Cob-Douglas and produced with skilled and unskilled labor;

$$Y = AL_Y^{\beta} H_Y^{1-\beta},$$

where A is productivity parameter, L_Y and H_Y denote unskilled and skilled labor employed in Y-sector.

Cost Functions and Prices

Since final good Y is numeraire and produced under perfectly competitive market, I have following unit cost function of Y-sector;

$$c_Y(w_L, w_H) = w_L^{\beta} w_H^{1-\beta} = 1 \tag{5}$$

with the normalization $A = \beta^{-\beta}(1-\beta)^{\beta}$.

Varieties of goods X are produced with an increasing returns to scale technology. Thus domestic and multinational firms face the following cost functions;

$$\begin{aligned} \Gamma_d &= \Psi^{-1}[(1-\mu)q_L + \mu\, q_H](X_d + F_d), \qquad (6) \\ \Gamma_m &= [(1-\mu)q_L + \mu(\, t_z q_H^* + \phi)](X_m + F_m), \qquad (7) \end{aligned}$$

where $q_i,\ i = L, H$ is the price of intermediate machine Z_i^j and q_H^* is the price of machine that multinational firms bring from their home country. t_z stands for either the transportation cost or policy variable, such as tariff. t_z is assumed to be greater than 1. Host country uses this variable to control the FDI inflow. This topic will be discussed in section 4. ϕ is an adjustment cost that is necessary to install the new machines into the host economy's production. F_d and F_m are fixed costs for each type of firm and are assumed $F_m < F_d$, that is, multinationals have some firm level advantage to establish new plants, such as marketing know-how, distribution network, management strategies and so forth. These cost functions say that the if the industry has a low μ, then it is characterized as a low-tech machine intensive industry, while if the industry has a high μ, then it is a relatively high-tech machine intensive industry.

Since X_d and X_m are produced in the monopolistic competitive market, their each price becomes

$$\begin{aligned} p_d &= \frac{\epsilon}{\epsilon - 1}\, c_d, \qquad (8) \\ p_m &= \frac{\epsilon}{\epsilon - 1}\, c_m, \qquad (9) \end{aligned}$$

where c_d and c_m are marginal costs of domestic and multinational firms, respectively.

Next I define the firm's profit functions for domestic and multinational firms;

$$\begin{aligned}\pi_d &= p_d X_d - c_d(X_d + F_d) \\ \pi_m &= p_m X_m - c_m(X_m + F_m)\end{aligned}$$

Each type of intermediate machines is produced with one unit of each type of labor, that is, low-tech machine Z_L^j is produced with one unit of unskilled labor and high-tech machine Z_H^j is produced with one unit of skilled labor. Intermediate good sectors are assumed perfectly competitive so that $q_i = w_i$, $i = L, H$.[16]

Making use of equation (5) and defining $w = w_H/w_L$, I can rewrite w_L and w_H as

$$w_L = w^{\beta-1}, \quad w_H = w^{\beta},$$

I assume that to make the best use of a high-tech machine brought by the multinational firm together with the low-tech machine which is produced by the local firm, the subsidiary needs a help of local skilled labor. In other words, adjustment cost ϕ is a function of skilled labor's wage rate. Using the transformation of wage rates above, unit cost functions become

$$c_d(w) = \Psi^{-1}\left[(1-\mu)w^{\beta-1} + \mu\ w^{\beta}\right], \tag{10}$$

$$c_m(w) = (1-\mu)w^{\beta-1} + \mu\ (t_z w^{*\beta} + \alpha w^{\beta}), \tag{11}$$

where w^* is the wage ratio of skilled to unskilled labor in multinational's home country and α is a unit of skilled labor required to adjust new machines to host country's low-tech machine assuming $0 < \alpha < 1$.[17] It is obvious that multinational's home country has a comparative advantage if $c_d(w) > c_m(w)$ and FDI inflow into host country occurs.

[16] Since intermediate machines are tradable across borders but workers are not, this assumption is needed.

[17] To produce one unit of X_m, less than one skilled labor is needed. This means that skilled labor works a part of the day not a full day.

Since multinational's home country is relatively a skilled labor abundant country by assumption, the relative wage in home country is cheaper than that in host country, $w^* < w$. Hence, the price of high-tech machines is less than the price of high-tech machines in host country, $q_H^* < q_H$.

Since I assume full employment and fixed labor supply, the total factor income, E, of this economy is $w_L L + w_H H$. Using the previous transformation of w, total factor income is rewritten as;

$$E(w) = w^{\beta-1} L + w^{\beta} H \tag{12}$$

Equilibrium Conditions

Two more equilibrium conditions are needed for closing the model, factor market equilibrium and zero profit conditions. Labor markets are assumed perfectly competitive with fixed labor supplies so the equilibrium conditions are described as $L = \beta\, Y w^{1-\beta} + L_X$ and $H = (1-\beta) Y w^{-\beta} + H_X$. L_X and H_X are unskilled and skilled labor required for X-industry. From these equations, the function of relative wage is expressed as a function of L_X and H_X,[18]

$$w = \frac{1-\beta}{\beta} \, \frac{L - L_X}{H - H_X}. \tag{13}$$

Unskilled and skilled labor in X-sector consist of local and multinational firms' employees,

$$L_X = n(1-\mu)(X_d + F_d) + m(1-\mu)(X_m + F_m), \tag{14}$$

$$H_X = n\mu(X_d + F_d) + \alpha m \mu (X_m + F_m). \tag{15}$$

The first term of right hand sides of equations (14) and (15) represent unskilled and skilled labor employed by local firms. The second term of right hand sides of equations (14) and (15) represent unskilled and skilled labor employed by multinational firms.

[18]Eliminating Y from equations for L and H, and solving the result for w lead equation (13).

Finally zero profit condition for each firm is directly derived from each profit function setting equal zero,

$$X_d = (\epsilon - 1)F_d, \tag{16}$$

$$X_m = (\epsilon - 1)F_m. \tag{17}$$

The system of equations consists of 15 equations, such as (1)(two equations), (2), (3), (4), (8), (9), (10), (11), (12), (13), (14), (15), (16), and (17). These 15 equations solve 15 unknown variables, such as $\{X,\ Y,\ X_d,\ X_m,\ p_d,\ p_m,\ c_d,\ c_m,\ Q_X,\ w,\ E,\ L_X,\ H_X,\ n,\ m\}$. (See Appendix 3 for more detail.).

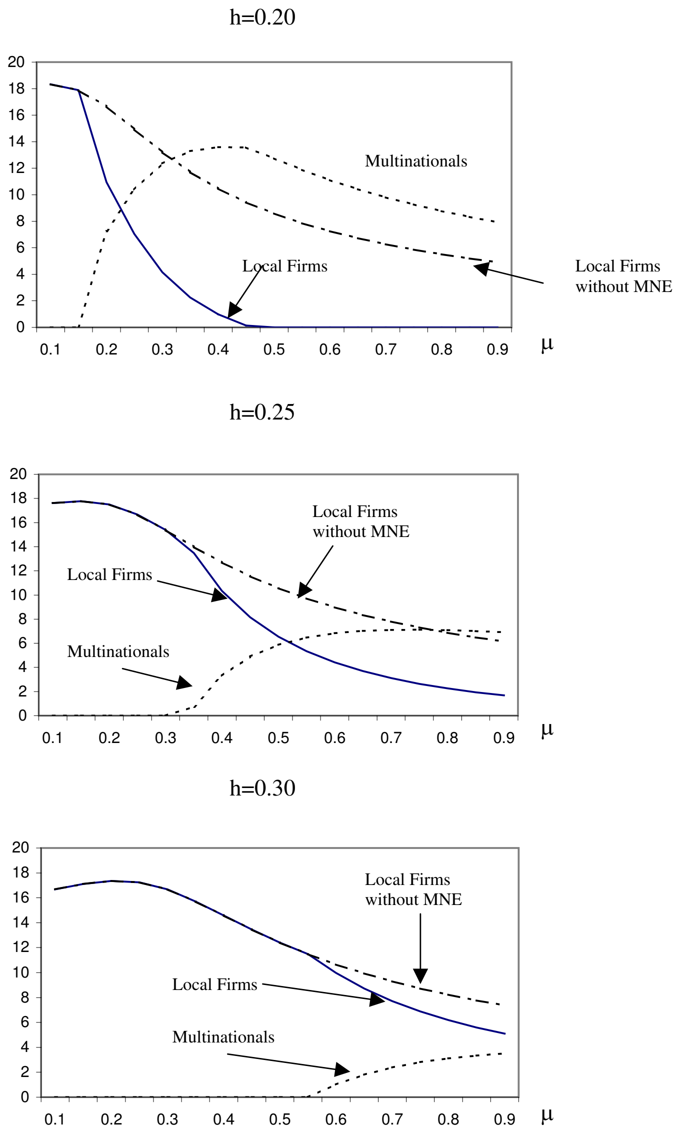
General Equilibrium

To show the characteristics of industry as well as country characteristics, I draw the graphs over μ for various skilled labor endowment ratios. Figure 2 shows the numbers of domestic and multinational firms without spillovers, i.e., $\Psi = 1$ over μ for three different cases of $h = H/(H + L)$: upper figure has $h = 0.20$, middle figure has $h = 0.25$, and lower figure has $h = 0.30$.

Upper panel ($h = 0.20$) says that the entry of multinationals drives local firms away from many high-tech industries. While the domestic firms prevail only relatively low-tech industries (low μ) multinational firms have large market shares in relatively high-tech sectors (high μ). This explains the case of least developed countries where multinational firms with relatively high technology overcome the local firms because of the large technology gap. Local and multinational firms compete each other only in low-tech sectors.

Middle panel ($h = 0.25$) shows the case where local firms are active for all sectors even after the entry of multinationals while multinational firms emerge in relatively high-tech sectors (higher μ). Multinational firms gain larger market shares in higher

Figure 2
Number of Local and Multinational Firms (without Spillovers)



technology sectors. Local and multinational firms compete in a wide range of industries.

Lower panel shows the case of $h = 0.30$ which is still a developing but not severely scarce in skilled labor. In this case, multinational firms emerge only in high-tech sectors and local firms exist for all sectors although the number of local firms is decreasing with μ. Local and multinational firms compete in only relatively high-tech sectors.

Country characteristics which is indicated by h bring the following insights: the number of multinational firms is declining and the range of sectors shifts toward high-tech sectors as h increases, while the range of local firms expands as h increases. These observations on the country characteristics match the empirical findings about vertical multinational firms that I have discussed in introduction section.

In the next section, introducing technology spillover into these general equilibrium insights of industry and country characteristics, I explain the main question in this paper, i.e., why technology spillovers hardly occur in less developed countries, and only low-tech sectors benefit from FDI.

3 Endogenous Technology Spillover

Technology spillovers pass two stages. The first stage is where subsidiaries of multinational firms bring superior technology and knowledge of production into the host country. At the second stage mainly local skilled workers employed by subsidiaries learn new technology and then new technology disperses to local firms via labor turnover.[19] In addition to these factors, the degree of technology spillover also depends on the absorption capability of the host industry as many empirical studies indicate.

[19]See, for example, Hall and Khan (2003) for the importance of skilled workes on the technology spillovers. See also Fosfuri et al.(2001). Other than labor turnover, spillovers may arise through demonstration effects and backward and forward production linkage effects.

Thus the degree of technology spillover depends on the number of skilled labor employed by the multinationals, the frequency of labor turnover, and absorption capability of the industry. To make the story simple, I assume that the absorption capability of each industry is the share of number of local firms in the total number of firms in the industry. Blomström and Kokko (1998) state that spillovers from competition are not determined by foreign presence alone, but rather by the simultaneous interaction between foreign and local firms. They also point out that large foreign presence may even be a sign of a weak local industry, where local firms have not been able to absorb any productivity spillovers, while a high level of local competence contributes to raise the absorptive capacity of the host country. Blomström et al. (2000) also state that spillovers appear in industries with moderate technology gaps between local and multinational firms, but not in industries with large technology gaps. I assume that labor turnover potentially occurs for every skilled worker employed by multinational firms. In this sense, I may refer to this measure as *potential* degree of spillover.

Hence the (potential) degree of technology spillover is defined as follows;

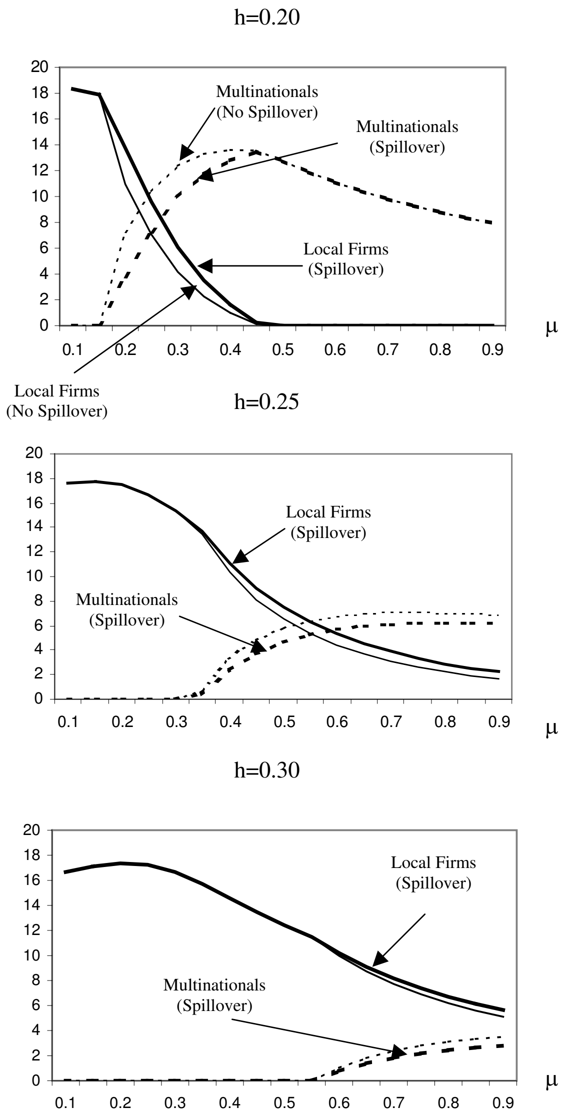
Share of Skilled Labor for MNE to Total Labor × Industry's Absorption Capability.

In our notation,

$$\frac{H^{\text{MNE}}}{L+H} \times \left(\frac{nX_n}{mX_m + nX_n} \right).$$

If there were no multinational in the host country, in other words, no skilled labor in multinational subsidiaries ($H^{MNE} = 0$), technology spillover never occurs. The other extreme case arises when there were no local firms ($n = 0$). In this case no spillover occurs because there are no receivers of new knowledge of high-tech machines. If there were many local firms and a small number of multinational subsidiaries, local firms compete one another to hire skilled workers who have learned new knowledge from the multinational subsidiaries and compete to provide a better offer to them. In this

Figure 3
Number of Local and Multinational Firms
(with and without Spillovers)



case, new technology is likely to be transferred to local firms with higher probability ($n/(n+m)$). I can interpret this to mean that there exists a small technology gap between local and foreign firms. On the other hand, if there were a few local firms and many multinational subsidiaries, skilled workers who have been working for the multinational subsidiaries have more choices to move to. In this case, technology spillover from multinationals to local firms is less likely to occur, because they are likely to move to other multinationals with higher probability ($1 - nX_n/(nX_n + mX_m) = mX_m/(nX_n + mX_m)$). I can interpret this to mean that there exists a large technology gap between local and multinational firms.

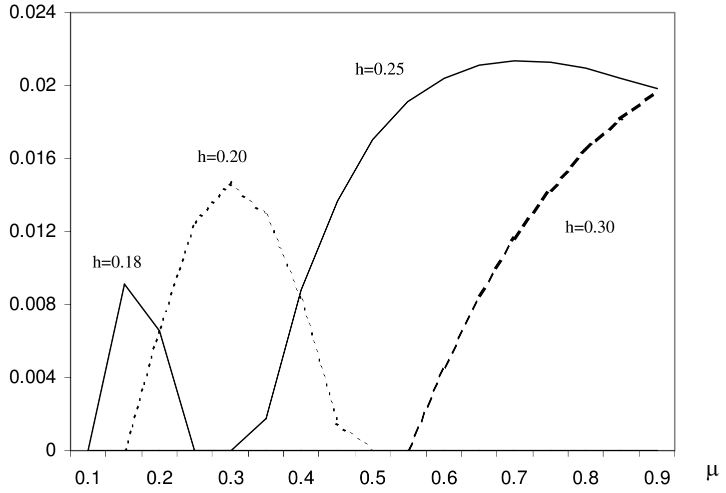
To endogenize spillover effects in the model, Ψ is now defined as follows:

$$\Psi = 1 + \left(\frac{H^{\text{MNE}}}{L+H}\right)\left(\frac{nX_n}{nX_n + mX_m}\right).$$

General equilibrium solutions are obtained by exactly same way as described in Appendix 3. However, I have now 16 equations including an equation for Ψ and 16 unknown variables including Ψ.

Figure 3 shows the number of local and multinational firms with and without spillover effects for various skilled labor ratios. All cases of hs show that technology spillover raises the number of local firms and reduces the number of multinational firms for sectors in which local and multinational firms coexist. Important finding from Figure 3 is that spillover occurs in relatively low-tech sectors for the economy with low hs and in relatively high-tech sectors for the economy with high hs. For example, while the economy with $h = 0.20$ has spillover effects in sectors from 0.15 to 0.5, the economy with $h = 0.30$ has effects in sectors over 0.55. Implication of this numerical example is that less developed country has spillover effects only in low-tech sectors while relatively skill abundant developing country has spillover effects in high-tech sectors. However Figure 3 does not tell the degree of spillover effects for different hs. Hence I isolate the effects of spillover next.

Figure 4
Technology Spillover Effects



Vertical axis : $\left(\frac{H^{MNE}}{L+H}\right)\left(\frac{nX_n}{nX_n + mX_m}\right)$

Figure 4 shows the effects of technology spillover over industry characteristics, μ. The vertical axis stands for the value of $\Psi - 1$ defined above. It is directly observed from Figure 4 that the locus of technology spillover becomes radically smaller as h decreases. This means that the less skilled labor ratio the less benefit from technology spillover. For example, the country with $h = 0.20$ potentially benefit from FDI much less than the country with $h = 0.25$ does. This prediction explains the empirical evidence that the endowment of skilled labor of a country is crucially important for technology spillovers.

Figure 4 also indicates that the host country with lower h has a potential spillover in only relatively low-tech industries. The economy with $h = 0.20$, for example, has an industry range of spillovers between 0.15 and 0.5 that are low-tech sectors, while the economy with $h = 0.30$ has an industry range over 0.6 that are high-tech industries. This prediction explains another empirical evidence that less developed countries benefit from FDI only in low-tech sectors. This also tells us the importance of the technology gap between local and multinationals for obtaining spillovers. The prediction, that spillovers appear only in sectors in which there is competition between local and multinationals, explains the empirical findings by Kokko (1994) and Blomström et al. (2000), etc.

4 FDI Policy and Spillovers

The model of this paper addresses the effects of the relative abundance of skilled workers and the degree of competition between local and multinationals on the magnitude of technology spillovers. The model provides a role for the government of the host economy to control volume of spillovers indirectly through changing t_z on FDI. In this section, the impact of liberalizing or restricting FDI policy is discussed. Host government can control the volume of FDI by choosing t_z. The cost function indicates that as t_z increases, the cost of multinationals in the host economy increases. Hence, it is expected that the number of multinationals would decline.

Figure 5 shows the spillover effects with various level of t_z for three types of countries, i.e., skilled labor scarce developing country ($h = 0.20$), medium skilled labor developing country ($h = 0.25$), and relatively skilled labor abundant developing country ($h = 0.3$).

The curve demonstrating the magnitude of spillovers on the economy with $h = 0.20$ (upper figure) moves rightward as t_z increases. If t_z is 1.0 or 1.1, multinationals drive the local firms out of the market and dominate the market. So the spillover effects are zero. When t_z is 1.3 spillover effects prevail from low-tech industry to high-tech industry. When t_z is 1.4, even high-tech industry with $\mu = 0.8$ or 0.9 has spillover effects ranging from $\mu = 0.2$ to $\mu = 0.9$. For this host economy, relatively restrictive FDI policy increases spillover effects. Hence, the skilled labor scarce developing country can promote spillover effects by controlling t_z appropriately. In other words, FDI liberalization is not always a good policy and may sometimes seriously hurt a skilled labor scarce developing economy, by driving local firms out of the market.

The moderately skilled labor scarce economy (with $h = 0.25$) is also affected by the level of t_z. As t_z increases, the range of spillovers moves rightward. The magnitude of spillover effects depends on the combination of t_z and skilled labor intensity of an industry. If the host country government needs relatively high-tech knowledge, which is often true in developing countries, the government can choose a relatively high t_z. In this case, FDI liberalization would be expected to bring spillover effects only into low-tech industry (low μ).

As we have seen in the previous section, a relatively skilled labor abundant developing country is likely to receive FDI inflow in high-tech industry (higher μ). If the industry has a high μ, then it benefits from FDI. When this economy's government chooses FDI liberalization level ($t_z = 1.0$), the range of industry between $\mu = 0.3$ and $\mu = 0.9$ benefits from FDI. When the government chooses higher t_z, e.g., $t_z = 1.3$, only a high-tech industry (e.g., $\mu = 0.8$ or 0.9) benefits from FDI. For the developing economy with relatively abundant skilled labor, FDI liberalization may encourage development.

To summarize, while a skilled labor scarce host economy may use FDI restriction policy to maximize the spillover effects from FDI, a skilled labor abundant developing host economy may choose FDI liberalization policy to maximize its spillover effects.

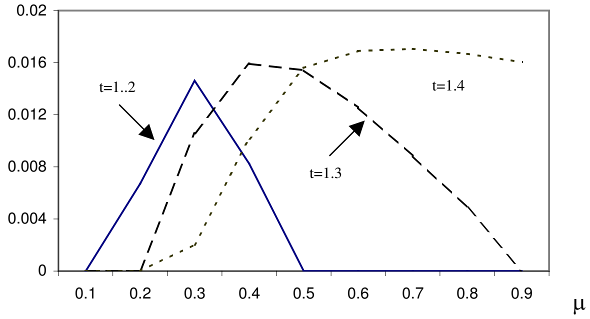
5 Conclusions

Although recent empirical evidence on multinational firms and technology spillovers suggest the importance of industry characteristics as well as country characteristics, little theoretical attention has been devoted to the industry differences. There are two important issues regarding the empirical evidence of industry differences. First, the impact of FDI varies across countries depending on the level of their human capital endowment. Second, the evidence also suggests that skilled labor scarce countries hardly benefit from FDI inflow and that if they do there are only spillovers in low-tech sectors.

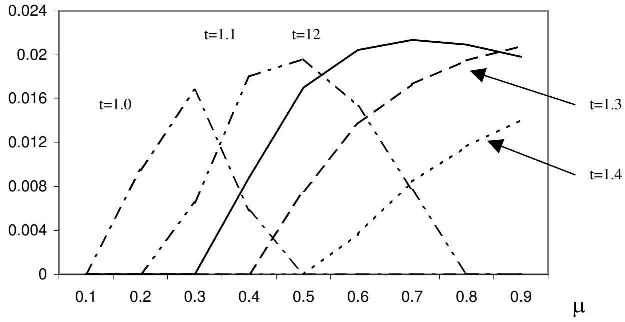
By introducing the industry characteristics, this endogenous technology spillover model of a small open economy with vertical multinationals has identified (1) in a severely skilled labor scarce country, local firms are active only in low-tech sectors while multinational firms emerge in relatively high-tech sectors. In this setting, multinational firms occupy the whole of the high-tech industry market. (2) in a moderately skilled labor scarce developing country, local firms are active in all sectors but tend to be more active in lower technology sectors. Multinational firms enter relatively high-tech industries. In these high-tech sectors, multinational firms get the larger share of the

Figure 5
FDI Policy and Spillovers

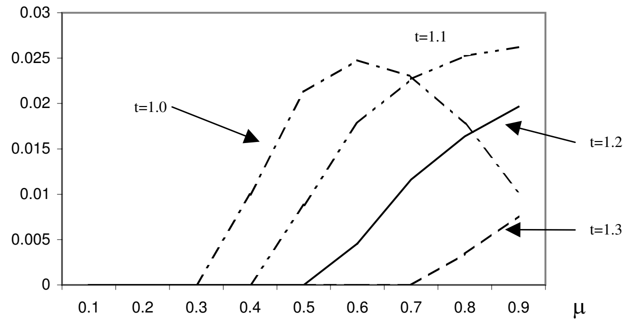
h=0.20



h=0.25



h=0.30



market than local firms but local firms are able to compete with multinational firms for a portion of market share. (3) In a country with relatively large amount of skilled labor, local firms are active in all sectors while multinationals are active only in high-tech industries. Market shares are dominated by local firms for all sectors.

Applying these features of my model to empirical findings, I have the following main result. Combining the industry characteristics of vertical multinationals together with the absorption capability of technology spillovers I explained that in less developed countries foreign multinationals drive out local firms in a high-tech sector because of the wide gap in technology. This in turn implies that spillover effects from multinationals to local firms are very small. In this case, local firms are too weak to compete with multinational firms in a high-tech sector. Only in low-tech sectors, can local firms compete with multinationals, and thus spillover effects occur only in a low-tech sector. In relatively skilled abundant economies, such as the Asian newly industrializing countries, local firms can survive after investment liberalization and compete with multinationals in all industries. In this case, knowledge of technology is smoothly transferred to local firms.

On designing investment liberalization policy, the clear message of this analysis is that different characteristics of industries, such as the share of local firms, absorption capability, and property rights. etc., should be taken into account as well as development level of the host country. Furthermore, my model predicts that the role of education to acquire skill and creation of competitive markets are especially important for technology spillover.

There are, of course, some important issues that are left out of this modelling strategy. Two possible extensions should be noted for the further research. First, as I have discussed in the introduction, for simplicity I have assumed that there are only vertical multinationals in the economy. However, horizontal multinationals may explain more clearly the threshold hypothesis of spillovers through multinational firms between developed and developing countries. Second, trade cost of intermediate goods do not play an important role in my model because trade-off between vertical FDI and international trade was not a main concern in this paper. However, decision making of trade-FDI option of foreign enterprizes may enrich the implications of the model.

Appendix

A Numerical Example

All simulated figures (from Figure 2 to Figure 5) have the following common numerical values;

α	β	γ	ϵ	F_d	F_m	w^*	t_z
0.5	0.5	0.5	3.0	1.0	0.7	1.2	1.2

Each industry characteristic $h = H/(H+L)$ is used from the following numerical values:

h	0.18	0.20	0.25	0.30
H	18	20	25	30
L	82	80	75	70
$H+L$	100	100	100	100

B General Equilibrium Structure

In Section 2, I assume that there are no spillovers ($\Psi = 1$). The system of general equilibrium consists of following 15 equations:

Demand Block: (1),(3),(4)

$$\begin{aligned} X &= \frac{\gamma E}{Q_X}, \\ Y &= (1-\gamma)E, \\ X_d &= p_d^{-\epsilon} Q_X^{\epsilon} X, \\ X_m &= p_m^{-\epsilon} Q_X^{\epsilon} X. \end{aligned}$$

Prices: (2),(8),(9),(13)

$$
\begin{aligned}
Q_X &= \left[\sum_{i=1}^{n} p_{di}^{1-\epsilon} + \sum_{j=1}^{m} p_{mj}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}, \\
p_d &= \frac{\epsilon}{\epsilon-1}\, c_d, \\
p_m &= \frac{\epsilon}{\epsilon-1}\, c_m, \\
w &= \frac{1-\beta}{\beta}\,\frac{L-L_X}{H-H_X}.
\end{aligned}
$$

Supply Block: (10),(11)

$$
\begin{aligned}
c_d(w) &= \Psi^{-1}\left[(1-\mu)w^{\beta-1} + \mu\ w^{\beta}\right], \\
c_m(w) &= (1-\mu)w^{\beta-1} + \mu\ (t_z w^{*\beta} + \alpha w^{\beta}).
\end{aligned}
$$

Factor Income: (12)

$$
E(w) = w^{\beta-1}L + w^{\beta}H.
$$

Labor Market Equilibrium Conditions: (14),(15)

$$
\begin{aligned}
L_X &= n(1-\mu)(X_d+F_d) + m(1-\mu)(X_m+F_m), \\
H_X &= n\mu(X_d+F_d) + \alpha m\mu(X_m+F_m).
\end{aligned}
$$

Zero Profit (Free Entry) Conditions: (16),(17)

$$
\begin{aligned}
X_d &= (\epsilon-1)F_d \\
X_m &= (\epsilon-1)F_m.
\end{aligned}
$$

These 15 equations solve 15 unknowns, such as X, Y, X_d, X_m, p_d, p_m, c_d, c_m, Q_X, w, E, L_X, H_X, n, and m.

To solve the system, with the function of $w(n, m : \mu)$, I can rewrite c_d and c_m (equations (10), (11)) as functions of n and m. Plugging $c_d(w(n, m : \mu))$ and $c_m(w(n, m : \mu))$ into equations (2), (8) and (9), I have Q_X, p_d and p_m as functions of $w(n, m : \mu)$. Combining these results together with equation (12), I obtain the equation of X, i.e., (1), as a function of $w(n, m : \mu)$. Finally using these results, I can describe the demand functions for X_d and X_m (equations (3) and (4)) as functions of n and m. Two equations, (3) and (4), solve the remaining endogenous variables, n and m

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