THE ECONOMIC IMPACTS
OF TECHNOLOGY TRANSFER AND SPILLOVERS
THROUGH FOREIGN DIRECT INVESTMENT
IN DEVELOPING COUNTRIES

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ABSTRACT

This dissertation consists of three essays. The overall theme is about the economic effects of technology transfer and spillovers in developing countries through foreign direct investment (FDI). The first essay is an oligopoly approach. The second essay is an endogenous growth approach. The third essay is a policy implication of intellectual property rights (IPRs) enforcement using the first oligopoly model.

The first essay develops an oligopoly model with endogenous technology spillovers through FDI. The foreign entrant brings a superior technology and therefore may spend resources to prevent spillovers of its technology to the home firm. The home firm has an incentive to spend resources to gain these spillovers. After firms strategically choose their expenditures to influence technology spillovers, they compete in a Cournot Nash quantity game. This study provides theoretical insight on the positive and negative empirical spillover results of FDI on productivity of local firms. Up to a critical bound, the larger the initial technology gap between the foreign and home firms, the more the home firm spends to gain spillovers. Past that boundary, the home firm decreases spending. As a result, the home firm's profits from spillovers vary, but larger technology gaps engender greater net profit losses from FDI. My results suggest that the developing countries should promote FDI when small technology gaps exist and support R&D activities of local firms in all cases.

The second essay modifies the endogenous growth model with learning-by-doing and knowledge spillovers of Barro and Sala-i-Martin (1999) to analyze the effects of FDI on economic growth in developing countries. The effects of technology transfer and
spillovers are separately analyzed. The growth of capital accumulation, consumption, and income depends on the conditions of the population growth, the rate of return on capital, and the net foreign capital inflow. For a developing country to sustain endogenous economic growth, the required conditions are the higher rate of return on investment and positive foreign capital inflow. The best policy package for the developing country is to promote FDI to increase the net foreign capital inflow, and to support R&D activities of local firms to increase their absorptive capacities.

The third essay provides theoretical policy analysis of the effects of IPR protection on the spillover equilibrium and home welfare, using the first oligopoly model. It concludes that private enforcement of the foreign firm’s spending to prevent technology spillovers is complementary to public enforcement of IPR protection. IPR protection affects the foreign firm’s behavior to spend more to prevent spillovers while its enforcement affects the home firm’s behavior to spend less to gain spillovers. As a result, the spillover ratio decreases in equilibrium. A decrease in the spillover ratio leads to reduction in consumers’ welfare with existing FDI as well as in the profits of the home firm. However, since the likelihood of FDI increases, home welfare improves by a new FDI which was not previously profitable because welfare gains for consumers dominate negative effects in the home firm’s profits. Therefore, a developing country can benefit from strengthening its IPR enforcement if this serves to attract additional FDI in the country.
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CHAPTER 1
INTRODUCTION

Industrialization has contributed to the economic growth of many countries. Those countries have obtained higher standard of living. Other countries are still poor and underdeveloped, and called as developing countries. If people in those developing countries can develop new products and technologies, they may be able to catch up with currently developed countries. Those countries need economic growth to get out of poverty (Dollar and Kraay 2002). They do not have the abilities or capabilities to develop new technologies. How can they obtain them? They can obtain their capabilities by imitation, which has played an important role in the transfer of technology to highly performing economies, such as the newly industrialized countries (Grossman and Helpman 1991b; Coe et al. 1997).

One of the important means of imitation activities can be through foreign direct investment (FDI). FDI involves with long term investment which is more likely to stay in the host country. FDI brings not only financial resources for capital formation, but also technology. FDI provides technology transfer from the parent firms to their affiliates. It may also provide the opportunities for imitation activities or technology spillovers that increase the productivity of host country firms. An increase in their productivity at the firm level leads to economic growth at the country level.

FDI has a long history. In 1600, the East India Company was established in London and established branches overseas (Wilkins 1970). As Lipsey (2001) summarizes that FDI flows have grown in importance and their production has increased. In 2002,
US$117 billion of FDI flowed from Organization for Economic Co-operation and Development (OECD) countries into non-OECD countries, which was about 20 percent of total OECD FDI outflows (OECD 2003).

When FDI comes into developing countries, imitation activities may violate patented intellectual property rights (IPRs) innovated in developed countries. IPR protection allows innovators and developers to be protected and motivated so that technology may be further advanced. Developed countries protest that IPR should be protected for FDI in developing countries, while developing countries worry that the costs incurred by IPR enforcement outweigh the benefits received from its enforcement.

In this dissertation, the economic effects of technology transfer and spillovers on developing countries are theoretically analyzed. This focus is worthwhile because there are not many theoretical studies on this topic while many empirical studies exist. My dissertation consists of two separate unique approaches to the analysis of FDI technology transfer and spillovers within a developing country. The first approach studies the effects of technology transfer and spillovers at the firm level using analysis of the endogenized spillover equilibrium. This approach also provides welfare analysis of technology transfer and spillovers from FDI. The second approach aggregates firm level profit maximization and consumer utility maximization to the national level to show the relationship between FDI and growth.

This dissertation consists of three essays. The first essay is an oligopoly approach at the firm level to technology transfer and spillovers in developing countries through FDI. The second essay is an endogenous growth approach at the country level to the same topic. The third essay examines the policy implication of IPR enforcement using the first
oligopoly model. The following are contributions of the three essays.

1.1 Contributions

The first essay provides a new theoretical attempt to analyze the behaviors of the foreign firm and the home firm in developing countries in terms of technology transfer and spillovers from FDI. It reveals how the foreign firm behaves to prevent its technology spillovers and how the home firm behaves to gain spillovers from the foreign technology. Because it provides a theoretical model to analyze the behaviors of firms and their effects on home welfare, it enables further research on the theoretical and empirical analyses of the behaviors of the foreign firm and the home firm.

Many researchers have focused on mutual knowledge spillovers typically produced by FDI from a developed country to a developed country such as Spence (1984), Tolwinski (1996) and Petit and Sanna-Randaccio (2000). However, this paper is focused on only one direction of spillover from the foreign firm to the home firm. This situation may be more realistic for FDI from a developed country to a developing country. In this model, spillovers are endogenized while other studies use spillovers exogenously for imitation activities. The spillover equilibrium is endogenized with the foreign firm’s expenditure to prevent spillovers of its technology and the home firm’s expenditure to gain spillovers from the foreign technology.

The second essay has a unique approach by applying FDI effects of technology transfer and spillovers separately to the economic growth in the situation of developing countries. Because technology transfer and spillovers are separated, their effects on

---

1 Fosfuri et al. (2001) endogenize spillovers for workers’ mobility.
growth can be analyzed separately. No other growth model has separated the effects of
technology spillovers from FDI in developing countries (Grossman and Helpman 1991a;
1991b, Walz 1997, and Reis 2001). This growth model is also used to analyze the
relationship between FDI and the growth rates of per capita income, consumption and
capital by aggregating the firm's profit maximization and consumer's utility
maximization.

The third essay is an extension of the first theoretical model for analysis of the policy
implications with respect to IPR protection. The government policy on IPR protection has
some significant effects on the behaviors of the foreign firm and the home firm. By using
the oligopoly model developed in the first essay, how IPR protection changes the
behaviors of the foreign firm and the home firm is analyzed. The analysis reveals that
IPR enforcement (public enforcement) and the foreign firm's spending to prevent
spillovers (private enforcement) act as complements as shown in other literature (Shavell
1984; 1987, Kolstad et al. 1990, and Kaplow and Shavell 1994; 1996), while many other
researchers view they act as substitutes. It also includes the effects of IPR enforcement on
the spillover equilibrium, on profits of both firms, and on welfare of the host country.
REFERENCES


CHAPTER 2
TECHNOLOGY SPILLOVERS AND WELFARE
THROUGH FOREIGN DIRECT INVESTMENT
IN DEVELOPING COUNTRIES: AN OLIGOPOLY APPROACH

2.1 Introduction

Foreign direct investment (FDI) to developing countries brings not only financial resources for capital formation, but also technology\textsuperscript{1}. FDI provides direct technology transfer from the parent firms to their affiliates in developing countries. Transferred technology can also provide various spillover effects\textsuperscript{2} to local economies. Imitation as one channel of spillovers has played an important role in the transfer of technology to highly performing economies, such as Japan and the newly industrialized countries (Grossman and Helpman 1991b; Coe et al. 1997).

To analyze technology spillovers, I develop a model of a duopoly competition between a foreign firm and a home firm. The paper treats imitation as the means of technology spillover from the foreign firm to the home firm. The foreign firm may have incentives to prevent spillovers to obtain higher profits, while the home firm may have incentives to gain spillovers. The paper aims to shed light on the following questions: How does the technology gap between firms affect the behaviors of the foreign firm and the home firm? How does the technology gap affect technology spillovers and the home firm?

\textsuperscript{1} Technology, in the context of the paper, includes product design, process design, production process, and management techniques, such as supplier management, inventory management, production management, marketing and sales skills, research and development (R&D), and other relevant techniques.

\textsuperscript{2} Blomström and Kokko (1998) provide intuitive explanations of possible spillovers from multinational corporations in developing countries.
welfare from the FDI and accompanying spillovers? What would be the best policy package that a developing country should use?

Many researchers have focused on mutual technology spillovers among firms within a developed country; however, this paper concentrates on only one direction of spillovers from the foreign firm to the home firm in a developing country. This situation of one direction of spillovers may be more realistic for FDI from a developed country to a developing country. In 2002, US$117 billion of FDI flowed from Organization for Economic Co-operation and Development (OECD) countries into non-OECD countries, which was about 20 percent of total OECD FDI outflows (OECD 2003).

This paper is unique in endogenizing spillovers in imitation activities while others treat spillovers as exogenous. It focuses on the equilibrium level of technology spillovers in a developing country. The spillover equilibrium is influenced by the foreign firm's attempts to prevent spillovers and the home firm's attempts to gain spillovers. Technology spillovers lead to a reduction in profits of the foreign firm. Therefore, it is willing to pay to prevent spillovers. Protecting a firm’s intellectual property rights involves various strategies. For example, a parent firm may prefer sending its own managers and engineers abroad rather than hiring locals in order to prevent leaks of technology to local firms. On the other hand, the home firm is willing to pay to gain spillovers because its spending promises to lower its production costs and thereby to increase its profits.

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3 See, for example, Spence (1984), Petit and Tolwinski (1996), and Petit and Sanna-Randaccio (2000).
4 Fosfuri et al. (2001) endogenize spillovers of the foreign technology through workers' mobility. Spillovers are endogenized with wage offered by the foreign firm to retain trained workers to prevent spillovers and wage offered by the home firm to hire trained workers to gain spillovers.
There are at least three channels of technology spillovers discussed in various literatures: (i) imitation, (ii) linkage, and (iii) acquisition of human capital. Imitation may stand for any imitation activity of foreign technologies. Linkage effects can be forward or backward, a customer or supplier linkage, respectively. Foreign affiliates provide technology support to their suppliers and customers. This support linkage brings technology or knowledge spillovers to their suppliers and customers. Worker’s mobility can be an example of acquisition of human capital. Some workers, managers, or engineers who are trained in foreign firms quit their jobs and take trained skills and technologies with them to local firms and provide spillovers. To avoid complexities in modeling input and output markets simultaneously, my model focuses on technology imitation as the only means of technology spillovers.

Wang and Blomström (1992) and Glass and Saggi (1998) use imitation as a means to explain technology spillovers in their theoretical models. Wang and Blomström consider the cost of learning for home firms in their model with the cost of transferring technology for foreign firms. They predict that technology spillovers through FDI are positively related to the level of the home firms’ investment for imitation. Glass and Saggi (1998) construct a two-country model to explain imitation by a home firm and innovation in the parent firm. Their model considers the home firm’s spending for imitation activities to gain spillovers or catch up with technology. As they allow the

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home firm to imitate only one level higher quality product in the quality ladder model, the technology gap must be small enough for the home firm to imitate. A large technology gap between the foreign firm and the home firm may create negative effects of technology spillovers if the home firm is forced to exit the industry. The model I develop differs from these papers in endogenizing technology spillovers.

The following section presents the basic model. Section 2.3 discusses a spillover equilibrium in a two-stage game. The effects of the technology gap on the spillover equilibrium are discussed in Section 2.4. Section 2.5 provides policy implications as well as the analysis of home welfare resulting from technology transfer and spillovers. The conclusion is in Section 2.6.

2.2 The Basic Model

The developing country market is composed of two firms, the home firm and the foreign firm. Market segmentation and Cournot competition with a homogeneous product are assumed. Constant marginal costs and non-negative profits are assumed for both the foreign firm and the home firm. An inverse linear demand function is also assumed for simplicity:

\[ P(Y) = a - b Y \]

where \( a > 0; b > 0 \); \( P \) denotes the price; and \( Y \) denotes total output.

There are two possible scenarios, one involving exports by the foreign firm and the other involving FDI and local production by the foreign firm. In both cases, the firms make simultaneous output decisions. The exporting equilibrium involves no technology

\(^7\) For the detail of quality ladder life cycle model, please refer to Grossman and Helpman (1991a; 1991b).
spillovers. It is a benchmark case used only for making welfare comparison. It involves a standard Cournot Nash equilibrium.\(^8\)

FDI must be more profitable than export for the foreign firm to decide to enter and produce in the local market. If the foreign firm chooses FDI, then the following two-stage game is played. In the first stage, the foreign firm and the home firm simultaneously decide on their spending to prevent spillovers and to gain spillovers, respectively. This spillover outcome is determined by the spending of the two firms to maximize their profits. In the second stage, the two firms are involved in Cournot competition, each firm simultaneously decides on its output level given the spillover outcome of the first stage. The game can be solved by backward induction, starting with the second stage. The equilibrium exists and is stable, provided the negative second order conditions and certain stability conditions\(^9\) (Friedman 1982; Shapiro 1989; Henriques 1990; Martin 2002) are satisfied in each period.

Spending of the home firm to gain spillovers from the foreign technology and that of the foreign firm to prevent spillovers of its own technology are defined as follows:

(i) The home firm’s expenditure to gain technology spillovers, \(g\)

This cost may represent a part of fixed costs of the home firm to imitate the foreign firm’s technology, such as reverse engineering costs. Spending \(g\) cannot increase spillovers above the technology level of the foreign firm.

(ii) The foreign firm’s expenditure to prevent technology spillovers, \(p\)

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\(^8\) Refer to Appendix 2A.

\(^9\) Own-spending effects on marginal profit dominate cross-spending effects in magnitude.
This cost may represent a part of fixed costs of the foreign firm, such as private enforcement costs to protect the foreign firm’s intellectual property rights. For example, the firm may pay to build a plant security system to prevent technology from leaking. Spending \( p \) cannot prevent the level of spillovers below zero.

Spending \( g \) and spending \( p \) are also considered as strategic substitutes to each other. Strategic substitute is defined that an increase in one firm’s spending to gain or prevent spillovers reduces the marginal profitability of such spending by the other firm (Bulow et al. 1985; Martin 2002).

In the first stage, firms maximize their profits by choosing optimal levels of spending \( g \) to gain spillovers and spending \( p \) to prevent spillovers:

\[
I^H(g) = P(Y) Y^H - C^H(Y^H, c^H, g, z^H) \quad (2-2)
\]

\[
I^F(p) = P(Y) Y^F - C^F(Y^F, c^F, p, z^F) \quad (2-3)
\]

where a superscript \( H \) denotes variables associated with the home firm, while a superscript \( F \) denotes variables associated with the foreign firm; \( II \) denotes the profits; total output \( Y = Y^H + Y^F \); \( C \) denotes total costs; \( c \) denotes marginal costs; and \( z \) denotes fixed costs excluding spending \( g \) and \( p \).

The outcome of FDI involves technology spillovers through imitation of the foreign firm by the home firm. Spillovers by imitation exist through knowledge spillovers or demonstration effects when the foreign firm produces in the home market. Imitation activities by the home firm may lower its marginal costs. Therefore, the change in the marginal cost of the home firm is used to measure the extent of technology spillovers. Marginal costs reflect the levels of technology of both firms. In the Cournot Nash competition at the second stage, outputs are a function of the marginal costs of the
foreign firm and the home firm. The foreign firm is assumed to have a lower marginal cost because its technology level is higher than that of the home firm:

\[ c^0 > c^F > 0 \]  

(2-4)

where \( c^0 \) denotes the initial marginal cost of the home firm.

The marginal cost of the home firm with spillovers can be expressed as:

\[ c^H = c^0 - s(g, p)(c^0 - c^F) \]  

(2-5)

where \( s \) denotes the spillover ratio and \( s(g, p) \in [0, 1] \) for \( \forall g \geq 0; \forall p \geq 0 \); The marginal costs \( c^0 \) and \( c^F \) are exogenously given.

The spillover ratio can be defined as a ratio of reduction in the marginal cost of the home firm to the difference in the marginal costs of both firms without spillovers. Since in the model a spillover ratio is endogenously determined through spending \( g \) and \( p \), the spillover ratio can be considered as a function of \( g \) and \( p \). Spillovers only affect the home firm’s marginal cost, not the foreign firm’s. The marginal cost of the home firm in the second stage is equivalent to that of Petit and Sanna-Randaccio (2000) by applying the following additional assumptions: (i) Spillovers are only one way from the foreign firm to the home firm, that is, the foreign firm brings technology and the home firm only imitates foreign technology; and (ii) Spillovers are endogenized.

The properties of the spillover ratio can be summarized as follows. Spending of the home firm \( g \) can increase the spillover ratio, while spending of the foreign firm \( p \) can prevent increasing of the spillover ratio. Spending \( g \) cannot increase the spillover ratio above one, while spending \( p \) cannot lower the spillover ratio below zero. For a given spending \( p \), the spillover ratio increases with a decreasing rate as spending \( g \) increases, while for a given spending \( g \), the spillover ratio decreases with a decreasing rate as
spending $p$ increases. The second-order cross-derivative of the spillover ratio is assumed to be non-positive. An increase in one firm's spending to gain or prevent spillovers does not have positive effects on the marginal gain or prevention of spillovers by such spending of the other firm. The properties of the spillover ratio $s$ can be expressed including the boundary conditions:

\begin{align*}
\forall p, \exists \bar{g}(p) \text{ s.t. } s(g, p) > 0 & \text{ if } g < \bar{g}(p); \text{ and } s(g, p) = 1 \text{ if } g \geq \bar{g}(p) \\
\forall g, \exists \bar{p}(g) \text{ s.t. } s(g, p) > 0 & \text{ if } p < \bar{p}(g); \text{ and } s(g, p) = 0 \text{ if } p \geq \bar{p}(g) \tag{2-6}
\end{align*}

where $\bar{g}$ denotes the maximum spending $g$ with a given $p$ at $s(g, p) = 1$; $\bar{p}(g)$ denotes the maximum spending $p$ with a given $g$ at $s(g, p) = 0$

\begin{align*}
& s_g > 0; \ s_{gg} < 0 \text{ for } s(g, p) \in [0, 1); \\
& s_g > 0; \ s_{gg} < 0 \text{ for } s(g, p) = 1 \text{ if } g \text{ decreases at } g = \bar{g}(p); \\
& \text{ or } s_g = 0; \ s_{gg} = 0 \text{ for } s(g, p) = 1 \text{ if } g \text{ increases at } g = \bar{g}(p) \text{ or if } g > \bar{g}(p) \tag{2-7}
\end{align*}

where a subscript $g$ denotes derivative with respect to $g$.

\begin{align*}
& s_p < 0; \ s_{pp} > 0 \text{ for } s(g, p) \in (0, 1]; \\
& s_p < 0; \ s_{pp} > 0 \text{ for } s(g, p) = 0 \text{ if } p \text{ decreases at } p = \bar{p}(g); \\
& \text{ or } s_p = 0; \ s_{pp} = 0 \text{ for } s(g, p) = 0 \text{ if } p \text{ increases at } p = \bar{p}(g) \text{ or if } p > \bar{p}(g) \tag{2-8}
\end{align*}

where a subscript $p$ denotes derivative with respect to $p$.

\begin{align*}
& s_{gp} = s_{pg} \leq 0 \text{ for } s(g, p) \in (0, 1) \\
& s_{gp} = s_{pg} \leq 0 \text{ for } s(g, p) = 0 \text{ if } p \text{ decreases or } g \text{ increases at } p = \bar{p}(g); \\
& s_{gp} = s_{pg} \leq 0 \text{ for } s(g, p) = 1 \text{ if } g \text{ decreases or } p \text{ increases at } g = \bar{g}(p); \\
& s_{gp} = s_{pg} = 0 \text{ for } s(g, p) = 0 \text{ if } p > \bar{p}(g), \text{ or if } p \text{ increases or } g \text{ decreases at } p = \bar{p}(g); \\
& s_{gp} = s_{pg} = 0 \text{ for } s(g, p) = 1 \text{ if } g > \bar{g}(p), \text{ or if } g \text{ increases or } p \text{ decreases at } g = \bar{g}(p) \tag{2-9}
\end{align*}
The derivative properties of the spillover ratio $s$ with respect to spending $g$ and $p$ can be illustrated as shown in Figure 2.1. If a given spending $g$ or $p$ increases, the curve shifts to the right. The initial conditions of the spillover ratio are: (i) $s(0, 0) = 0$. No spillovers occur when neither firm spends resources; (ii) $s(0, p) = 0$ if $p > 0$. No spillovers occur as long as the home firm does not spend resources even if the foreign firm spends; and (iii) $s(g, 0) \in (0, 1]$ if $g > 0$. Spillovers occur when the foreign firm does not spend resources if the home firm spends.

For example, the spillover function $s(g, p) = \ln\{(g+1)/(p+1)\}$ can be used as an example of a case where $s_{gp} = s_{pg} = 0$. The derivative properties (2-7) (2-8) and (2-9) of the spillover ratio are satisfied. The spillover ratio can be expressed as (i) $s(g, p) = \min[1, \ln\{(g+1)/(p+1)\}]$ if $\ln\{(g+1)/(p+1)\} > 0$; and (ii) $s = 0$ if $\ln\{(g+1)/(p+1)\} < 0$. The initial conditions of the spillover ratio are also satisfied: (i) $s(0, 0) = \ln 1 = 0$; (ii) $s(0, p) = 0$ if $p > 0$ or $\ln\{1/(p+1)\} < 0$; and (iii) $s(g, 0) = \min[1, \ln(g+1)]$ or $s(g, 0) \in (0, 1]$, if $g > 0$. 

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2.3 Equilibrium of Technology Spillovers

This two-stage game can be analyzed by applying backward induction, starting with the second stage.

2.3.1 Equilibrium in Stage Two

Let \( s(g, p) \) be the spillover level that has been endogenously determined in the first stage. In the second stage, each firm decides its output to maximize its profits. Given \( s(g, p) \) by solving a Cournot Nash competition, the equilibrium outputs for each firm are:

\[
Y_{H*}^*(g, p) = \frac{1}{3b} \{ a - 2(1 - s(g, p)) c^0 + (1 - 2s(g, p)) c^F \}
\] (2-10)

where \( c^0 < \frac{a + (1 - 2s(g, p))c^F}{2(1 - s(g, p))} \) because \( Y_{H*}^* \) must be positive.

\[
Y_{F*}^*(g, p) = \frac{1}{3b} \{ a + (1 - s(g, p))c^0 - (2 - s(g, p))c^F \}
\] (2-11)

at the equilibrium price level of

\[
P^*(g, p) = \frac{1}{3} \{ a + (1 - s(g, p)) c^0 + (1 + s(g, p)) c^F \}
\] (2-12)

The equilibrium output of the foreign firm is always at least as large as that of the home firm, because the home firm’s marginal cost cannot fall below that of the foreign firm through spillovers. The difference in the equilibrium output is proportional to the difference in the marginal costs of the home firm and the foreign firm. As the equilibrium spillover ratio increases towards one, the output of the home firm gets closer to the output of the foreign firm.
The Cournot Nash equilibrium\(^{10}\) gives the following profits in the second stage:

\[
\Pi^H(g, p) = \frac{1}{9b} \{a - 2(l - s)c^0 + (1 - 2s)c^F\}^2 - g - z^H
\]

\[
\Pi^F(g, p) = \frac{1}{9b} \{a + (1 - s)c^0 - (2 - s)c^F\}^2 - p - z^F
\]

2.3.2 The Spillover Equilibrium in Stage One

In the first stage, each firm decides on the level of spending \(g\) or \(p\) to maximize its profits in the second stage. This spending outcome determines the equilibrium level of spillovers \(s^*\). The spending \(g\) or \(p\) affects profits of the two firms, not only by increasing respective fixed costs but also by changing the marginal cost of the home firm through spillovers.

From (2-13) and (2-14), the necessary first order conditions for the optimal level of \(g\) and \(p\) are:

\[
\Pi^H_g = \frac{4}{9b} s_g \{c^0 - c^F\} \{a - 2(l - s)c^0 + (1 - 2s)c^F\} - 1 = 0
\]

\[
\Pi^F_p = \frac{-2}{9b} s_p \{c^0 - c^F\} \{a + (1 - s)c^0 - (2 - s)c^F\} - 1 = 0
\]

From the first order conditions (2-15) and (2-16), the optimal spillover ratio can be solved:

\[
s^*(g^*, p^*) = \frac{9b}{8(c^0 - c^F)^2 s_g} - \frac{a - c^F}{2(c^0 - c^F)} + 1
\]

\[
s^*_g = \frac{9b}{4(c^0 - c^F) \{a - 2(1 - s^*)c^0 + (1 - 2s^*)c^F\}} > 0
\]

\(^{10}\) Refer to Appendix 2B.
\[ s^*(g^*, p^*) = \frac{9b}{2(c^0 - c^F)^2 s_p^*} + \frac{a - c^F}{c^0 - c^F} + 1 \]  
(2-16)’

\[ s_p^* = -\frac{9b}{2(c^0 - c^F)(a + (1 - s^*)c^0 - (2 - s^*)c^F)} < 0 \]  
(2-16)’’

(2-15)’’ and (2-16)’’ satisfy the derivative properties of (2-7) and (2-8) for \( s_g \) and \( s_p \).

**Proposition 2.1: Existence of a Unique Spillover Equilibrium**

If the negative second order conditions \( \Pi_{gs}^H < 0; \Pi_{pp}^F < 0 \) and the stability conditions 
\( |\Pi_{is}^H| > |\Pi_{ip}^H|; |\Pi_{rs}^F| > |\Pi_{rp}^F| \), are satisfied, then there exists a unique equilibrium, which is determined by the first order conditions (2-15) and (2-16).

**Proof:** Refer to Appendix 2C.

Simulation results in Appendix 2D provide an example of a unique spillover equilibrium. The function of the spillover ratio \( s = \ln((g+1)/(p+1)) \) is used with the assumptions of \( a = 30, b = 1, \text{ and } c^0 = 10 \). The spillover equilibrium is identified at \( s^* = 0.48, g^* = 25.53 \) and \( p^* = 15.37 \) for \( c^F = 7 \). There are unique spillover equilibria for the range of \( c^F \in [5.49, 9.78] \).

**2.4 The Technology Gap**

The technology gap is defined as the magnitude of the difference in the marginal costs of the home firm and the foreign firm without spillovers in the developing country market. The technology gap can be represented by \( (c^0 - c^F) \) in this spillover equilibrium.
model. The effects of the technology gap on the spillover equilibrium can be analyzed by changing $c^F$, the marginal cost of the foreign firm, while keeping $c^0$, the marginal cost of the home firm without spillovers constant. A lower marginal cost of the foreign firm reflects a larger technology gap.

**Proposition 2.2: The Effects of the Technology Gap on the Spillover Equilibrium**

(i) For technology gaps above a critical minimum level $[c^0 - c^F > (5 - 8s)c^0 - a)/(2(1 - 2s))]$, as the technology gap increases, spending $p$ increases, spending $g$ decreases, and the spillover ratio $s$ decreases. In other words, the further behind the home firm is in technology the less it spends to catch up. The further ahead the foreign firm is in technology the more it spends to prevent spillovers.

(ii) For technology gaps below the critical level, as the technology gap increases, spending $p$ always increases, but changes in spending $g$ and the spillover ratio $s$ are ambiguous.

**Proof:** Refer to Appendix 2E.

For the smaller technology gaps, the home firm may have incentives to spend more to imitate the foreign technology. However, as the foreign technology advances, it becomes more difficult for the home firm to imitate. At a certain point, it becomes no longer profitable for the home firm to spend more to imitate the foreign technology. Then it starts to reduce spending $g$ to imitate. For the larger technology gaps above the critical level, the home firm loses incentives to spend more to gain spillovers because its
marginal spending does not return enough spillover gains. On the other hand, the foreign firm always has incentives to receive larger returns from additional spending to prevent spillovers as the technology gap increases. In other words, for the smaller technology gaps, the home firms can gain more spillovers than for the larger technology gaps, while the foreign firms can prevent their technology spillovers more for the larger technology gaps than for the smaller technology gaps. This result supports Glass and Saggi (1998)'s assumption that large technology gaps prevent spillovers of the foreign technologies while small technology gaps allow spillovers in their theoretical model.

Figure 2.2 illustrates an example of the effects of the technology gap on the spillover equilibrium. Below the critical level of the technology gap as marked by a star, the equilibrium spending of the home firm \( g^* \) may increase or decrease as the technology gap increases. At first, the home firm may increase spending to gain spillovers, then at a certain level, the home firm may start decreasing in its spending to gain spillovers. Above the critical level, the home firm continues to decrease spending to gain spillovers.

Kokko (1994) empirically shows that spillovers are less likely to occur in industries with large technology gaps and high foreign shares in the example of Mexico. Existing empirical literature on FDI and spillovers is inconclusive. Some empirical studies show negative effects of FDI on spillovers, while many other studies show positive effects of FDI on spillovers in developing countries.\(^\text{11}\) These positive and negative effects of FDI on spillovers may be explained by this model; positive or negative effects of FDI on

spillovers can be obtained at the different level of the technology gaps, as an inversed u-shaped relationship shown in Figure 2.2. The effects of FDI on spillovers are positive for smaller technology gaps as the technology gap increases, while the effects of FDI on spillovers are negative for larger technology gaps.

**Figure 2.2: The Effects of the Technology Gap on the Spillover Equilibrium**

Simulation results in Appendix 2D illustrate the theoretical example with the assumptions of \( a = 30, b = 1, c^0 = 10 \) and the equilibrium spillover ratio \( s^* = \ln((g^* + 1)/(p^* + 1)) \). As the technology gap increases, both spending \( p^* \) and \( g^* \) always increases. The equilibrium spillover ratio always decreases as the technology gap increases. Simulation results only show that the home firm has incentives to spend more to gain spillovers as one example of the smaller technology gaps. As the technology gap increases, the amount of spillovers in terms of the marginal cost \( s(c^0 - c^\ell) \) increases from 0.15 at \((c^0 - c^\ell) = 0.22\) up to 1.47 at \((c^0 - c^\ell) = 3.50\) for smaller technology gaps, thereafter the amount of spillovers decreases for larger technology gaps beyond \((c^0 - c^\ell) = 3.50\). The amount of spending needed to gain unit marginal cost always increases from
6.47 at \((c^0 - c^F)\) = 0.22 to 33.85 at \((c^0 - c^F)\) = 4.51 as the technology gap increases. This implies that the larger the technology gap is, the more difficult it is for the home firm to imitate the foreign technology. This simulation result matches the empirical conclusion of Mansfield et al. (1981).

2.5 Welfare Analysis

To analyze welfare change in the home country, the Cournot Nash equilibrium at the spillover equilibrium must be compared with the benchmark Cournot Nash equilibrium of the foreign exporting firm and the home firm. Changes in home welfare can be analyzed by subtracting home welfare without FDI from home welfare with FDI \(\Delta W(c^0, s^*, c^F, c^F) = W^{FDI}(c^0, s^*, c^F) - W^{NoFDI}(c^0, c^F)\). The required conditions for the foreign firm to enter the home market must be included. Then, the effects of FDI on home welfare can be analyzed by total welfare changes in terms of consumer surplus and home producer surplus.

The effects of the technology gap with FDI \((c^0 - c^F)\) on the foreign entry conditions and home welfare can be analyzed by changing the marginal cost of the foreign firm with FDI, while keeping the initial marginal cost of the home firm constant. One condition before FDI which affects home welfare can be the difference between the marginal costs of the two firms before FDI. The marginal cost of the foreign firm before FDI can be larger than, equal to, or smaller than that of the home firm. The marginal cost of the foreign firm before FDI including transportation costs and higher wages must be larger than that of the foreign firm after FDI. Otherwise, the foreign firm would never invest and produce in the home market.
2.5.1 Foreign Entry Conditions

For the foreign firm to enter the home market in production, its profits must be improved through FDI. The positive gain in the foreign firm’s profits yields the following conditions for the entry as shown in Appendix 2F:

\[
\alpha^x > \frac{a + c^0 - A}{2}
\]  \quad (2-17)

where a superscript \( x \) denotes variables associated with the foreign exporting firm, and

\[
A = \sqrt{\left(a + c^0\right)^2 - 4\left(sc^0 + (2-s)c^F\right)(2a + (2-s)(c^0-c^F)) - 9b\left(p + z^F - z^x\right)/4}.
\]

**Proposition 2.3: The Effects of the Technology Gap on the Foreign Entry Conditions**

As the technology gap increases, the foreign entry conditions are lowered. In other words, the likelihood of FDI increases.

**Proof:** Refer to Appendix 2F.

The effects of changes in the technology gap include three changes, in the technology transfer effects without spillovers, in the spillover effects on the profits of the foreign firm, and in spending \( p \). Changes in the transfer effects are always positive. Net changes of the spillover effects and spending \( p \) are always positive, because additional spending \( p \) gains more profits from prevention of spillovers than spending \( p \) itself \((+\Delta p < +\Delta IT^F)\). By increasing the technology gap, both the transfer effects and the spillover effects increase the profits of the foreign firm. An increase in the profits of the foreign
firm implies that the entry conditions become lower and previously unprofitable FDI may become profitable; hence, the likelihood of FDI increases.

For example, using simulation results in Appendix 2D of the function of the spillover ratio \( s = \ln\{(g+1)/(p+1)\} \) with \( a = 30, b = 1, c^F = 7, c^0 = 10, s = 0.483, p = 15.367 \), and the assumption of \( z^F = z^* \), as the technology gap increases from \( c^0 - c^F = 3 \) to 4, the indirect effects are \( \Delta p/\Delta c^F = -7.31 \) and \( \Delta s/\Delta c^F = 0.1422 \). \( \Delta X/\Delta c^F = 0.1470 > 0. \) This result illustrates that an increase in the technology gap provides the lower entry conditions for the foreign firm.

### 2.5.2 Home Welfare Analysis

When the foreign firm invests in the home country, consumers are expected to increase their welfare through FDI because of lower price and increased production in the market. On the other hand, the home firm may lose its profits if negative effects of competition from the foreign firm dominate positive effects from spillovers. The effects of technology transfer without spillovers, and the net effects of technology spillovers are separated for the welfare analysis of the home country. The net effects of spillovers include positive effects from spillovers and negative effects of spending \( g \). An increase in profits of the foreign firm is not available for home use; hence, its profits are excluded in the analysis.

**Proposition 2.4: The FDI Effects on Home Welfare**

*If the entry condition (2-17) for the foreign firm is satisfied,*
(i) If $c_0 - c^F > c^X - c^0$, home welfare always increases as a result of FDI. The spillover effects are always positive, and the FDI effects without spillovers are also positive because the positive effects on consumers’ welfare dominate the negative effects on the profits of the home firm.

(ii) If $c_0 - c^F < c^X - c^0$, changes in home welfare due to FDI are ambiguous. The spillover effects are always positive, while the FDI effects without spillovers are negative because the negative effects on the profits of the home firm dominate the positive effects on consumers’ welfare.

**Proof:** Refer to Appendix 2G.

Home welfare depends on which is larger, the technology gap defined by the difference of the marginal cost of the two firms with FDI, but without spillovers $(c_0 - c^F)$ or the difference of the marginal costs of the two firms before FDI $(c^X - c^0)$. If the marginal cost of the foreign firm before FDI is less than the marginal cost of the home firm, home welfare always increases. If the difference between the marginal costs of the foreign firm before and after FDI is less than twice as much as the technology gap, home still gains the positive transfer effects. If the difference is more than twice as much as the technology gap, the transfer effects become negative and total changes in home welfare become ambiguous. Consumers gain their welfare from both technology transfer and spillovers because more products are available with lower price. For the home firm, the technology transfer effects without spillovers are negative because of the foreign entry,
while the net spillover effects are non-negative because the spillover gains always exceed spending \( g \) or otherwise no spending \( g \) can be the best choice.

**Proposition 2.5: The Effects of the Technology Gap on Changes in Home Welfare with FDI**

As the technology gap \( (c^0 - c^F) \) increases:

(i) Home welfare always increases by the FDI effects without spillovers, but the rate of increase is decreasing.

(ii) Home welfare increases by the spillover effects if the spillover ratio \( s^* \) increases \((ds/dc^F < 0 \) for the smaller technology gaps of Proposition 2), otherwise the effects are ambiguous.

(iii) Home welfare increases if the spillover ratio \( s^* \) increases, otherwise ambiguous.

**Proof:** Refer to Appendix 2H.

The FDI effects without spillovers always increase with a decreasing rate because the decreasing rate of the home firm’s profits is faster than the increasing rate of consumers’ welfare. The competitive effects of the foreign entry gives more welfare to consumers as the technology gap increases, while it gives the opposite effects to the profits of the home firm. The positive FDI effects without spillovers on consumers dominate the negative FDI effects on the home firm. On the other hand, the spillover effects include ambiguous changes. If the spillover ratio increases as the technology gap increases \((ds/dc^F < 0)\) for the smaller technology gaps of Proposition 2.2, the spillover
effects on consumers’ welfare always increase. Otherwise, the spillover effects on consumers’ welfare decrease as the technology gap increases. Since the spillover effects on the home firm always increase because the home firm makes no changes in its spending if changes reduce its profits. Total spillover effects on home welfare increase if the spillover ratio increases

\( \frac{ds}{de^F} < 0 \). Otherwise the effects are ambiguous.

From Propositions 2.4 and 2.5, home welfare is always positive and increases if the marginal cost of the foreign firm before FDI \( (c^x) \) is less than the sum of the marginal cost of the home firm before FDI and the technology gap \( (c^0 - c^x) > (c^x - c^0) \). However, when \( (c^0 - c^x) < (c^x - c^0) \), the change in home welfare may be negative because the negative effects on the home firm dominate the positive effects on consumers. As the technology gap increases, the change in home welfare may turn into positive as it becomes in the range of \( (c^0 - c^x) > (c^x - c^0) \). The change in home welfare is affected by the marginal cost of the foreign firm before FDI as well as the technology gap. If the foreign firm’s gains are larger, the home firm’s losses are larger as well.

Figure 2.3: The Effect of the Technology Gap on Changes in Home Welfare

![Figure 2.3: The Effect of the Technology Gap on Changes in Home Welfare](image)

Only if the spillover ratio decreases, the spillover effects on consumers’ welfare become negative. The negative spillover effects on consumers may be dominated by the
positive net FDI effects without spillovers and the positive spillover effects on the home firm. Home welfare approximately increases with a decreasing rate as shown in Figure 2.3. For smaller technology gaps, the spillover ratio increases and the spillover effects become all positive. Home welfare definitely improves by both positive FDI and spillover effects as the technology gap increases.

**Proposition 2.6: The Effects of Changes in the Marginal Costs of the Exporting Foreign Firm on Changes in Home Welfare from FDI**

As the marginal costs of the exporting foreign firm \((c^x)\) increases:

(i) If \(c^x < c^0\), home welfare increases with a constant decreasing rate until \(c^x\) becomes \(c^0\).

(ii) If \(c^x > c^0\), home welfare decreases with an increasing rate.

(iii) Home welfare can be maximized at \(c^x = c^0\) and the decreasing rate is always constant.

**Proof:** Refer to Appendix 21.

From Propositions 2.4 and 2.6, as the marginal cost of the exporting foreign firm increases, the effects on changes in home welfare from FDI are shown in Figure 4. The effects of changes in the marginal cost of the foreign firm before FDI are symmetric at \(c^x = c^0\). Since this effect only affects the technology transfer effect, consumers gain welfare while the home firm loses profits. As the marginal cost of the exporting foreign firm increases, home welfare increases with a constant decreasing rate until \(c^x = c^0\). Thereafter, home welfare starts to decrease with a constant decreasing rate as \(c^x\) increases.
The maximum welfare can be obtained at the point when the marginal costs of the two firms before FDI are the same \((c^x = c^0)\).

Figure 2.4: The Effects of the Difference in the Marginal Costs of the Foreign Firm and the Home Firm before FDI on Changes in Home Welfare from FDI

2.5.3 Policy Implications of Welfare Analysis

Several policy implications can be discussed based on the spillover equilibrium and welfare analysis. The policy package that the developing economy can use is to promote FDI for smaller technology gaps, and at the same time to support local firms to improve their absorptive capacities.\(^{12}\) Subsidies, tax incentives, and the intellectual property rights protection can be used for promotion of FDI. Subsidies or tax incentives for FDI are effective especially when the foreign firm chooses exports instead of its entry with smaller technology gaps, yet the home country gains welfare from FDI. The host country may invite the foreign firms that decide FDI only if subsidies or tax incentives are provided. Janeba (2004) provides several examples where the foreign firms invested with subsidies, but they pulled out their investments after the government changed its subsidy

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\(^{12}\) Katrak (1989) and Kokko (1994) provide empirical evidence that technology transfer from FDI and domestic R&D are complimentary activities in developing countries.
policy. The enforcement of intellectual property rights protection can also promote FDI, though it may have negative effects on spillovers. If intellectual property rights protection is enforced, the imitation activities may be limited to other technologies than the patented ones; however, the home firms can still gain a lot from other technologies which are not patented, such as management techniques.

Consumers enjoy their benefits from FDI, while the home firms lose their profits by competition. The larger technology gaps are not suitable for import-substitution FDI because the negative transfer effects on local firms may be too large while the smaller technology gaps may help the home firms to gain more spillovers from FDI. The policy must be not only to support the local firms to increase their absorptive capacities, but also to provide subsidies or other financial incentives to promote R&D activities in order for local firms to accumulate their absorptive capacities. As Hoekman et al. (2004) indicate, FDI promotion policy must be complemented by policies to promote education and human capital accumulation as well as R&D activities. The accumulated absorptive capacities help local firms to innovate new products or technologies as did Japan and the newly industrialized countries.

2.6 Conclusion

This study reveals the endogenized behaviors of the foreign firm and the home firm in technology spillovers through FDI in developing countries. The foreign firm is willing
to spend to prevent technology spillovers while the home firm is willing to spend to gain spillovers. It also provides theoretical insight for the positive and negative empirical spillover results of FDI on productivity of local firms.

As the technology gap between the foreign and home firms increases from a small initial level, technology spillovers increase. However, when the technology gap exceeds a certain critical level, further increases lead to smaller spillovers. Since the foreign entry conditions are lowered as the technology gap increases, the likelihood of FDI increases. Home welfare always increases due to the FDI if the foreign firm has a cost advantage over the home firm prior to the FDI. If the spillover ratio increases as the technology gap increases for the smaller technology gap, home welfare always increases.

In order to make analysis more realistic, the following generalizations may be considered; however, it makes analysis more complicated.

(i) Differentiated products may be used instead of a homogeneous product, for example, a quality ladder model of Grossman and Helpman (1991a; 1991b) may be applied.
(ii) By using differentiated products, prices may be differentiated.
(iii) Instead of one home firm and one foreign firm, multiple home firms may be applied by using a multiple-firm Cournot model.

This model has another weakness because of a partial equilibrium model. An increase in employment and changes in wages cannot be included for the analysis of the effects on home welfare.

The best policy package for developing countries may be suggested to assist R&D activities of local firms as well as to promote FDI with smaller technology gaps. The local firms can increase their absorptive capacities with government supports while more
foreign technologies are available by the promotion of FDI. In order to promote FDI, for example, intellectual property rights may be protected for the patented foreign technologies in developing countries. The results may be uncertain because the enforcement reduces technology spillovers of the home firms from the foreign technologies while it promotes FDI to increase available sources of technology spillovers. Using this model, further research may be extended to study how the intellectual property rights protection may affect the behaviors of the foreign firm and the home firm, technology spillovers, and home welfare.
APPENDIX 2A

COURNOT NASH EQUILIBRIUM IN A BENCHMARK PERIOD

\[ \Pi^0 = P(Y^i) Y^0 - C^0(Y^0, c^0, z^0); \Pi^x = P(Y^i) Y^x - C^x(Y^x, c^x, z^x) \]  
(2A-1)

where a superscript 0 or x denotes variables associated with the home firm or the foreign firm in this period, respectively; \( Y^i = Y^0 + Y^x \).

Each firm maximizes its profit with respect to own output.

\[ \Pi^0 = P(Y^0 + Y^x) + P^r(Y^0 + Y^x)Y^0 - c^0 = 0 \]  
(2A-2)

\[ \Pi^x = P(Y^0 + Y^x) + P^r(Y^0 + Y^x)Y^x - c^x = 0 \]  
(2A-3)

From (2A-2) and (2A-3), the equilibrium outputs can be obtained with a linear inverse demand function:

\[ Y^0* = \frac{1}{3b} (a - 2c^0 + c^x); Y^x* = \frac{1}{3b} (a + c^0 - 2c^x) \]  
(2A-4)

Price can be calculated by \( P(Y^i) = a - b(Y^0 + Y^x) \):

\[ P^*(Y^i) = a - b \left\{ \frac{1}{3b} (a - 2c^0 + c^x) + \frac{1}{3b} (a + c^0 - 2c^x) \right\} = \frac{1}{3} (a + c^0 + c^x) \]  
(2A-5)

The equilibrium profits are obtained by adding fixed costs \( z^0 \) and \( z^x \):

\[ \Pi^0* = P^*(Y^i) Y^0* - c^0 Y^0* - z^0 = \frac{1}{9b} (a - 2c^0 + c^x)^2 - z^0 \]  
(2A-6)

\[ \Pi^x* = P^*(Y^i) Y^x* - c^x Y^x* - z^x = \frac{1}{9b} (a + c^0 - 2c^x)^2 - z^x \]  
(2A-7)
APPENDIX 2B
COURNOT NASH EQUILIBRIUM WITH SPILLOVERS

\[ \Pi^H = P(Y) Y^H - C^H (Y^H, c^F, g, z^H) \quad \Pi^F = P(Y) Y^F - C^F (Y^F, c^F, p, z^F) \] (2B-1)

Each firm maximizes its profit with respect to own output.

\[ \Pi^H_{y^H} = P(Y^H + Y^F) + P' (Y^H + Y^F) Y^H - c^H = 0 \] (2B-2)

where \( c^H = (1-s)c^0 + sc^F \) or \( c^0 - s(c^0 - c^F) \) from (2-5)

\[ \Pi^F_{y^F} = P(Y^H + Y^F) + P' (Y^H + Y^F) Y^F - c^F = 0 \] (2B-3)

From (2B-2) and (2B-3), the equilibrium outputs can be obtained with a linear inverse demand function:

\[ Y^{H*} = \frac{1}{3b} (a - 2(1-s)c^0 + (1-2s)c^F) ; \quad Y^{F*} = \frac{1}{3b} (a + (1-s)c^0 - (2-s)c^F) \] (2B-4)

Price can be calculated by \( P(Y) = a - bY \)

\[ P^*(Y) = \frac{1}{3} \{ a + (1-s)c^0 + (1+s)c^F \} \] (2B-5)

The equilibrium profits are obtained with the equilibrium outputs and price by adding fixed costs.

\[ \Pi^{H*} = \frac{1}{9b} (a - 2(1-s)c^0 + (1-2s)c^F)^2 - g - z^H \] (2B-6)

\[ \Pi^{F*} = \frac{1}{9b} (a + (1-s)c^0 - (2-s)c^F)^2 - p - z^F \] (2B-7)
In order for the spillover equilibrium to exist, the spillover equilibrium in (2-15)' and (2-16)' must be equal. The first order conditions are satisfied as long as $s_g > 0$ and $s_p < 0$. If the profit functions (2-13) and (2-14) of the both firms are strictly concave functions, it is sufficient for the first order conditions (2-15) and (2-16) to have equilibrium. Therefore the following negative second order conditions must be satisfied:

\[ \Pi_{gg}^H = \frac{4}{9b} (c^0 - c^F) \left[ s_{gg} \{ a - 2(1 - s)c^0 + (1 - 2s)c^F \} + 2s_g s_{g}(c^0 - c^F) \right] < 0 \]  
\[ (2C-1) \]

\[ \Pi_{pp}^F = -\frac{2}{9b} (c^0 - c^F) \left[ s_{pp} \{ a + (1 - s)c^0 - (2 - s)c^F \} - s_p s_{p}(c^0 - c^F) \right] < 0 \]  
\[ (2C-2) \]

In order for equilibrium to be stable, the following stability conditions must be satisfied (Friedman 1982; Shapiro 1989; Martin 2002):

\[ \left| \Pi_{gg}^H \right| > \left| \Pi_{gg}^F \right| ; \left| \Pi_{pp}^F \right| > \left| \Pi_{pg}^F \right| \]  
\[ (2C-3) \]

where

\[ \Pi_{gg}^H = \frac{4}{9b} (c^0 - c^F) \left[ s_{gg} \{ a - 2(1 - s)c^0 + (1 - 2s)c^F \} + 2s_g s_{g}(c^0 - c^F) \right] < 0 \]  
\[ (2C-4) \]

\[ \Pi_{pg}^F = -\frac{2}{9b} (c^0 - c^F) \left[ s_{pg} \{ a + (1 - s)c^0 - (2 - s)c^F \} - s_p s_{g}(c^0 - c^F) \right] < 0 \]  
\[ (2C-5) \]

Since spending $g$ and $p$ are strategic substitutes, (2C-4) and (2C-5) must be negative (Bulow et al. 1985; Martin 2002). The negative second-order conditions with the stability conditions are sufficient for the equilibrium to be stable. The following conditions are obtained from (2C-1), (2C-2), and (2C-3):

\[ s_{gg} + \delta - \gamma < s_{gp} < s_{pp} + \alpha - \beta \]  
\[ (2C-6) \]
From (2C-5), another condition for \( s_{gp} \) to satisfy strategic substitutes:

\[
\beta < s_{gp} \quad (2C-7)
\]

(2C-6) and (2C-7) give the conditions, \( \max\{s_{gg} + \delta - \gamma, \beta\} < s_{gp} \leq 0 \), to be stable. Therefore, there exists a unique spillover equilibrium.
APPENDIX 2D

SIMULATION RESULTS

The function of the spillover ratio \( s = \ln \frac{(g+1)/(p+1)} \) is used with the assumptions of \( a = 30, b = 1, c^0 = 10 \), and an inverse demand function \( P = a - bY \). The following data are simulated results with the different values of the marginal costs of the foreign firm, \( c^F \).

The equilibrium satisfies the conditions derived from the first order conditions (2-15) and (2-16), the negative second order conditions, and the stability conditions.

Table 2.1: Simulation Results of Technology Spillovers

<table>
<thead>
<tr>
<th>( c^F )</th>
<th>( p^* )</th>
<th>( g^* )</th>
<th>( s^* )</th>
<th>( II^{F #(b)} )</th>
<th>( II^{H #(b)} )</th>
<th>( s ) index(^{(a)} )</th>
<th>Difficulty(^{(c)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.00</td>
<td>32.332</td>
<td>32.339</td>
<td>0.0002</td>
<td>67.660</td>
<td>-7.330</td>
<td>0.0010</td>
<td>N/A</td>
</tr>
<tr>
<td>5.4945</td>
<td>27.039</td>
<td>34.056</td>
<td>0.2233</td>
<td>60.100</td>
<td>0.000</td>
<td>1.0062</td>
<td>33.846</td>
</tr>
<tr>
<td>5.50</td>
<td>26.988</td>
<td>34.048</td>
<td>0.2249</td>
<td>60.050</td>
<td>0.080</td>
<td>1.0122</td>
<td>33.636</td>
</tr>
<tr>
<td>6.00</td>
<td>22.677</td>
<td>32.292</td>
<td>0.3408</td>
<td>56.158</td>
<td>6.673</td>
<td>1.3633</td>
<td>23.687</td>
</tr>
<tr>
<td>6.50</td>
<td>18.853</td>
<td>29.255</td>
<td>0.4213</td>
<td>53.541</td>
<td>12.775</td>
<td>1.4745</td>
<td>19.840</td>
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<tr>
<td>7.00</td>
<td>15.367</td>
<td>25.530</td>
<td>0.4830</td>
<td>51.605</td>
<td>18.462</td>
<td>1.4490</td>
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<tr>
<td>7.50</td>
<td>12.149</td>
<td>21.405</td>
<td>0.5329</td>
<td>50.091</td>
<td>23.775</td>
<td>1.3324</td>
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</tr>
<tr>
<td>8.00</td>
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<td>17.044</td>
<td>0.5747</td>
<td>48.860</td>
<td>28.740</td>
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</tr>
<tr>
<td>8.50</td>
<td>6.361</td>
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<td>0.6105</td>
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<td>0.9157</td>
<td>13.710</td>
</tr>
<tr>
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<td>46.941</td>
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<td>0.6415</td>
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<tr>
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<td>46.008</td>
<td>42.485</td>
<td>0.2696</td>
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<td>9.70</td>
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<td>1.681</td>
<td>0.6789</td>
<td>45.864</td>
<td>43.242</td>
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<td>8.254</td>
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</tr>
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<td>0.000</td>
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<td>45.752</td>
<td>43.826</td>
<td>0.1514</td>
<td>6.468</td>
</tr>
</tbody>
</table>

(a) : \( s \) index is defined as the amount of spillovers in terms of the marginal cost. 
\( s(c^0 - c^F) \)

(b) : \( II^{H \#} \) or \( II^{F \#} \) only includes spending \( g \) or \( p \) respectively in its fixed costs.

(c) : Difficulty is defined as the amount of money needed to gain one marginal cost.
**Findings:**

As the technology gap increases,

(i) Spending $p^*$ always increases as the technology gap increases, $dp^*/dc^F < 0$.

(ii) Spending $g^*$ always increases $dg^*/dc^F < 0$

(iii) The spillover ratio $s^*$ always decreases.

(iv) The home firm needs to spend more to gain the same amount of spillovers.

(v) The home firm’s profit decreases, while the foreign firm’s profit increases.
APPENDIX 2E

PROOF OF PROPOSITION 2.2

The effects of the technology gap on the equilibrium spending can be analyzed by the comparative static of \( \frac{dg^*}{dc^F} \) and \( \frac{dp^*}{dc^F} \). Total differentiation of the first order conditions (2-15) and (2-16) yields:

\[
\Pi_{gg}' \frac{dg^*}{dc^F} + \Pi_{gp}' \frac{dp^*}{dc^F} + \Pi_{gc}' dc^F = 0 \tag{2E-1}
\]
\[
\Pi_{pg}' \frac{dg^*}{dc^F} + \Pi_{pp}' \frac{dp^*}{dc^F} + \Pi_{pc}' dc^F = 0 \tag{2E-2}
\]

where a subscript \( c, g \) or \( p \) denotes derivative with respect to \( c^F, g \) or \( p \), respectively.

\[ \Pi_{gc}' = -\frac{4}{9b} s_g \{ a - (3 - 4s^*) c^0 + 2(1 - 2s^*) c^F \} \tag{2E-3} \]
\[ \Pi_{pc}' = \frac{2}{9b} s_p \{ a + (3 - 2s^*) c^0 - 2(2 - s^*) c^F \} \tag{2E-4} \]

\[ \Pi_{gg}' = \frac{4}{9b} (c^0 - c^F) [s_{gg} (a - 2(1 - s^*) c^0 + (1 - 2s^*) c^F) + 2s_{gg} s_g (c^0 - c^F)] < 0 \tag{2E-5} \]
\[ \Pi_{pp}' = -\frac{2}{9b} (c^0 - c^F) [s_{pp} (a + (1 - s^*) c^0 - (2 - s^*) c^F) - s_p s_p (c^0 - c^F)] < 0 \tag{2E-6} \]
\[ \Pi_{pg}' = \frac{4}{9b} (c^0 - c^F) [s_{pg} (a - 2(1 - s^*) c^0 + (1 - 2s^*) c^F) + 2s_{pg} s_p (c^0 - c^F)] < 0 \tag{2E-7} \]
\[ \Pi_{pp}' = -\frac{2}{9b} (c^0 - c^F) [s_{pp} (a + (1 - s^*) c^0 - (2 - s^*) c^F) - s_p s_p (c^0 - c^F)] < 0 \tag{2E-8} \]

These equations can be put in matrix form and solved using Cramer's rule:

\[ \frac{dg^*}{dc^F} = (-\Pi_{gg}' \Pi_{pp}' + \Pi_{gc}' \Pi_{pc}') / D \tag{2E-9} \]
\[ \frac{dp^*}{dc^F} = (-\Pi_{gg}' \Pi_{pc}' + \Pi_{pg}' \Pi_{pp}') / D \tag{2E-10} \]
where \( D = \Pi_{gg}^H \Pi_{pp}^F - \Pi_{gp}^H \Pi_{pg}^F > 0 \) from the stability conditions.

The signs of (2E-9) and (2E-10) are obtained:

From (2E-9), \( dg*/dc^F > 0 \) for the larger technology gaps \( c^0 - c^F > \{(5 - 8s)c^0 - a\}/\{2(1 - 2s)\} \) where \( \Pi_{gg}^H > 0 \) because \( \Pi_{pp}^H < 0, \Pi_{pc}^H < 0, \) and \( \Pi_{gp}^H < 0. \) For the smaller technology gaps \( c^0 - c^F < \{(5 - 8s)c^0 - a\}/\{2(1 - 2s)\} \) where \( \Pi_{gg}^H < 0, \) the sign of \( dg*/dc^F \) could be ambiguous because the first term is negative while the second term is positive. From (2E-10), \( dp*/dc^F < 0 \) for the larger technology gaps where \( \Pi_{gg}^H > 0 \) because \( \Pi_{gg}^H < 0, \Pi_{pc}^H < 0, \) \( \Pi_{pg}^F < 0, \Pi_{gg}^H \Pi_{pc}^H < 0, \) and \( \Pi_{gg}^H \Pi_{pg}^F < 0. \) For the smaller technology gaps where \( \Pi_{gg}^H < 0, \) the sign of \( dp*/dc^F \) could be ambiguous because the first term is negative, while the second term is positive. However, by checking the sign of \( dp*/dc^F, \) it is confirmed to be negative:

\[
\text{Proof: } (-\Pi_{gg}^H \Pi_{pc}^H + \Pi_{gg}^H \Pi_{pg}^F) / D < 0 \rightarrow -\Pi_{gg}^H \Pi_{pc}^H + \Pi_{gg}^H \Pi_{pg}^F
\]

\[
= 8(c^0 - c^F)[s_{gg}(a - 2(1 - s)c^0) + (1 - 2s)c^F)(a + (3 - 2s)c^0 - 2(2 - s)c^F)
\]

\[
- s_g(a + (1 - s)c^0 - (2 - s)c^F)(a - (3 - 4s)c^0 + 2(1 - 2s)c^F)
\]

\[
- s_g s_p(c^0 - c^F)(2s_p(a + (3 - 2s)c^0 - 2(2 - s)c^F) - s_g(a - (3 - 4s)c^0 + 2(1 - 2s)c^F)) \} < 0 \text{(2E-11)}
\]

The effects of spending \( g \) and \( p \) on the spillover ratio at the equilibrium can be analyzed by the comparative static of \( ds^* / dc^F. \) Total differentiation of the function of the spillover ratio \( s^* = s (g^*, p^*) \) and dividing both sides by \( dc^F \) yield:

\[
\frac{ds^*}{dc^F} = s_g \frac{dg^*}{dc^F} + s_p \frac{dp^*}{dc^F} \quad \text{(2E-12)}
\]
From (2B-9) and (2B-10), $ds*/dc^F > 0$ above the critical technology gap, while below the critical technology gap the sign of $ds*/dc^F$ is ambiguous because the sign of $s_g dg*/dc^F$ is ambiguous.
APPENDIX 2F
FOREIGN ENTRY CONDITIONS AND PROOF OF PROPOSITION 2.3

The Cournot Nash equilibrium in the exporting period of the foreign firm gives the profits and outputs of both firms as shown in Appendix 2A.

\[ \Pi^0 = \frac{1}{9b} (a + c^x - 2c^0)^2 - z^0; \quad \Pi^x = \frac{1}{9b} (a + c^0 - 2c^x)^2 - z^x \]  
\[ (2F-1) \]

\[ Y^0 = \frac{1}{3b} (a + c^0 - 2c^0); \quad Y^x = \frac{1}{3b} (a + c^0 - 2c^x) \]  
\[ (2F-2) \]

where \( P = (a + c^0 + c^x)/3 \); A superscript \( x \) denotes variables associated with the exporting foreign firm, while a superscript \( 0 \) denotes variables associated with the home firm in the same period.

\( (\Pi^F - \Pi^x) \) must be positive using (2-17) and (2F-2) for the foreign firm to decide to produce products in the home market:

\[ \Pi^F - \Pi^x = \frac{1}{9b} (a + (1 - s^*)c^0 - (2 - s^*)c^F)^2 - p^* - z^F - \frac{1}{9b} (a + c^0 - 2c^x)^2 + z^x \]

\[ = -\frac{4}{9b} \left[ c^x - (a + c^0)c^x - (s^*c^0 + (2 - s^*)c^F)(s^*c^0 + (2 - s^*)c^F - 2(a + c^0))] - p^* - (z^F - z^x) \right] > 0 \]
\[ (2F-3) \]

The required condition for the foreign firm to make an entry decision can be derived from (2F-3) by solving for \( c^x \):

\[ -(c^x - \frac{1}{2} ((a + c^0) - A))(c^x - \frac{1}{2} ((a + c^0) + A)) > 0 \]
\[ (2F-4) \]
where

\[ A = \sqrt{(a + c^0)^2 - 4(s^* c^0 + (2 - s^*)c^F)(2a + (2 - s^*)(c^0 - c^F)) - 9b(p^* + z^F - z^*)/4}. \]

From the above condition, the foreign firm can make an entry decision if the following condition is met:

\[ c^x > \frac{(a + c^0) - A}{2} \]  

(2F-5)

where \( A < (a + c^0) \).

The effects of changes in the technology gap \((c^0 - c^F)\) on the lower limit of the marginal cost of the foreign firm before FDI, \(c^{xl} = \frac{(a + c^0) - A}{2}\), can be obtained by taking derivative with respect to \(c^F\):

\[
\frac{\partial c^{xl}}{\partial c^F} = -\frac{1}{4} \left[-9b \frac{dp}{dc^F} - 4 \{ c^F (2 - s) + c^0 s \} \{ 2 + s - (c^0 - c^F) \} \frac{ds}{dc^F} \right] \left[ 2 - s + (c^0 - c^F) \frac{ds}{dc^F} \right] / A^{0.5}
\]

\[
= -\frac{1}{4} \left[-9b \frac{dp}{dc^F} + 4 \{ 2 - s + (c^0 - c^F) \} \frac{ds}{dc^F} \{ 2s + c^0 - c^F - A \} \right] / A^{0.5} > 0 \]

(2F-6)

Because the spillover gains are larger than spending increase \(dp/dc^F\), \(\partial c^{xl}/\partial c^F\) is always positive. In other words, the lower limit becomes lower as the technology gap increases.
APPENDIX 2G

PROOF OF PROPOSITION 2.4

By using (2-9), (2-10) and (2-11), welfare change can be obtained:

\[ \Delta CS^T = \frac{1}{18b} (c^x - c^F)(4a - 2c^0 - c^x - c^F) > 0 \]  \hspace{1cm} (2G-1)

\[ \Delta CS^S = \frac{1}{18b} s(c^0 - c^F)(4a - (2 - s)c^0 - (2 + s)c^F) > 0 \]  \hspace{1cm} (2G-2)

\[ \Delta PS^T = \frac{1}{9b} (c^F - c^x)(2a - 4c^0 + c^F + c^x) < 0 \]  \hspace{1cm} (2G-3)

\[ \Delta PS^S = \frac{1}{9b} 4s(c^0 - c^F)(a - (2 - s)c^0 + (1 - s)c^F) - g > 0 \]  \hspace{1cm} (2G-4)

\[ \Delta W^T = \Delta CS^T + \Delta PS^T = \frac{1}{6b} (c^x - c^F)\{(c^0 - c^F) - (c^x - c^0)\} \]  \hspace{1cm} (2G-5)

\[ \Delta W^S = \Delta CS^S + \Delta PS^S = \frac{1}{6b} s(c^0 - c^F)(4a - 3(2 - s)c^0 + (2 - 3s)c^F) - g > 0 \]  \hspace{1cm} (2G-6)

where a superscript \( T \) or \( S \) denotes technology transfer or spillovers, respectively.

\[ \Delta W = \frac{1}{6b} [(c^x - c^F)\{(c^0 - c^F) - (c^x - c^0)\} + s(c^0 - c^F)(4a - 3(2 - s)c^0 + (2 - 3s)c^F)] - g \]  \hspace{1cm} (2G-7)

where the first term represents the effects of technology transfer; the second term represents the gain from technology spillovers; and the third term represents spending to gain spillovers.
The effects of changes in the technology gap on changes in home welfare from FDI are analyzed by taking derivative of $\Delta W$, $\Delta CS^T$, $\Delta CS^S$, $\Delta PS^T$, and $\Delta PS^S$ with respect to $c^F$:

$$\Delta W_c =$$

$$-\frac{1}{3b} \left[ (c^0 - c^F) \frac{ds}{dc^F} (c^0 - c^F) \right] \left[ 2a - 3(1-s)c^0 + (1-3s)c^F \right] + s \left[ 2a - (4-3s)c^0 + (2-3s)c^F \right] - \frac{dg}{dc^F}$$

(2H-1)

$$\Delta CS^T_c = -\frac{1}{9b} \left( 2a - c^0 - c^F \right) < 0; \quad \Delta CS^T_{cc} = \frac{1}{9b} > 0$$

(2H-2)

$$\Delta CS^S_c = \frac{1}{9b} \left[ \frac{ds}{dc^F} (c^0 - c^F) \right] \left[ 2a - (1-s)c^0 + c^F \right] - s \left( 2a + sc^0 \right)$$

(2H-3)

$$\Delta CS^S_{cc} = \frac{1}{9b} \left[ \frac{d^2 s}{dc^F} (c^0 - c^F) \right] \left[ 2a - (1-s)c^0 + c^F \right] - \frac{ds}{dc^F} \left( 4a + 3sc^0 \right) + \left( \frac{ds}{dc^F} \right)^2 (c^0 - c^F)c^0$$

(2H-4)

$$\Delta PS^T_c = \frac{2}{9b} \left( a - 2c^0 + c^F \right) > 0; \quad \Delta PS^T_{cc} = \frac{2}{9b} > 0$$

(2H-5)

$$\Delta PS^S_c = \frac{4}{9b} \left[ \frac{ds}{dc^F} (c^0 - c^F) \right] \left[ a - 2(1-s)c^0 + (1-2s)c^F \right] - s \left( a - (3-2s)c^0 + 2(1-s)c^F \right)$$

$$- \frac{dg}{dc^F}$$

(2H-6)

$$\Delta PS^S_{cc} = \frac{4}{9b} \left[ \frac{d^2 s}{dc^F} (c^0 - c^F) \right] \left[ a - 2(1-s)c^0 + (1-2s)c^F \right] - 2 \frac{ds}{dc^F} \left( a - (3-2s)c^0 + 2(1-s)c^F \right)$$

$$+ 2 \left( \frac{ds}{dc^F} \right)^2 (c^0 - c^F)^2 - \frac{d^3 g}{dc^F^2}$$

(2H-7)
\[ \Delta W_c^\tau = -\frac{1}{3b^2} (c^0 - c^F) < 0; \quad \Delta W_c^{\tau^\tau} = \frac{1}{3b^2} > 0 \] (2H-8)

\[ \Delta W_c^s = \frac{1}{3b^2} \left[ \frac{ds}{dc^F} (c^0 - c^F) \{2a(1 - s)c^0 + (1 - 3s)c^F\} + s\{2a - (4 - 3s)c^0 + (2 - 3s)c^F\}\right] - \frac{dg}{dc^F} \] (2H-9)
APPENDIX 21

PROOF OF PROPOSITION 2.6

The effects of changes in the difference of the marginal costs of the two firms before FDI on changes in home welfare from FDI are analyzed by taking derivative with respect to $c^x$.

\[ \Delta W_{c^x} = \frac{1}{3b} \left( c^0 - c^x \right); \quad \Delta W_{c^x} = -\frac{1}{3b} < 0 \]  
\[ (21-1) \]

\[ \Delta CS_{ex} = \frac{1}{9b} \left( 2a - c^0 - c^x \right) > 0; \quad \Delta CS_{ex} = -\frac{1}{9b} < 0 \]  
\[ (21-2) \]

\[ \Delta PS_{ex} = -\frac{2}{9b} \left( a - 2c^0 + c^x \right) < 0; \quad \Delta PS_{ex} = -\frac{2}{9b} < 0 \]  
\[ (21-3) \]
REFERENCES


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3.1 Introduction

Foreign direct investment (FDI) brings technology to developing countries as well as capital.\(^1\) Findlay (1996) points out that successful technology transfer can take place in the presence of foreign firms from developed countries. The foreign firms transfer their technologies to their affiliates in the host countries. Transferred technology can also provide various spillover effects to local economies.\(^2\) FDI from developed countries to developing countries can play an important role in the economic growth of developing countries from technology transfer and spillovers.

Many empirical results indicate that FDI contributes to the growth of developing countries. For example, Blomström et al. (1994) find a strong effect of FDI on economic growth in developing countries. Balasubramanyam et al. (1996) also find a positive effect of FDI on economic growth, and conclude that the impact of FDI on economic growth is stronger in countries with export-promotion oriented FDI than that in countries with import-substitution oriented FDI. Borensztien et al. (1998) find that FDI transfers technology and contributes more to economic growth than domestic investment. De

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\(^1\) Technology includes anything advantageous that comes with FDI. It consists of any knowledge associated with technology and management.

\(^2\) Blomström and Kokko (1998) provide intuitive explanations of possible spillovers from multinational corporations in developing countries.
Mello (1999) estimates the impact of FDI on economic growth and proves long term growth in host economies through the spillovers of technology and knowledge.

Many developing countries have enjoyed positive per capita GDP growth, while the sub-Saharan countries, locating in the south of the Sahara desert in Africa, suffered negative per capita GDP growth from the second half of 1970s to the first half of 1990s. Artadi and Sala-i-Martin (2003) point out that investment rate, the ratio of investment to GDP, also declined in the sub-Saharan countries for the same periods. It implies that if FDI increases, negative per capita GDP growth may become positive.

This theoretical model applies the effects of technology transfer and spillovers separately to the growth in developing countries in order to analyze the effects of FDI on per capita GDP growth as well as on per capita capital accumulation and per capita consumption. It is also integrated with the open economy assumption allowing repatriation of foreign earnings. The open economy assumption is valid because the returns on foreign capital are the possession of foreign investors and therefore not available for domestic consumption, though the foreign firms may decide to reinvest. My model provides the answers to the following questions: How does the net FDI inflow affect per capita capital accumulation, per capita consumption, and per capita income? Why does the developing country have positive or negative growth? How does technology spillover affect the growth rates of per capita capital, per capita consumption, and per capita income? What are the implications of technology spillovers?
The early theoretical growth model with FDI technology transfer is Findlay (1978)'s simple dynamic model. Findlay shows that the rate of technical progress in a developing country is an increasing function of both the relative technology gap and the share of FDI in total capital stock. Wang (1990) also uses the technology gap and provides a two-country model with the assumption that technology is transferred through FDI from developed countries to developing countries to promote economic growth. He highlights that human capital and technology spillovers interact with FDI and domestic physical capital formation in economic development.

This model is based on endogenous growth theory. There are two endogenous growth approaches to analyze the effects of FDI on growth in existing theoretical models: (i) a dynamic general equilibrium model with endogenous technological change (Walz 1997, Grossman and Helpman 1991a; 1991b); and (ii) a growth model with endogenous technological change (Reis 2001). Walz builds a dynamic general equilibrium model based on the quality ladder approach of Grossman and Helpman by allowing geographical separation of innovation and production. Walz shows that FDI brings interregional spillovers of knowledge from more to less advanced countries by allowing innovation to take place in developing countries, while Grossman and Helpman (1991a, 1991b) exclusively locate innovation in developed countries, and integrate imitation and trade for their studies. Reis (2001)'s endogenous technological change is built on rising

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3 Caves (1996) and Wacziarg (2002) point out that there are only a few theoretical models on the subject of FDI and growth, contrary to the vast amount of empirical studies on this subject.
4 Romer (1986) assumes that knowledge is an input in production that has increasing marginal productivity in his endogenous growth theory. His model is a competitive equilibrium model with endogenous technological change.
product quality (Grossman and Helpman 1991a; 1991b). Reis analyzes the welfare effects of FDI as well as the growth effects.

This model is modified from the endogenous growth model of Barro and Sala-i-Martin (1999, Ch. 4). They introduce two productivity growth assumptions of learning-by-doing and knowledge spillovers in their model. Learning-by-doing assumes, “an increase in a firm’s capital stock leads to a parallel increase in its stock of knowledge.” Knowledge spillovers assume that each firm’s knowledge is a public good that knowledge spills over instantly across the economy (Barro and Sala-i-Martin 1999, p.147). In contrast to their assumption, I assume that technology or knowledge of foreign firms is not a public good, but a partially excludable yet non-rival good.

The following section introduces the basic model. Section 3.3 discusses capital accumulation, consumption, income, and the effects of the net foreign capital flow on them and their growth rates. Section 3.4 provides the effects of a change in the spillover ratio on growth and their policy implications. The conclusion is in Section 3.5.

3.2 The Basic Model

The following assumptions are applied in order to analyze the effects of technology transfer and spillovers separately:

(i) Technology transfer and learning-by-doing

When the foreign firms in developed countries invest in developing countries, the foreign firms bring their technologies and transfer them to all the relevant workers of the affiliates. Learning-by-doing is in effect through the foreign firms’ investment.

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5 See Arrow (1962), Levhari (1966), and Sheshinski (1967).
Therefore, an increase in foreign firms’ capital stock leads to a parallel increase in its stock of knowledge.

(ii) Technology spillovers

The assumption of a public good is too strong for technology. Technology can be non-rival, but it is partially excludable (Sala-i-Martin 2002). This partial excludability allows technology spillovers. The foreign firms have incentives to keep secrecy of their technologies, while the home firms have incentives to gain some technologies or spillovers through various means. These spillovers can be obtained through imitation of the foreign technologies. Imitation can be accomplished through reverse engineering, common suppliers and customers, and previous trained workers and managers of the foreign firms. Imitation of management techniques can be considered as spillovers. This spillover can go beyond the specific industry. The amount of technology spillovers is assumed to be exogenously determined. The model also assumes that there are no spillovers of the home firms’ technologies to other firms in the economy.

(iii) Productivity to Growth

Technology transfer brings the foreign technologies with higher productivity. Technology spillovers lead to an increase in productivity of the local firms. Thus, an increase in productivity due to both technology transfer and spillovers leads to the economic growth of host countries.

(iv) Repatriation of the foreign earnings

The model allows repatriation of the foreign earnings as well as allowing FDI inflows. Outward capital investment from the domestic firms or individuals is excluded or zero.
(v) The rate of return or the interest rate

Home and foreign claims on capital are perfect substitutes. Therefore, each pays the same rate of return or the interest rate \( r \) as a cost of capital. The developing country situation with the open economy assumption must be a small open economy with imperfect capital mobility. Therefore, the interest rate in the economy is not necessarily the same as the world interest rate.

3.2.1 Technology

A home country has assets or capital \( K_H \) while the net foreign capital owned by foreigners on the home economy is \( K_F \). Total capital \( K \) can be expressed as:

\[
K = K_H + K_F
\]  

(3-1)

The index \( A \) of total knowledge available to all the firms in a home country is the sum of the index of knowledge available to both the foreign firms and the home firms:

\[
A = A_T + A_S
\]  

(3-2)

where a subscript \( T \) or \( S \) denotes the index of knowledge related to technology transfer to the affiliates or technology spillovers to home firms, respectively.

The parent firms transfer their technologies to their affiliates in the home economy. All workers in the foreign firms receive relevant trainings in order to use available technologies. The model assumes that the effects of technology transfer are proportional to total foreign capital as Barro and Sala-i-Martin (1999), though, in reality, it is proportional to the labor forces of the foreign firms because the nature of technology transfer includes knowledge transfer. The labor augmenting portion of \( A_T \) the index of knowledge available to the affiliates from technology transfer is a foreign capital share of
$A_F$ the full index of knowledge from the foreign firms to the firms in the economy if all investments are by the foreign firms:

$$A_T = b A_F$$  \hspace{1cm} (3-3)

where the foreign capital ratio $b = K_F / K$ for $0 \leq b \leq 1$.

Some portion of the foreign technologies transferred to their affiliates spills over to the local firms in the economy. This portion of spillovers can be expressed by using the spillover ratio $\beta$. When the spillover ratio $\beta$ is one, full spillovers are accomplished in the economy. When the spillover ratio is zero, there are no spillovers in the economy. Labor augmenting portion of $A_S$, the index of knowledge to the home firms through technology spillovers is expressed:

$$A_S = \beta (1 - b) A_F$$  \hspace{1cm} (3-4)

where $0 \leq \beta \leq 1$; $(1 - b)$ is equivalent to the home capital ratio which is $K_H / K$.

From (3-3) and (3-4), the total index of knowledge available to all of the firms in the home economy can be expressed in terms of $\beta$, $b$ and $A_F$:

$$A = bA_F + \beta(1 - b)A_F = \eta A_F$$  \hspace{1cm} (3-2)'

where $\eta = b + \beta(1 - b)$.

For analysis, the assumption of the average capital stock per firm $i$ is used, because the aggregate of the average capital stock per firm can be equivalent to the average capital stock in the home country. The production function has two inputs, physical capital $K$, and labor $L$:

$$Y_i(t) = F(K_i(t), A_i, L_i(t))$$  \hspace{1cm} (3-5)

where a subscript $i$ denotes variables associated with the average firm $i$; $t$ denotes time; $K_i = K_{Hi} + K_{Fi}$; $A_i = A_{Ti} + A_{Si}$.  

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$F(t)$ satisfies the same neoclassical properties as Barro and Sala-i-Martin (1999)'s model:

Positive and diminishing marginal products of each input:

$$\frac{\partial F}{\partial K} > 0; \frac{\partial F}{\partial L} > 0; \frac{\partial^2 F}{\partial K^2} < 0; \frac{\partial^2 F}{\partial L^2} < 0;$$

Constant returns to scale; Inada conditions (Inada 1963)

$$\lim_{K \to 0} \frac{\partial F}{\partial K} = \lim_{L \to 0} \frac{\partial F}{\partial L} = \infty, \text{ and } \lim_{K \to \infty} \frac{\partial F}{\partial K} = \lim_{L \to \infty} \frac{\partial F}{\partial L} = 0 \quad (3-6)$$

The change in the index of knowledge corresponds to the firms' overall learning and is therefore proportional to a change in the aggregate capital stock. The foreign firms have incentives to maintain secrecy over their technologies as well as a formal patent protection for invention or new technology. The home firms have incentives to gain spillovers from the foreign firms' technologies. By combining the assumptions of learning-by-doing and partial knowledge spillovers, we can replace $A_F$ by $K_F$, and $A_i$ by $A$ (Barro and Sala-i-Martin 1999). Labor augmenting portion of the index of knowledge available to the firms in the economy becomes:

$$A = \eta K_F \quad (3-2)$"'

Therefore, the neo-classical production function (3-5) can be modified as follows:

$$Y(t) = F(K(t), \eta K_{F} L(t)) \quad (3-5)'$$

### 3.2.2 Household Utility Maximization Behaviors

Each infinite-lived household maximizes its utility $U$ (Barro and Sala-i-Martin, 1999):

$$U = \int_0^\infty u(c(t)) e^{\rho t} e^{-\rho t} dt \quad (3-7)$$
where the function \( u[c(t)] \) relates the flow of utility per person to the quantity of consumption per person, \( c \); \( \rho \) denotes the rate of time preference \((\rho > 0)\); \( n \) denotes the population growth\(^6\); and \( \rho > n \).

The budget constraint for the representative household can be given in the per capita form (Barro and Sala-i-Martin 1999):

\[
\dot{k}_H = w + r k_H - c - n k_H
\]

where \( w \) is the wage income per person\(^7\); \( c \) is per capita consumption; and \( n \) is the rate of population growth.

Assets per person rise with per capita income \( w + r k_H \), fall with per capita consumption \( c \), and fall due to expansion of the population in accordance with the term \( nk_H \).

For utility maximization behaviors of consumers, the present-value Hamiltonian can solve dynamic optimization problem:

\[
J = u(c) e^{-(\rho-n)t} + v \left[ w + (r - n) k_H - c \right]
\]

The first order conditions for utility maximization are

\[
\begin{align*}
\frac{\partial J}{\partial c} &= 0 \quad \Rightarrow \quad v = u'(c) e^{-(\rho-n)t} \\
\dot{v} &= -\frac{\partial J}{\partial k_H} \quad \Rightarrow \quad \dot{v} = -(r - n) v
\end{align*}
\]

From (3-10) and (3-11),

\[
\dot{v} = u''(c) \frac{c}{u'(c)} e^{-(\rho-n)t} - (\rho - n) u'(c) e^{-(\rho-n)t} = - (r - n) u'(c) e^{-(\rho-n)t}
\]

\[
\frac{u''(c) c}{u'(c)} \frac{\dot{c}}{c} - (\rho - n) = -(r - n)
\]

\(^6\) Population grows at a constant and exogenous rate, \( n = \dot{L}/L, e^{\rho t} = L \) (Barro and Sala-i-Martin 1999, Ch.1).

\(^7\) I assume each person works one unit of labor services per unit of time as Barro and Sala-i-Martin (1999, Ch. 2). Therefore, the wage income per person is \(w(t)\).
\[ \frac{\dot{c}}{c} = \frac{1}{\theta} (r - \rho) \]

(3-12)

where \( \theta = -\frac{u''(c)}{u'(c)} \) is the reciprocal of the elasticity of intertemporal substitution.

The transversality condition is:

\[ \lim_{t \to \infty} [v(t) \cdot a(t)] = 0 \]

(3-13)

### 3.2.3 Firms Profit Maximization Behavior

Firms maximize their profits. An average firm's profit can be expressed:

\[ \Pi_i = L_i [f(k_i, A) - (r + \delta) k_i - w] \]

(3-14)

where \( \delta \) is depreciation; \( f(k_i, A) \) is per capita form of the production function; and \( r + \delta \) is the user cost.

Each competitive firm takes these factor prices as given. The profit maximization conditions are found by taking derivative with respect to \( k_i \) and \( L_i \).

\[ \frac{\partial \Pi_i}{\partial k_i} = L_i \left[ \frac{\partial f(k_i, A)}{\partial k_i} - (r + \delta) \right] = 0 \]

(3-15)

\[ \frac{\partial \Pi_i}{\partial L_i} = f(k_i, A) - (r + \delta) k_i - w = 0 \]

(3-16)

From the first order condition (3-15), the user cost is

\[ r + \delta = \frac{\partial f(k_i, A)}{\partial k_i} \]

(3-17)

The function for the wage rate is obtained by substituting the user cost into another first order condition (3-16). It also satisfies the zero profit condition from (3-14).
\[ w = f(k, A) - k \frac{\partial f(k, A)}{\partial k} \]  \hspace{1cm} (3-18)

where \( \frac{\partial f(k, A)}{\partial k} \) is the private marginal product of capital.

The average product of capital is by replacing \( k_i \) by \( k \) and from (3-2)"):

\[ \bar{f}(k, A) = \bar{f}(\frac{A}{k}) = \bar{f}(\frac{\eta K_F}{k}) = \bar{f}(\frac{\eta K_F L}{K}) = \bar{f}(\eta bL) \]  \hspace{1cm} (3-19)

where \( \bar{f}'(\cdot) > 0 \) and \( \bar{f}''(\cdot) < 0 \).

The average product of capital is a function of \( L, \beta \) and \( b \).

The private marginal product of capital can also be obtained from (3-19):

\[ \frac{\partial f(k, A)}{\partial k} = \bar{f}'(\eta bL) + k \bar{f}'(\eta bL) \frac{\partial(\eta bL)}{\partial k} = \bar{f}'(\eta bL) - \eta bL \bar{f}''(\eta bL) \]  \hspace{1cm} (3-20)

### 3.3 Capital Accumulation, Consumption, and Income

The foreign capital inflows affect not only the behaviors of consumers and firms, but income as well. The foreign capital inflows increase average productivity of the firms in the host country as well as total production, since the foreign capital comes with advance technology. Technology transfer of the foreign technologies to their affiliates increases productivity of the affiliates. Technology spillovers from the foreign technologies to the home firms increase their productivity. An increase in productivity of these firms leads to an increase in production with lower prices. Increased production with productivity improvement leads to higher consumption opportunities for consumers and higher investment opportunities for firms.

The foreign firms are allowed to repatriate some of their earnings. Therefore, the foreign capital outflows as well as its inflows must be considered by using the net inflow.
Changes in capital accumulation affect the behaviors of consumers. The behaviors of consumers and firms change national income. All the analysis is done with per capita forms. Hereafter, the terms of consumption, capital, income, and the net FDI inflow represent in per capita values.

**Capital Accumulation**

Capital accumulation of the foreign firms and the home firms is analyzed before the analysis of consumption and income, because capital accumulation affects consumption and income. The changes in capital of the home firms can be determined from the budget constraint (3-8), the wage rate (3-18), the average product of capital (3-19), and the private marginal product of capital (3-20):

\[
\dot{k}_H = w + (r - n)k_H - c = f(k, A) - k f'(k, A) + (r - n) k_H - c
\]

\[
= \eta b L \tilde{f}'(\eta b L) k_F + \{f(\eta b L) - \delta - n\} k_H - c
\]

The capital accumulation of the home firms is affected by the foreign capital accumulation.

The earnings of the foreign firms can be reinvested in the home country or taken back to the foreign countries where the parent firms are. The foreign capital increases by FDI inflows and the earnings of the foreign firms, and it decreases by repatriation. Therefore, an increase in the foreign capital can be expressed as the motion of \(k_F\):

\[
\dot{k}_F = m + (r - n)k_F = m + (\tilde{f}(\eta b L) - \eta b L \tilde{f}'(\eta b L) - \delta - n) k_F
\]

where \(m\) denotes the net FDI inflow, and \((r - n)k_F\) denotes the earnings of the foreign firms. The net FDI inflow \(m\) is exogenously determined in this model. The earning is
negative when the return of capital \( r \) is less than the population growth rate \( n \). The foreign capital is not affected by the home capital in this model.

The motion of \( k_F \) may be positive or negative depending on the net FDI inflow \( m \), the population growth rate \( n \), and the rate of return on capital \( r \). From (3-21) and (3-22), the motion of \( k \) can be expressed:

\[
\dot{k} = \dot{k}_H + \dot{k}_F = (\tilde{f}(\eta b L) - \delta - n) k + m - c \tag{3-23}
\]

The capital accumulation behaviors of the home firms and the foreign firms can be analyzed by using the phase diagram of the motions of the home capital and the foreign capital.\(^8\)

**Proposition 3.1: The Effects of Changes in the Net FDI Inflow on Capital Accumulation of the Home Firms and the Foreign Firms**

As the net FDI inflow \( m \) increases:

(i) If \( n < r \) (\( n > r \)) and \( m < 0 \) (\( m > 0 \)), the home capital decreases (increases) while the foreign capital increases (decreases) and there is an equilibrium. However, a new equilibrium in total capital always decreases.

(ii) If \( n < r \) (\( n > r \)) and \( m > 0 \) (\( m < 0 \)), both the home capital and the foreign capital keep increasing (decreasing) and there is no equilibrium. Therefore, total capital keeps increasing (decreasing).

**Proof:** Refer to Appendix 3A

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\(^8\) Refer to Appendix 3A for the dynamic analysis of the foreign capital and the home capital the phase diagram.
When the rate of return \( r \) is higher than the population growth rate \( n \), the firms invest more because an expected return of investment is higher. In other words, the expected net FDI inflow becomes positive. The positive net FDI inflow means more investments from the foreign firms to accumulate the foreign capital in the host country. The more the foreign capital increases, the more technology transfer of their technologies are provided. The home firms can obtain technology spillovers from the foreign technologies, and they invest more because of competitive and spillover effects from the foreign technologies. This is a desirable condition of endogenous growth for developing countries.

On the contrary, for example, if the country is politically unstable, the foreign firms pull out their earnings to safer places than the host country even if the rate of return is higher. Collier and Gunning (1999) state, “the return on investment in Africa during 1990-94 was around 60 percent higher than that in other developing regions,” yet it was not sufficient to offset the high risks of Africa. Svensson (1998) also concludes with cross country data for around 100 countries that political instability leads to insufficient intellectual property rights (IPRs) protection, thus it reduces FDI. The result is the negative net FDI inflow. The home firms invest more to replace the foreign investments, because the rate of return on capital is higher for the home firms to invest more if the foreign firms would not invest nor reinvest their earnings. The degree of political instability may affect the investment behaviors of both the foreign firms and the home firms (Barro 1991; and Gyimah-Brempong and Traynor 1999). Total capital decreases as the theory predicts if the country is politically unstable.

When the rate of return is lower than the population growth rate, the firms generally invest less because the rate of return is lower. The foreign firms reduce investments or
increase repatriation of their earnings, and the net FDI inflow becomes negative. The domestic firms may not increase their investments either because the rate of return is lower. This vicious cycle continues until all the foreign capital and earnings are completely pulled out.

If the foreign firms find some benefits in investing more in the host country, the net FDI inflow may become positive even though the rate of return is not high. For example, according to Balasubramanyam et al. (1996)'s analysis, if the host government invites import-substitution oriented FDI, FDI would replace the domestic investments since the host country market may not be large enough. However, if the government invites export-promotion oriented FDI when the market has an advantage in factor wages, the foreign firms can gain benefits from investing. The rate of return may be improved and total capital increases. Now it turns to desirable conditions for the host country to have endogenous growth if investment climates are appropriate. To promote FDI, the government must improve investment climates, such as political stability, both physical and social infrastructure, the government deficit, the absorptive capacity of local firms, health, education, financial system, and even corruption (Easterly and Levine 1998; Collier and Gunning 1999; and Artadi and Sala-i-Martin 2003).9

Consumption and Income

The change in consumption can be obtained from (3-12), (3-17) and (3-20):

\[ \dot{c} = \frac{1}{\theta} \{ \tilde{f}(\eta bL) - \eta bL \tilde{f}'(\eta bL) - \delta - \rho \} c \]  

(3-24)

9 Hall and Jones (1999) show in their empirical analysis that social infrastructure, institutions and government policies, also increases capital accumulation, productivity, and output per worker.
The change in output income can be obtained from the production function \( y = f(k, A) \) taking derivative of \( y \) with respect to time \( t \):

\[
\dot{y} = (\partial f / \partial k) \dot{k} = (\tilde{f} (\eta bL) - \eta bL \tilde{f}' (\eta bL)) \dot{k}
\]  

(3-25)

From (3-25), the change in income is proportional to the change in total capital \( k \), since the marginal product of capital is positive. If capital increases, income also increases. An increase in capital means expansion of production capability; hence, total production or income increases.

**Proposition 3.2: The Effects of the Net FDI Inflow on Consumption and Income**

As the net FDI inflow \( m \) increases:

(i) If \( n < r \) and \( m < 0 \), consumption and income decrease.

(ii) If \( n > r \) and \( m > 0 \), changes in consumption and income are ambiguous.

(iii) If \( n < r \) (\( n > r \)) and \( m > 0 \) (\( m < 0 \)), consumption and income keep further increasing (decreasing).

**Proof:** Refer to Appendix 3B

Changes in income may not give the same direction as changes in capital, especially, when the net FDI inflow is positive while total capital decreases. When total capital decreases in the steady state as the net FDI inflow increases, there are two scenarios. When an increase in the foreign capital is less than a decrease in the home capital, consumption increase may be ambiguous because an increase in production of the foreign firms with higher productivity may be larger or less than a decrease in production of the
home firms. On the other hand, when an increase in the home capital is less than a
decrease in the foreign capital, production definitely decreases. As available production
decreases, consumption opportunity also decreases. However, when a change in
production is ambiguous, consumption is also ambiguous.

When total capital keeps increasing or decreasing, changes in income have the same
direction as changes in capital. As total capital keeps increasing when both the foreign
capital and the home capital increase, both consumption and income keep increasing.
When the rate of return on capital investment is higher and the net FDI inflow is positive,
both consumption and income keep increasing. On the contrary, as total capital keeps
decreasing when both the foreign capital and the home capital keep decreasing, both
consumption and income also keep decreasing. When the rate of return on capital
investment is lower and the net FDI inflow is negative, both consumption and income
keep decreasing unless the desirable policy package of improving investment climates is
applied.

**The Growth Rates**

An increase in capital, consumption, or income does not necessarily mean an increase in
its growth rate. The growth rate may decrease even capital, consumption, or income
increases. This section provides the analysis of the growth rates of capital, consumption,
and income.

The growth rate of capital can be obtained from (3-23) dividing by total capital $k$.

$$
\gamma_k = \frac{\tilde{f}(\eta bL)}{k} + \frac{m-c}{k} - (n + \delta)
$$

(3-26)
The relations between the growth rates of per capita foreign capital and per capita home capital can therefore be derived from (3-24), dividing by $k$:

$$\gamma_k = b \gamma_{k_F} + (1 - b) \gamma_{k_H} \tag{3-26}$$

The growth rate of income can be derived from (3-24), dividing by $y = f(k, A)$ and from the average product of capital (3-19):

$$\gamma_y = \left( \frac{\partial f}{\partial k} \right)_k \frac{k}{f(k, A)} = \frac{\tilde{f}(\eta bL) - \eta bL f'(\eta bL)}{\tilde{f}(\eta bL)} \gamma_k \tag{3-27}$$

where $\left( \frac{\partial f}{\partial k} \right)_k$ is per capita income earned by owners of capital.

Since $\left( \frac{\partial f}{\partial k} \right)_{k_F}$ is income earned by the foreign owners of capital, $\left( \frac{\partial f}{\partial k} \right)_{k_H}$ is income earned by the home owners of capital, $\left( \frac{\partial f}{\partial k} \right)_{k_H} / f(k, A)$ is the foreign share of total income. In the same way, since $\left( \frac{\partial f}{\partial k} \right)_{k_H}$ is income earned by the home owners of capital, $\left( \frac{\partial f}{\partial k} \right)_{k_H} / f(k, A)$ is the home share of total income. The growth rate of income consists of the shares of income by the growth rates of the foreign capital stock and the home capital stock. The growth rate of income is determined by the growth rate of capital, more specifically, by the growth rates of both the foreign capital and the home capital.

From Proposition 3.1, when there is an equilibrium ($n < r$ and $m < 0$, or $n > r$ and $m > 0$), the growth rates of capital and income are zero. As the net FDI inflow increases, new equilibrium also provides zero growth rates in the model. However, as the net FDI inflow increases when $n < r$ and $m < 0$, the equilibrium shifts to new equilibrium until the net FDI inflow becomes positive. Once the net FDI inflow becomes positive, capital keeps increasing. When $n < r$ and $m > 0$, or when $n > r$ and $m < 0$, the effects of the net FDI inflow on changes in the growth rates of capital and income and on changes in the
growth rate of consumption, can be analyzed by taking derivative with respect to the net FDI inflow.

**Proposition 3.3: The Effects of Changes in the Net FDI Inflow on the Growth Rates of Consumption, Capital, and Income**

As the net FDI inflow $m$ increases:

(i) If $n < r$ and $m < 0$, or if $n > r$ and $m > 0$, the growth rates are zero at equilibrium.

(ii) If $n < r$ ($n > r$) and $m > 0$ ($m < 0$), the growth rates of capital, consumption, and income increase (decrease).

**Proof:** Refer to Appendix 3C

Desirable conditions for the host developing country are $n < r$ with the positive net FDI inflow. Since the rate of return on capital is higher than the population growth, the firms invest more to increase production. The foreign firms bring the foreign technologies with higher productivity. The growth rates of consumption, capital, and income increase as the net FDI inflow increases. As the net FDI inflow increases when it is positive, the foreign technologies which the foreign firms bring accelerated increase in productivity of the firms with both technology transfer and spillovers. This increase in productivity leads to an increase in the growth rate of production. Increased production further increases the consumers’ opportunity to consume as well as the opportunity of the firms to invest more. Examples of empirical evidence of endogenous growth are the East Asian countries (Sala-i-Martin et al. 2004).
Undesirable conditions are $n > r$ with the negative net FDI inflow. This is what the host government would like to avoid, vicious cycle. The growth rates of consumption, capital, and income all decrease. Since the rate of return is relatively low, both the foreign firms and the home firms are less willing to invest in the host country. The foreign firms’ withdrawal from the host country further speeds up the negative growth rates. The withdrawal of the foreign technologies reduces productivity of the firms by reduction of technology transfer for the affiliates and technology spillovers to the home firms. The reductions in productivity and capital lead to the reduction in production of both the foreign firms and the home firms. Reduction of production leads to reduction in consumers’ opportunity to consume as well as to reduction in firms’ opportunity to invest. It would further decrease the growth rates of consumption as well as capital and income, as the net FDI inflow increases. Empirical examples are the sub-Saharan African countries, as Easterly and Levine (1998) and Artadi and Sala-i-Martin (2003) show negative GDP growth.

When there is a steady state equilibrium (when $n > r$ and $m > 0$, or when $n < r$ and $m < 0$), the growth rates of capital and income are zero since there is an equilibrium level of the foreign capital and the home capital. When $n < r$ and $m < 0$, since the net FDI inflow is negative and the foreign capital decreases, reduction in the availability of the foreign technologies reduces productivity of the firms as well as their production. Since the rate of reduction in productivity and production decelerate as the net FDI inflow increases, the growth rate of consumption decreases. When $n > r$ and $m > 0$, since the net FDI inflow is positive and the foreign capital increases by replacing domestic investments, there exists a new equilibrium with no growth.
3.4 The Spillover Ratio Analysis

The higher the spillover ratio is, the more technology spillovers occur. The spillover ratio affects consumption, capital, and income as well as their growth rates. The effects of changes in the spillover ratio can be analyzed by taking derivative with respect to the spillover ratio, since the spillover ratio is exogenously determined in this model.

**Proposition 3.4: The Effects of Changes in the Spillover Ratio on Consumption, Capital, Income and Their Growth Rates**

*As the spillover ratio increases,*

(i) *If* $n < r$ *and* $m < 0$, consumption, total capital, and income decrease. However, the growth rates stay zero at new equilibrium.

(ii) *If* $n > r$ *and* $m > 0$, total capital increases, but changes in consumption and income are ambiguous. However, the growth rates stay zero at new equilibrium.

(iii) *If* $n < r$ $(n > r)$ *and* $m > 0$ $(m < 0)$, changes in consumption, capital, income, and their growth rates are ambiguous; however, the growth rates are positive (negative).

*Proof:* Refer to Appendix 3D.

An increase in the spillover ratio means that the home firms have more spillover gains from the foreign technologies. Technology spillovers positively affect productivity and production of the home firms. An increase in productivity and production affects the competitiveness of the home firms to the foreign firms and increases home capital. The foreign firms may need to reduce their investments because the competitiveness of the
home firms increases. The net FDI inflow may decrease as a result. An increase in spillovers has positive impacts on home capital while it has negative impacts on foreign capital. Positive or negative effects depend on which effects are larger. These mixed effects lead to ambiguous impacts on changes in total capital, consumption, income, and their growth rates in most of cases mentioned in Proposition 3.4.

As the spillover ratio increases, when \( n < r \) and \( m < 0 \), or when \( n > r \) and \( m > 0 \), foreign capital decreases while home capital increases from one equilibrium to another. When \( n < r \) and \( m > 0 \), or when \( n > r \) and \( m < 0 \), changes in consumption, total capital, and income are ambiguous because there exist both positive effects on home capital and negative effects on foreign capital. However, these effects are not large enough to change the direction of the growth rates of consumption, total capital, and income. When \( n < r \) and \( m > 0 \), or when \( n > r \) and \( m < 0 \), the growth rates of consumption, capital, and income stay in positive or negative respectively with slight changes as the spillover ratio increases.

There are several factors which may affect the spillover ratio, such as the absorptive capacities of the home firms, and the enforcement of IPR. Kokko (1994), Borensztein et al. (1998), and Haskel et al. (2002) conclude with empirical evidence that spillovers increase with the absorptive capacities of the home firms in the host country. In order to improve the absorptive capacities of local firms, the government may support their R&D activities to accumulate their absorptive capacities. The IPR protection may have possible negative effects, even though it may promote FDI.\(^\text{10}\)

\(^\text{10}\) See Mansfield et al. (1981) for negative empirical evidence, and see Glass and Saggi (2002) for a negative theoretical result. For promotion of FDI, see Mansfield (1994) and Lai (1998) for empirical evidence and see Markusen (2001) for theoretical analysis.
3.5 Conclusion

This study provides theoretical insight for the empirical results of the negative and positive per capita GDP growth in developing countries. The growth of capital accumulation, consumption, and income depends on the conditions of the population growth, the rate of return on capital, and the net FDI inflow. For a developing country to sustain endogenous economic growth, the required conditions are the higher rate of return on investment and positive net FDI inflow. In order to have positive net FDI inflow, the developing country needs to promote FDI by improving investment climate or key determinants of growth, such as political instability, education, health, and infrastructure. In order to increase technology spillovers from available foreign technologies, local firms need to have high absorptive capacities. The best policy package for the developing country is to promote FDI to increase the net foreign capital inflow, and to support R&D activities of local firms to increase their absorptive capacities.

Further research may be extended for the analysis of policy implications. To increase the absorptive capacity of local firms increases spillovers. The developing country government may support R&D activities of local firms to increase technology spillovers, but this may have negative impacts on FDI. The IPR protection can be one policy to promote FDI; however, it has negative effects on spillovers. Further research can be also conducted to analyze the economic impacts of the policy package of FDI promotion, such as the IPR protection, and R&D supports on economic growth.
APPENDIX 3A
PROOF OF PROPOSITION 3.1

Capital accumulation of the home firms and the foreign firms can be analyzed from (3-21) and (3-22):

\[
\dot{k}_H = \eta b L \tilde{f}'(\eta b L) k_F + \{\tilde{f}'(\eta b L) - (\delta + n)\} k_H - c \\
\dot{k}_F = m + \{\tilde{f}'(\eta b L) - \eta b L \tilde{f}'(\eta b L) - (\delta + n)\} k_F
\]

(3A-1) \hspace{1cm} (3A-2)

From (3A-2), when \( m > 0 \) and \( r > n \), \( \dot{k}_F \) is always positive (\( \dot{k}_F > 0 \)) and there is no equilibrium in the foreign capital. On the other hand, when \( m < 0 \) and \( r < n \), \( \dot{k}_F \) is always negative (\( \dot{k}_F < 0 \)) and there is no equilibrium. The foreign capital is not affected by the home capital, but the net FDI inflow. However, when \( m > 0 \) and \( r < n \), or when \( m < 0 \) and \( r > n \), there is equilibrium for the foreign capital (\( \dot{k}_F = 0 \)).

From (3A-1), (3-19), and (3-20), the home capital may have equilibrium as well, and it is a function of the foreign capital:

\[
k_H = \frac{c}{\tilde{f}(\eta b L) - (n + \delta)} - \frac{\eta b L \tilde{f}'(\eta b L)}{\tilde{f}(\eta b L) - (n + \delta)} k_F
\]

(3A-3)

The slope of the \( \dot{k}_H = 0 \) locus can be checked by taking derivative of \( a = -\frac{\eta b L \tilde{f}'(\eta b L)}{\tilde{f}(\eta b L) - (n + \delta)} \) in order to draw the phase diagram:

\[
\frac{\partial \alpha}{\partial k_F} = \frac{\partial \alpha}{\partial b} \frac{\partial b}{\partial k_F}
\]

(3A-4)

where

\[
\frac{\partial \alpha}{\partial b} = \frac{\{2b(1-\beta) + \beta\} L [\tilde{f}'(n-r) - \eta b L \tilde{f}'' \{\tilde{f}'(n+r)\}]}{\{\tilde{f}'(n+r)\}^2}
\]

(3A-5)

If \( n > r \), \( \frac{\partial \alpha}{\partial b} > 0 \), \( \frac{\partial \alpha}{\partial k_F} > 0 \); If \( n < r \), the signs of \( \frac{\partial \alpha}{\partial b} \) and \( \frac{\partial \alpha}{\partial k_F} \) are ambiguous

(3A-6)
In order to analyze the changes in total capital, the slope of the $\hat{k}_H = 0$ locus can be checked.

When $n < r$ or $\tilde{f}(\eta b L) - \eta b L \tilde{f}'(\eta b L) - (n + \delta) > 0$, the slope is always flatter than $-1$:

$$
\tilde{f}(\eta b L) - \eta b L \tilde{f}'(\eta b L) - (n + \delta) > 0 \Rightarrow \tilde{f}(\eta b L) - (n + \delta) > \eta b L \tilde{f}'(\eta b L)
$$

$$
1 - \frac{\eta b L \tilde{f}'(\eta b L)}{\tilde{f}(\eta b L) - (n + \delta)} < 1
$$

(3A-7)

When $n > r$ or $\tilde{f}(\eta b L) - \eta b L \tilde{f}'(\eta b L) - (n + \delta) < 0$, the slope is always steeper than $-1$:

$$
\tilde{f}(\eta b L) - \eta b L \tilde{f}'(\eta b L) - (n + \delta) < 0 \Rightarrow \tilde{f}(\eta b L) - (n + \delta) < \eta b L \tilde{f}'(\eta b L)
$$

$$
1 - \frac{\eta b L \tilde{f}'(\eta b L)}{\tilde{f}(\eta b L) - (n + \delta)} > -1
$$

(3A-8)

Dynamic transitions of the foreign capital and the home capital can be analyzed by using the phase diagram of Figures 3.1 to 3.4. When $n < r$ and $m < 0$ or when $n > r$ and $m > 0$, there are possible steady state paths in areas II and IV, while both capital expand in area I and shrink in area III as shown in Figure 3.1 or in Figure 3.2, respectively. When $n < r$ and $m > 0$ as shown in Figure 3.3, location of the foreign capital and the home capital must be in area I since the foreign capital is increasing ($\hat{k}_F > 0$). When $n > r$ and $m < 0$ as shown in Figure 3.4, location of the foreign capital and the home capital must be in area III since the foreign capital is decreasing ($\hat{k}_F < 0$).

Analysis of the behaviors of both the foreign firms and the home firms in capital accumulation can be analyzed using each phase diagram. The effects of an increase in the net FDI inflow on each capital accumulation are summarized below:
$n < r$ and $m < 0$ (Figure 3.1)

There is equilibrium of the foreign capital and the home capital as shown in Figure 3.1. As the net FDI inflow increases, the foreign capital decreases until the net FDI inflow becomes positive, while the home capital increases. In other words, the home capital is replacing the foreign capital to meet the needs of consumers. However, an increase in the home capital is less than a decrease in the foreign capital because the slope of the $\dot{k}_H = 0$ locus is always flatter than $-1$. Therefore, total capital decreases.

$n > r$ and $m > 0$ (Figure 3.2)

There is equilibrium of the foreign capital and the home capital as shown in Figure 3.2. As the net FDI inflow increases, it shifts the $\dot{k}_F = 0$ locus further to the right. The foreign capital increases while the home capital decreases. An increase in the foreign capital is less than a decrease in the home capital because the slope of $\dot{k}_H = 0$ locus is always steeper than $-1$. Total capital decreases.
Both the home capital and the foreign capital are unstable on the $\dot{k}_H = 0$ locus. Since $\dot{k}_F$ is positive ($\dot{k}_F > 0$), the foreign capital always increases and it is above $\dot{k}_H = 0$ locus. Both the foreign capital and the home capital increase. The foreign firms are investing more because the return of capital is higher. As the foreign firms invest more, the home firms invest more as well because they gain spillovers from the foreign firms and the return of capital is higher. Therefore, total capital keeps increasing. As the net FDI inflow increases, an increase in both capital accumulations is further accelerated.

$n < r$ and $m > 0$ (Figure 3.3)

Both the home capital and the foreign capital are unstable on the $\dot{k}_H = 0$ locus. Since $\dot{k}_F$ is positive ($\dot{k}_F > 0$), the foreign capital always increases and it is above $\dot{k}_H = 0$ locus. Both the foreign capital and the home capital increase. The foreign firms are investing more because the return of capital is higher. As the foreign firms invest more, the home firms invest more as well because they gain spillovers from the foreign firms and the return of capital is higher. Therefore, total capital keeps increasing. As the net FDI inflow increases, an increase in both capital accumulations is further accelerated.

$n > r$ and $m < 0$ (Figure 3.4)

Both the home capital and the foreign capital are unstable on $\dot{k}_H = 0$ locus. Since $\dot{k}_F < 0$, the foreign capital decreases and it is below $\dot{k}_H = 0$ locus. Both the foreign capital and the home capital keep decreasing until the foreign capital becomes zero. Both firms
have no incentives to invest more because the rate of return of investment is low. Therefore, total capital keeps decreasing. As the net FDI inflow $e$ increases, the decreasing rate of the foreign capital is decreasing, yet it keeps decreasing until it become positive or zero. Once it turns to become positive, then the $\dot{k}_F = 0$ locus appears in the phase diagram and there would be equilibrium with both the foreign capital and the home capital as shown in Figure 3.2.
APPENDIX 3B

PROOF OF PROPOSITION 3.2

The changes in per capita consumption, capital, and income are obtained from (3-23), (3-24), and (3-25):

\[
\begin{align*}
\dot{c} &= \frac{I}{\theta} \{ \tilde{f}' (\eta bL) - \eta bL \tilde{G}' (\eta bL) - \delta - \rho \} c \quad (3B-1) \\
\dot{k} &= \{ \tilde{f}' (\eta bL) - \delta - n \} k + m - c \quad (3B-2) \\
\dot{y} &= \{ \tilde{f}' (\eta bL) - \eta bL \tilde{G}' (\eta bL) \} \dot{k} \quad (3B-3)
\end{align*}
\]

When \( n < r \) and \( m < 0 \), or when \( n > r \) and \( m > 0 \), capital has equilibrium as shown in Appendix 3A, while when \( n < r \) and \( m > 0 \), or when \( n > r \) and \( m < 0 \), capital has no equilibrium. Equilibrium in consumption can be analyzed by a phase diagram of \( \dot{c} = 0 \) and \( \dot{k} = 0 \) as shown in Figures 3.5 and 3.6.

Consumption

From (3B-2), it can be rewritten at equilibrium:

**Figure 3.5: Phase Diagram**
Consumption and Capital
\((n < r \text{ and } m < 0)\)

**Figure 3.6: Phase Diagram**
Consumption and Capital
\((n > r \text{ and } m > 0)\)
Differentiating both sides with respect to time \( t \) yields:

\[
\dot{c} = \dot{k} \{ f'(k) - \delta - n - \gamma_k \} + \dot{m}
\]  

(3B-5)

From the transversality condition, \( \lim_{t \to \infty} \int k(t) \cdot \exp(-\int (f'(k) - \delta - n - \gamma_k) \, dv) \, dt = 0 \),

\[
\tilde{f}(\eta L) - \eta L \tilde{f}'(\eta L) - \delta - n - \gamma_k > 0 \text{ where } f'(k) = \tilde{f}(\eta L) - \eta L \tilde{f}'(\eta L) \text{ from (3-20)}. \]  

When the net FDI inflow is constant (\( \dot{m} = 0 \)), \( c \) and \( k \) have the same sign when there is not equilibrium. On the other hand, when there is equilibrium in capital and consumption, \( \dot{c} = 0 \), \( \dot{k} = 0 \), and \( \dot{m} = 0 \).

The behaviors of consumers and the effects of an increase in the net FDI inflow on them are summarized in each case:

\[ n < r \text{ and } m < 0 \]

There is equilibrium in the capital accumulation. Since total capital \( k \) decreases as the net FDI inflow increases, the average product of capital or \( f(\eta L) \) also decreases because a decrease in the foreign capital is more than an increase in the home capital, that is, the foreign capital ratio decreases. From (3B-2), the \( \dot{k} = 0 \) locus is shifted downward as shown in Figure 3.5 as long as the increase in the net FDI inflow is not too large. Consumption may immediately increase and it eventually decreases to the lower equilibrium level.

\[ n > r \text{ and } m > 0 \]

There is equilibrium in the capital accumulation. From (3B-2), even though total capital \( k \) decreases, \( f(\eta L) \) may not decrease, instead it increases. An increase in the
foreign capital is less than a decrease in the home capital. However, productivity of the foreign firms is higher than that of the home firms. The shift of the \( k = 0 \) locus may be upward or downward depending on the magnitude of a decrease in total capital and an increase in the average capital. Changes in consumption are ambiguous. Consumption may increase or decrease depending on which effect is larger, the production increase by the foreign firms or the production decrease by the home firms.

**Figure 3.7: Phase Diagram**
Consumption and capital

\( (n < r \text{ and } m > 0) \)

There is no equilibrium, instead endogenous growth is expected. Since total capital keeps increasing, consumption also keeps increasing. When the net FDI inflow increases, consumption increases further.

**Figure 3.8: Phase Diagram**
Consumption and capital

\( (n > r \text{ and } m < 0) \)

There is no equilibrium, instead there is a vicious cycle. Since total capital keeps decreasing, consumption keeps decreasing. When the net FDI inflow increases, consumption still decreases with a decreasing rate.

**Income**

From (3B-3), the sign of a change in income is the same as that of a change in total capital because \( \tilde{f} (\eta bL) - \eta bL \tilde{f}' (\eta bL) > 0. \) If total capital increases, income increases.
APPENDIX 3C

PROOF OF PROPOSITION 3.3

The growth rates of per capital consumption, capital, and income are as follows:

\[ \gamma_c = \frac{1}{\theta} \left\{ \frac{f'(\eta \beta) - \eta bL f''(\eta \beta)}{f(\eta L)} - \delta \frac{m-c}{k} \right\} \]  
\[ \text{(3C-1)} \]

\[ \gamma_k = f(\eta bL) + \frac{m-c}{k} - (n + \delta) \]  
\[ \text{(3C-2)} \]

\[ \gamma_y = \frac{f(\eta bL) - \eta bL f'(\eta bL)}{f(\eta bL)} \left\{ f(\eta bL) + \frac{m-c}{k} - (n + \delta) \right\} \]  
\[ \text{(3C-3)} \]

How an increase in the net FDI inflow changes these growth rates can be analyzed by taking derivative with respect to \( m \):

\[ \frac{\partial \gamma_c}{\partial m} = \frac{\partial \gamma_k}{\partial b} \frac{\partial b}{\partial m} + \frac{\partial \gamma_y}{\partial b} \frac{\partial b}{\partial m} + \frac{\partial \gamma_y}{\partial m} \frac{\partial m}{\partial m} \]  
\[ \text{(3C-4)} \]

where \( \frac{\partial b}{\partial m} = (\partial b/\partial \kappa_F)(\partial \kappa_F/\partial m) \); \( \frac{\partial \kappa_F}{\partial m} > 0 \) if \( m > 0 \); \( \frac{\partial \kappa_F}{\partial m} < 0 \) if \( m < 0 \)

when \( n < r \) and \( m > 0 \) or when \( n > r \) and \( m < 0 \).

Consumption

From (3C-1), when \( n < r \) and \( m > 0 \) or when \( n > r \) and \( m < 0 \), we can analyze by taking derivative of \( \gamma_c \) with respect to \( b \):

\[ \frac{\partial \gamma_c}{\partial b} = \frac{1}{\theta} \left\{ f'(\eta \beta) (2b(1-\beta)+\beta)L - (2b(1-\beta)+\beta)L f'(\eta \beta) - \eta bL f'''(\eta \beta)(2b(1-\beta)+\beta)L \right\} \]  
\[ \text{(3C-5)} \]

From (3C-4) and (3C-5), \( \frac{\partial \gamma_c}{\partial m} \) can be expressed:
\[
\frac{\partial \gamma_c}{\partial m} = \frac{\partial \gamma_c}{\partial b} \frac{\partial b}{\partial m} > 0 \text{ if } n < r \text{ and } m > 0; \quad \frac{\partial \gamma_c}{\partial m} = \frac{\partial \gamma_c}{\partial b} \frac{\partial b}{\partial m} < 0 \text{ if } n > r \text{ and } m < 0 \quad (3C-6)
\]

**Capital**

When there is equilibrium of capital, there is no change in the growth rate because zero growth at equilibrium. When there is no equilibrium, we can analyze the effects of changes in the net FDI inflow on the growth rate of capital. When \( n < r \) and \( m > 0 \) or when \( n > r \) and \( m < 0 \), we can analyze by taking derivative of \( \gamma_k \) with respect to \( b \):

\[
\frac{\partial \gamma_k}{\partial b} = \tilde{f}'(\eta b L) (2b(1 - \beta) + \beta) L > 0 \quad (3C-7)
\]

Therefore, from (3C-4) and (3C-7), \( \partial \gamma_k / \partial m \) can be:

\[
\frac{\partial \gamma_k}{\partial m} > 0 \text{ if } n < r \text{ and } m > 0; \quad \frac{\partial \gamma_k}{\partial m} < 0 \text{ if } n > r \text{ and } m < 0 \quad (3C-8)
\]

**Income**

Taking derivative of \( \gamma_y \) with respect to \( b \) yields:

\[
\frac{\partial \gamma_y}{\partial b} = -\frac{\tilde{f}'(\eta b L)}{\tilde{f} L} \{2b(1 - \beta) + \beta\} L(r + \delta)\left\{\frac{m - c}{k} - (n + \delta)\right\} > 0 \quad (3C-9)
\]

where \( \frac{m - c}{k} - (n + \delta) < 0 \).

From (3C-4) and (3C-9), \( \partial \gamma_y / \partial m \) can be expressed:

\[
\frac{\partial \gamma_y}{\partial m} > 0 \text{ if } n < r \text{ and } m > 0; \quad \frac{\partial \gamma_y}{\partial m} < 0 \text{ if } n > r \text{ and } m < 0 \quad (3C-10)
\]

Therefore, the sign of \( \partial \gamma_y / \partial m \) is the same as that of \( \partial \gamma_k / \partial m \).
The effects of changes in the spillover ratio on the growth rates of consumption, capital, and income are analyzed by taking derivative with respect to the spillover ratio $\beta$:

For capital, taking derivative of $\gamma_k$ with respect to the spillover ratio yields:

$$\frac{\partial \gamma_k}{\partial \beta} = \tilde{f}' \{b(1-b)L + (2b(1-\beta)+\beta)L \frac{db}{d\beta}\} - \frac{1}{k} \frac{dc}{d\beta} \left(1 - \frac{(m-c)dk}{k^2} \right)$$  \hspace{1cm} (3D-1)

where $\frac{db}{d\beta} = \left(\frac{dk_F}{d\beta} - \frac{dk_H}{d\beta}\right)/k^2$; $\frac{dk}{d\beta} = \frac{dk_F}{d\beta} + \frac{dk_H}{d\beta}$.

For consumption, taking derivative of $\gamma_c$ with respect to the spillover ratio yields:

$$\frac{\partial \gamma_c}{\partial \beta} = \frac{1}{\theta} \{b(1-b)L(\tilde{f}' - \tilde{f}' - \eta bL \tilde{f}'') + (2b(1-\beta)+\beta)L(\tilde{f}' - \tilde{f}' - \eta bL \tilde{f}'') \frac{db}{d\beta}\}$$

$$= \frac{1}{\theta} \eta bL \tilde{f}'' L(b(1-b) + (2b(1-\beta)+\beta) \frac{db}{d\beta})$$  \hspace{1cm} (3D-2)

For income, taking derivative of $\gamma_y$ with respect to the spillover ratio yields:

$$\frac{\partial \gamma_y}{\partial \beta} = -\eta bL \tilde{f}'' \{b(1-b)L + (2b(1-\beta)+\beta)L \frac{db}{d\beta}\} \left(\frac{1}{k} \frac{dc}{d\beta} + \left(\frac{m-c}{k^2} \frac{dk}{d\beta}\right)(1 - \frac{(m-c)\eta bL}{k^2})\right)$$

$$+ \left\{\frac{m-c}{k} - (n + \delta)\right\} \{b(1-b)L + (2b(1-\beta)+\beta)L \frac{db}{d\beta}\} \left\{\frac{\tilde{f}' + \tilde{f}'' \eta bL}{f} + \frac{\eta bL \tilde{f}'^2}{f^2}\right\}$$

$$= \{b(1-b)L + (2b(1-\beta)+\beta)L \frac{db}{d\beta}\} \{-\eta bL \tilde{f}'' \left[\frac{\tilde{f}' + \tilde{f}'' \eta bL}{f} + \frac{\eta bL \tilde{f}'^2}{f^2}\right]\}$$

$$- \left(\frac{1}{k} \frac{dc}{d\beta} + \left(\frac{m-c}{k^2} \frac{dk}{d\beta}\right)(1 - \frac{(m-c)\eta bL}{k^2})\right)$$  \hspace{1cm} (3D-3)
From (3A-2), as the spillover ratio increases, if foreign capital increases at the new equilibrium, \( \tilde{J}(\eta bL) - \eta bL \tilde{J}'(\eta bL) \) must decrease. However, since the foreign capital ratio increases as foreign capital increases, \( \tilde{J}(\eta bL) - \eta bL \tilde{J}'(\eta bL) \) increases because its derivative is positive. Thus it contradicts. If foreign capital decreases, \( \tilde{J}(\eta bL) - \eta bL \tilde{J}'(\eta bL) \) must increase. \( \tilde{J}(\eta bL) - \eta bL \tilde{J}'(\eta bL) \) increases when \( b(1 - b) + (2b (1 - \beta) + \beta)db/db > 0 \). Therefore, foreign capital at the new equilibrium decreases. The \( \dot{k}_F = 0 \) locus shifts to the left as shown in Figure 3.9.

From (3A-3) for the \( \dot{k}_H = 0 \) locus, the intercept decreases because consumption is more likely to decrease if total capital decreases. The slope of the \( \dot{k}_H = 0 \) locus flattens because an increase in denominator is larger than that in numerator of (3A-3) as illustrated in Figure 3.9.

As total capital decreases, the \( \dot{c} = 0 \) locus shifts to the left while the \( \dot{k} = 0 \) locus may shifts downward as consumption is more likely to decrease because an increase in home capital would be less than a decrease in foreign capital. However, from (3B-1) in this
case an increase in consumption is positive while total capital may decrease as shown in Figure 3.10. Consumption, capital, and income decrease in this case, and the growth rates stay zero at the new equilibrium.

\( n > r \) and \( m > 0 \)

From (3A-2), as the spillover ratio increases, if foreign capital increases at the new equilibrium, \( f' (\eta bL) - \eta bL f'' (\eta bL) \) must increase. Since the foreign capital ratio increases as foreign capital increases, \( f' (\eta bL) - \eta bL f'' (\eta bL) \) increases because its derivative is positive. Thus there exists equilibrium. On the contrary, if foreign capital decreases, \( f' (\eta bL) - \eta bL f'' (\eta bL) \) must also increase to have equilibrium. \( f' (\eta bL) - \eta bL f'' (\eta bL) \) increases when \( b(1 - b) + (2b (1 - \beta) + \beta)db/db > 0 \). Therefore, foreign capital at the new equilibrium increases or decreases when \( b(1 - b) + (2b (1 - \beta) + \beta)db/db > 0 \). The \( k_F = 0 \) locus shifts to the left as shown in Figure 3.11 because of an increase in the spillover ratio must have negative impacts on foreign capital.

From (3A-3) for the \( k_H = 0 \) locus, the intercept decreases because consumption is more likely to decrease if total capital decreases. The slope of the \( k_H = 0 \) locus flattens because an increase in denominator is larger than an increase in numerator of (3A-3) as illustrated in Figure 3.11, but it is still steeper than \(-1\).

Total capital may increase because an increase in home capital is more than a decrease in foreign capital as shown in Figure 3.12. The \( \dot{c} = 0 \) locus shifts to the right while the \( \dot{k} = 0 \) locus may shifts either upward or downward as changes in consumption are ambiguous. The growth rates of consumption, capital, and income are zero at the new equilibrium.

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The increasing rate of foreign capital decreases while that of home capital would further increase. From (3D-1) for total capital accumulation, there are positive effects on an increasing rate of home capital while there are negative effects on an increasing rate of foreign capital. Therefore, total effects on the growth rate of total capital are ambiguous. The growth rates of consumption and income are also ambiguous from (3D-2) and (3D-3). However, the growth rates maintain positive with continuous growth.

The decreasing rate of foreign capital would further increase while the decreasing rate of home capital would be reduced. From (3D-1) for total capital accumulation, there are positive effects on home capital as the spillover ratio increases while there are negative effects on foreign capital. Since the effects of changes in the spillover ratio on the growth rate of total capital, the effects on the growth rates of consumption and income are also ambiguous from (3D-2) and (3D-3). However, the growth rates maintain negative with continuous negative growth.
REFERENCES


CHAPTER 4

THE EFFECTS OF INTELLECTUAL PROPERTY RIGHTS PROTECTION ON TECHNOLOGY SPILLOVERS AND WELFARE THROUGH FOREIGN DIRECT INVESTMENT IN DEVELOPING COUNTRIES

4.1 Introduction

Intellectual property rights (IPRs) protection plays an important role in international policy agenda for foreign direct investment (FDI). IPR protection for FDI affects the behaviors of both foreign firms and home firms in developing countries. Changes in the behaviors of both foreign and home firms affect FDI, technology spillovers, and welfare of a host country. The profits of both foreign firms and home firms are also affected. IPR protection makes it more difficult for the home firm to imitate the foreign technologies from FDI while it affects the foreign firms for their prevention activities of technology spillovers. As a result, spillovers from the foreign technologies to the home firms and the host country’s welfare are affected.

To analyze the impacts of IPR protection on technology transfer, spillovers, and local welfare, the endogenous spillover model of Chapter 2 is used. The spillover equilibrium is determined by a foreign firm’s spending to protect its technology and a home firm’s spending to gain spillovers from the foreign technology. Since IPR enforcement affects the behaviors of the foreign firm and the home firm, the spillover equilibrium is also affected. If spillovers are affected, the profits of the foreign firm and the home firm, and local welfare are also affected. The following questions are answered by this analysis:
How does IPR enforcement influence the behaviors of the foreign firm and the home firm. How does it affect the spillover equilibrium? How does it affect the home welfare from the FDI and accompanying spillovers?

This paper provides the following results to the above questions. As IPR is enforced, the foreign firm increases its spending to prevent spillovers while the home firm reduces its spending to gain spillovers. By considering the foreign firm’s spending to prevent its technology spillovers as private enforcement, private enforcement and public enforcement (IPR protection) may act as complements. Spillovers from the existing foreign technologies will be reduced. However, the likelihood of FDI increases. Therefore, as the home country strengthens its IPR enforcement, its welfare increases due to new FDI attracted by stronger IPR enforcement. However, the home country also suffers welfare losses in terms of lower welfare gains from existing FDI.

Various literature analyze the impacts of IPR protection on imitation activities of local firms as follows: Many theoretical papers use a two-country model to analyze the impacts of the IPR protection on innovation in the north (developed countries), and on imitation in the south (developing countries). A typical result shows that the IPR protection decreases both the rate of innovation in developed countries and the rate of imitation in developing countries. IPR protection makes it easier for the foreign firms to protect their technologies. On the contrary, it makes it more difficult for the home firms to gain spillovers from the foreign technologies because IPR protection increases imitation costs of the home firms. Mansfield et al. (1981) empirically conclude that imitation costs increase for the home firms if the stronger patent protection is enforced.

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Many analyses examine which is the most efficient means to enforce, private or public enforcement, where researchers generally view that private enforcement and public enforcement are substitutes. For example, see Polinsky (1980) and Garoupa and Jellal (2002). However, several studies examine a joint use of private enforcement and public enforcement, and conclude that the joint use is more efficient. In other words, as Shavell (1984; 1987), Kolstad et al. (1990), and Kaplow and Shavell (1994:1996) show in their theoretical models, private enforcement and public enforcement may act as complements. Earnhart (1998) finds the complementary relation of private enforcement and public enforcement in the Czech Republic.

A number of theoretical studies indicate that stronger enforcement of IPR increases FDI from developed countries to developing countries. Helpman (1993), Lai (1998), and Markusen (2001) show that stronger enforcement of IPR in developing countries increases FDI from developed countries in their theoretical models.2

As Hoekman et al. (2004) summarize in their review of existing literature, the empirical studies estimating the effects of IPR protection on inward FDI find mixed results. Lee and Mansfield (1996) and Maskus (2005) identify positive impacts of IPR protection on FDI while Smith (2001) and Blyde and Acea (2003) find that IPR protection has no impacts on FDI in poor countries. Smith (2001) and Nicholson (2002) identify that only developing countries with strong imitative abilities have positive impacts of strong IPR protection to shift from exports and FDI to licensing and to affect

---

2 Lai (1998) modifies the model of Grossman and Helpman (1991b) and Helpman (1993) to allow the foreign firms to undertake FDI in a developing country and local firms to imitate only after the foreign firms transfer production to a developing country.
inflows of technology transfer, while other countries have no impacts of IPR protection.\(^3\) Oxley (1999) and Yang and Maskus (2001) empirically find that strong IPR protection reduces FDI and encourages licensing. Svensson (1998) empirically finds that the weak IPR protection leads to lower FDI through the links of IPR protection to FDI and political instability. Javorcik (2004) also finds that weak IPR protection lowers FDI in technology-intensive sectors using firm-level data set from Eastern Europe and the former Soviet Union. On the contrary, Ferrantino (1993) and Maskus and Konan (1994) find no statistical significance between IPR protection and FDI.

The effects of IPR protection on welfare have been analyzed by the following theoretical models. Helpman (1993) concludes that IPR protection reduces welfare of developing host countries due to the terms of trade and efficiency effects. Markusen (2001) concludes that if stronger IPR protection induces the foreign firm to switch from exporting to local production, welfare of a host country improves.

IPR protection does not play an important role in all sectors as Mansfield (1995) revealed by a survey of U. S. manufacturing firms. For example, the automobile industry is less sensitive to IPR protection because many inputs are too complex and too expensive to be imitated, while IPR protection may be crucial in other sectors, such as machinery and equipment, electrical equipment, drugs, cosmetics and health care products, and chemicals. A survey of Mansfield (1994) shows that investment decision based on IPR protection depends on the investment purposes. For example, when R&D facilities are involved, about 80 percent of respondents were concerned about IPR protection.

\(^3\) Eaton and Kortum (1996) find that patent protections are associated with productivity growth in host countries, while McCalman (2001) finds that the poorest countries are unlikely to benefit from the stronger IPR protection.
protection. For manufacturing components and finished products, about 50 to 60 percent were concerned about IPR protection. About 30 percent were for basic production and assembly facilities, and about 20 percent were for sales and distribution outlets.

The following section presents the basic model. Section 4.3 discusses the effects of IPR protection on the spillover equilibrium in a two-stage game. Section 4.4 provides the analysis of the effects of IPR protection on home welfare. The conclusion is in Section 4.5.

4.2 The Basic Model

The endogenous spillover model of Chapter 2 is used as a base model for the analysis of the effects of IPR protection on the spillover equilibrium and home welfare. The developing country market consists of two firms, the home firm and the foreign firm. Market segmentation and Cournot competition with a homogeneous product are assumed. Constant marginal costs and non-negative profits are also assumed. For simplicity, an inverse linear demand function is assumed:

\[ P(Y) = a - bY \]  

(4-1)

where \( a > 0; b > 0; P \) denotes the price; and \( Y \) denotes total output.

Chapter 2 has two possible scenarios, one involving exports by the foreign firm and the other involving FDI and local production by the foreign firm. In both cases, the firms make simultaneous output decisions. For my analysis, I assume that the IPR enforcement has no influence on output decisions in the exporting equilibrium, but on the FDI decision and output decisions under FDI. If the foreign firm chooses FDI, then the following two-stage game is affected by IPR enforcement. In the first stage, IPR
enforcement affects the simultaneous decisions of the foreign firm and the home firm on their spending to prevent spillovers and to gain spillovers, respectively. Therefore, IPR protection affects this spillover outcome determined by the spending of the two firms to maximize their profits. The second stage is Cournot competition between the two firms. Each firm simultaneously decides on its output level given the spillover outcome of the first stage.

Spending of the home firm to gain spillovers from the foreign technology and that of the foreign firm to prevent spillovers of its own technology are defined as follows:

(i) The home firm’s expenditure to gain technology spillovers, $g$

This cost may represent a part of fixed costs of the home firm to imitate the foreign firm’s technology, such as reverse engineering costs. Spending $g$ cannot increase spillovers above the technology level of the foreign firm.

(ii) The foreign firm’s expenditure to prevent technology spillovers, $p$

This cost may represent a part of fixed costs of the foreign firm, such as private enforcement costs to protect the foreign firm’s IPR. For example, the firm may pay to build a plant security system to prevent technology from leaking. Spending $p$ cannot prevent the level of spillovers below zero.

IPR enforcement makes it more difficult or costly for the home firm to gain spillovers from the foreign technology, while its enforcement makes it easier or less costly for the foreign firm to prevent spillovers of its technology. For analysis, I assume that stronger IPR protection increases the imitation costs of the home firm.
The effects of IPR enforcement on the behaviors of the foreign firm and the home firm may be represented by a multiplier $t$. The effects of IPR enforcement are on both spending $g$ of the home firm and spending $p$ of the foreign firm:

$$g_0 = gt^g, p_0 = pt^p$$

(4-2)

However, the direct effects of IPR protection are assumed to be only on spending $g$. Changes in spending $g$ of the home firm affects spending $p$ of the foreign firm as well. A change in one firm’s spending mutually affects the other firm’s spending. The magnitudes of the overall effects on spending $g$ and $p$ are different, but the directions of the effects of changes are not affected. Therefore, for analysis, the direct effects of IPR protection are assumed to be only on the home firm’s spending $g$ by using a multiplier $t$.

$$g_0 = gt; p_0 = p$$

(4-2)’

where $t \in (0, 1]$.

The effects of IPR protection may be easily analyzed with this assumption. Thereby the function of the spillover ratio $s$ can be expressed as $s (gt, p)$.

In the first stage, firms maximize their profits by choosing optimal levels of spending $g$ to gain spillovers and spending $p$ to prevent spillovers:

$$\Pi^H (g, s(gt, p)) = P (Y) Y^H - c^H Y^H - g - z^H$$

(4-3)

$$\Pi^F (p, s(gt, p)) = P (Y) Y^F - c^F Y^F - p - z^F$$

(4-4)

where a superscript $H$ or $F$ denotes variables associated with the home firm or the foreign firm with FDI, respectively; $Y = Y^H + Y^F$; and $z$ denotes fixed costs excluding spending $g$ and $p$.

The marginal cost of the home firm with spillovers can be expressed:

$$c^H = c^0 - s (gt, p) (c^0 - c^F)$$

(4-5)
where a superscript \( \theta \) denotes variables associated with the home firm without FDI; \( s(gt, p) \in [0, 1] \) for \( \forall g \geq 0 \) and \( \forall p \geq 0 \); the marginal costs \( (c^0, c^F) \) are exogenously given; and \( c^0 > c^F > 0 \).

A multiplier \( t \) represents the level of IPR enforcement. No IPR protection is assumed for \( t = 1 \). IPR protection exists for \( t \in (0, 1) \). The stricter IPR protection is, the smaller the multiplier becomes. In other words, stronger IPR protection reduces the ability of the home firm to gain spillovers by spending on imitation activities of the foreign technologies. This multiplier may reflect legal defense fees the home firm may need to spend.

The derivative properties of the spillover ratio with respect to IPR protection are assumed as follows: As IPR is enforced, the spillover ratio decreases. The first derivative of the spillover ratio with respect to a multiplier \( t \) is positive with the following boundary conditions:

\[
\begin{align*}
  s_t &= 0 \text{ at } s = 1 \text{ if } p > \bar{p} \text{ or if } p \text{ decreases at } p = \bar{p}_{s=1} \\
  s_t &= 0 \text{ at } s = 0 \text{ if } g < \bar{g} \text{ or if } g \text{ decreases at } g = \bar{g}_{s=0}
\end{align*}
\]

Otherwise, \( s_t > 0 \). (4-6)

where a subscript \( t \) denotes derivative with respect to a multiplier \( t \); \( \bar{p}_{s=1} \) denotes the maximum spending \( p \) at \( s = 1 \); and \( \bar{g}_{s=0} \) denotes the maximum spending \( g \) at \( s = 0 \).

The home firm needs to spend more to gain the same spillovers for a given spending \( p \) of the foreign firm, while the foreign firm needs to spend less to prevent the same spillovers for a given spending \( g \) of the home firm. As spending \( g \) increases, the marginal increase of the spillover ratio decreases for a given spending \( p \), while as spending \( p \) increases, the marginal decrease of the spillover ratio increases for a given spending \( g \). The
second-order cross-derivative of the spillover ratio is assumed to be non-positive\(^4\) as shown in Chapter 2. The properties of the spillover ratio \(s\) can be expressed including the boundary conditions:

\[
\forall p, \exists \bar{g}(p) \text{ s.t. } s(gt, p) > 0 \text{ if } g < \bar{g}(p); \text{ and } s(gt, p) = 1 \text{ if } g \geq \bar{g}(p)
\]

\[
\forall g, \exists \bar{p}(g) \text{ s.t. } s(gt, p) > 0 \text{ if } p < \bar{p}(g); \text{ and } s(gt, p) = 0 \text{ if } p \geq \bar{p}(g)
\] (4-7)

where \(\bar{g}(p)\) denotes the maximum spending \(g\) with a given \(p\) at \(s(gt, p) = 1\) and \(\bar{g}(p)\) increases for \(t \in (0, 1)\); \(\bar{p}(g)\) denotes the maximum spending \(p\) with a given \(g\) at \(s(gt, p) = 0\) and \(\bar{p}(g)\) decreases for \(t \in (0, 1)\). 

\[
s_g > 0; s_{gg} < 0; s_{gt} > 0 \text{ for } s(gt, p) \in [0, 1);
\]

\[
s_g > 0; s_{gg} < 0; s_{gt} > 0 \text{ for } s(gt, p) = 1 \text{ if } g \text{ decreases at } g = \bar{g}(p);
\]

or \(s_g = 0; s_{gg} = 0; s_{gt} = 0 \text{ for } s(gt, p) = 1 \text{ if } g \text{ increases at } g = \bar{g}(p) \) or if \(g > \bar{g}(p)\) \hspace{1cm} (4-8)

where a subscript \(g\) denotes derivative with respect to \(g\).

\[
s_p < 0; s_{pp} > 0; s_{pt} > 0 \text{ for } s(gt, p) \in (0, 1];
\]

\[
s_p < 0; s_{pp} > 0; s_{pt} > 0 \text{ for } s(gt, p) = 0 \text{ if } p \text{ decreases at } p = \bar{p}(g);
\]

or \(s_p = 0; s_{pp} = 0; s_{pt} = 0 \text{ for } s(gt, p) = 0 \text{ if } p \text{ increases at } p = \bar{p}(g) \) or if \(p > \bar{p}(g)\) \hspace{1cm} (4-9)

where a subscript \(p\) denotes derivative with respect to \(p\).

The initial conditions of the spillover ratio are the same as without IPR protection:

\[
s(0, 0) = 0.
\] (4-10)

No spillovers occur when neither firm spends resources.

For example, the spillover function \(s(gt, p) = \ln((gt+1)/(p+1))\) can be used for simulation as shown in Appendix 4A, where \(t\) is a multiplier as described above. The

\footnote{One firm's spending does not improve the other firm's marginal spending to gain or prevent spillovers.}
spillover ratio can be expressed as (i) \( s(gt, p) = \min\{1, \ln\{(gt+1)/(p+1)\}\} \) if \( \ln\{(gt+1)/(p+1)\} > 0 \); and (ii) \( s = 0 \) if \( \ln\{(gt+1)/(p+1)\} < 0 \). The initial conditions of the spillover ratio are also satisfied for this example function.

4.3 The Effects of IPR Protection on the Spillover Equilibrium

The effects of IPR protection on the spillover equilibrium are analyzed in each stage of the two-stage game. This two-stage game can be analyzed by applying backward induction, starting with the second stage.

4.3.1 The Effects of IPR Protection on the Outcomes in Stage Two

The spillover level has been endogenously determined in the first stage. In the second stage, each firm decides its output to maximize its profits. By solving a Cournot Nash competition, the equilibrium outputs for each firm changes as the spillover ratio changes by IPR enforcement:

\[
Y^H*(s(gt, p)) = \frac{1}{3b} \{a - 2(1 - s(gt, p)) c^0 + (1 - 2s(gt, p)) c^F\} \tag{4-11}
\]

where \( a - 2(1 - s(gt, p)) c^0 + (1 - 2s(gt, p)) c^F > 0 \) because \( Y^H* \) must be positive.

\[
Y^F*(s(gt, p)) = \frac{1}{3b} \{a + (1 - s(gt, p)) c^0 - (2 - s(gt, p)) c^F\} \tag{4-12}
\]

at the equilibrium price level of

\[
P*(s(gt, p)) = \frac{1}{3} \{a + (1 - s(gt, p)) c^0 + (1 + s(gt, p)) c^F\} \tag{4-13}
\]

The Cournot Nash equilibrium gives the following profits in the second stage by IPR enforcement:
4.3.2 The Effects of IPR Protection on the Spillover Equilibrium in Stage One

In the first stage, IPR enforcement affects each firm’s decision on the level of spending $g$ or $p$ in order to maximize its profits in the second stage. These changes in spending affect the equilibrium level of spillovers $s^*$. The spending $g$ or $p$ affects profits of the two firms, not only by increasing respective fixed costs but also by changing the marginal cost of the home firm through spillovers.

From (4-14) and (4-15), the necessary first order conditions for the optimal level of $g$ and $p$ are:

$$
\Pi^H_g = \frac{4}{9b} s_g (c^0 - c^f) \{ a - 2(1 - s(gt, p))c^0 + (1 - 2s(gt, p))c^F \} - 1 = 0
$$

(4-16)

$$
\Pi^F_p = \frac{-2}{9b} s_p (c^0 - c^f) \{ a + (1 - s(gt, p))c^0 - (2 - s(gt, p))c^F \} - 1 = 0
$$

(4-17)

From the first order conditions (4-16) and (4-17), the optimal spillover ratio can be solved:

$$
s^*(gt, p) = \frac{9b}{8(c^0 - c^f)^2 s_g (g, t)} - \frac{a - c^F}{2(c^0 - c^f)} + 1
$$

(4-16)’

$$
s^*_g = \frac{9b}{4(c^0 - c^f) \{ a - 2(1 - s(gt, p))c^0 + (1 - 2s(gt, p))c^F \}} > 0
$$

(4-16)”

$$
s^*(gt, p) = \frac{9b}{2(c^0 - c^f)^2 s_p (p)} + \frac{a - c^F}{c^0 - c^f} + 1
$$

(4-17)’
\[ s_p^* = -\frac{9b}{2(c^0 - c^F)\{a + (1-s(gt,p))c^0 - (2-s(gt,p))c^F\}} < 0 \] (4-17)''

(4-16)'' and (4-17)'' satisfy the derivative properties of (4-8) and (4-9) for \( s_g \) and \( s_p \).

**Proposition 4.1: The Effects of IPR Protection on the Spillover Equilibrium**

As IPR is enforced, spending \( p^* \) increases, however, spending \( g^* \) and the spillover ratio \( s^* \) both decrease. In other words, the more IPR is enforced, the more the foreign firm spends to prevent spillovers, while the less the home firm spends to gain spillovers.

**Proof:** Refer to Appendix 4B.

IPR enforcement helps the foreign firm to prevent its technology spillovers because its enforcement protects the foreign technology, while it becomes more difficult for the home firm to gain spillovers from the foreign technology. The marginal profitability of the foreign firm by unit spending \( p \) increases as IPR is enforced. The foreign firm spends more to obtain more profits by preventing more spillovers. Since the costs of the home firm’s imitation activities increase, profitability of the foreign firm increases. Therefore, the foreign firm is willing to spend more to prevent spillovers to further increase its profits. As IPR is enforced, the marginal profitability of the home firm worsens; hence, the home firm should reduce its spending \( g \) to prevent losing more profits of the home firm with given spending \( p \) of the foreign firm. As a result, spillovers are further reduced for stronger IPR protection.

Under the assumptions of this model, **Proposition 4.1** implies that public and private
enforcement of IPR can act as complements. Hay and Shleifer (1998) find when public enforcement is weak, private enforcement reinforces the existence of the public rules and helps economies well in Russia and other emerging economies.\(^5\) Besides, it is the foreign firm to get direct benefits from prevention of its technology spillovers by both private and public enforcement of IPR.

Simulation results in Appendix 4A also support Proposition 4.1. For example, the function of the spillover ratio \(s(gt, p) = \ln((gt+1)/(p+1))\) is used with \(a = 30, b = 1, c^\ell = 10, \) and \(c^F = 8.\) As \(t\) decreases from 1 to 0.9 (as IPR is enforced), spending \(g\) of the home firm decreases from 17.04 to 16.41, and the spillover ratio decreases from 0.57 to 0.43, while spending \(p\) of the foreign firm increases from 9.16 to 9.29.

### 4.4 The Effects of IPR Protection on Home Welfare

IPR enforcement affects spending \(p\) of the foreign firm to prevent spillovers, and spending \(g\) of the home firm to gain spillovers from the foreign technology, as shown in Proposition 4.1. Since IPR enforcement also affects the spillover ratio and the profits of both firms, it affects both the foreign entry conditions and home welfare from FDI. First the effects of IPR protection on the foreign entry conditions are discussed. Then the effects of IPR protection on welfare of a home country are discussed.

**Proposition 4.2: The Effects of IPR Protection on the Foreign Entry Conditions**

*As IPR is enforced, the foreign firm's profits increase, and the foreign entry conditions are lowered. Therefore, the likelihood of FDI increases.*

\(^5\) For a case study, see Gow et al. (2002) on a Slovakian sugar processor.
Proof: Refer to Appendix 4C.

IPR protection increases the marginal profitability of the foreign firm's spending to prevent its technology spillovers. Since IPR enforcement lowers the equilibrium spillover ratio, the profits of the foreign firm increases. Because an equilibrium spending \( p^* \) increases, the profit gains of the foreign firm from additional spending on \( p \) should be more than the additional spending. On the other hand, IPR enforcement has negative effects on the profits of the home firm because the equilibrium spillover ratio decreases. As the profits of the foreign firm increases, previously unprofitable FDI may become profitable because IPR enforcement lowers the foreign entry conditions for FDI. Therefore, the likelihood of FDI increases.

For example, simulation results in Appendix 4A show that the foreign firm increases its profits as IPR is enforced. The function of the spillover ratio \( s(gt, p) = \ln(\frac{(gt+1)}{(p+1)}) \) is used with \( a = 30, b = 1, c^0 = 10, \) and \( c^F = 8. \) The profits of the foreign firm increase from 48.86 to 50.24. When \( c^F = 9, \) the profits of the foreign firm increase from 46.94 to 47.50. Therefore, the likelihood of foreign entry increases because some firms that previously chose to export can now enter local production under the IPR protection.

Proposition 4.3: The Effects of IPR Protection on Home Welfare from FDI

As IPR is enforced, home welfare always decreases for existing FDI. However, if the foreign firm enters the home economy because of IPR protection when previously FDI was not profitable, home welfare increases.
Proof: Refer to Appendix 4D.

Consumers’ welfare decreases as IPR is enforced because a decrease in the equilibrium spillover ratio provides less quantity of products with a higher price to consumers. The home firm’s profits also decrease because the impacts of IPR enforcement on spillovers are negative. The spillover gains are reduced by IPR enforcement. However, an increase in home welfare can be obtained when the foreign firm enters to produce locally where previously its entry was not profitable for smaller technology gaps. Gains for consumers’ welfare from a new FDI will be larger than the loss of the profits of the home firm from the new FDI.

For example, simulation results in Appendix 4A show that the profits of the home firm decrease. The function of the spillover ratio \( s(gt, p) = \ln\{(gt+1)/(p+1)\} \) is used with \( a = 30, b = 1, c^0 = 10, \) and \( c^F = 8. \) The profits of the home firm decreases from 28.74 to 26.75, and the spillover ratio from 0.57 to 0.43. When \( c^F = 9, \) the profits of the home firm decreases from 37.69 to 36.81, and the spillover ratio from 0.64 to 0.52. For this example, since both the profits of the home firm and consumers’ welfare decrease, home welfare also decreases by IPR protection.

4.5 Conclusion

This paper concludes that private enforcement of the foreign firm’s spending to prevent technology spillovers is complementary to public enforcement of IPR protection. IPR protection affects the foreign firm’s behavior to spend more to prevent spillovers, because the marginal profitability of the foreign firm’s spending to prevent spillovers
increases. On the contrary, IPR protection affects the home firm’s behavior to spend less to gain spillovers, because the marginal profitability of the home firm’s spending to gain spillovers decreases. As a result, the spillover ratio decreases in equilibrium. A decrease in the spillover ratio leads to reduction in consumers’ welfare as well as in the profits of the home firm. However, since the likelihood of FDI increases, home welfare improves by a new FDI which was not previously profitable because welfare gains for consumers dominate negative effects on the home firm’s profits.

Since this analysis is based on partial equilibrium model, the following effects are not included. When a home country receives FDI, a positive effect on local economies can be an increase in employment because of an increase in total production. IPR enforcement may reduce this increase in employment from existing firms, while the enforcement may improve employment by an additional FDI. For a negative effect of its enforcement, the host government bears additional costs of public enforcement of IPR, which are not included in the analyses.

Many developing countries hesitate to enforce IPR enforcement because they worry that the costs associated with the enforcement outweigh the benefits. However, some countries, such as Malaysia, South Korea and Mexico, have implemented the policy to enforce IPR to promote FDI. Further research may be necessary to analyze the effects of IPR protection and accompanying spillovers including forward and backward linkages.
APPENDIX 4A

SIMULATION RESULTS

The function of the spillover ratio $s = \ln\{(gt+1)/(p+1)\}$ is used with the assumptions of $a = 30$, $b = 1$, $c^0 = 10$, and an inverse demand function $P = a - bY$. The following data are simulated results with the different values of the marginal costs of the foreign firm, $c^F$ as well as with the different values of a multiplier $t$. The equilibrium satisfies the conditions derived from the first order conditions, with the negative second order conditions and the stability conditions.

Table 4.1: Simulation Results of IPR Protection

<table>
<thead>
<tr>
<th>$t$</th>
<th>$c^F$</th>
<th>$p^*$</th>
<th>$g^*$</th>
<th>$s^*$</th>
<th>$\Pi^F*$</th>
<th>$\Pi^H*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>22.6770</td>
<td>32.2920</td>
<td>0.3408</td>
<td>56.158</td>
<td>6.673</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>15.3671</td>
<td>25.5316</td>
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Note: $\Pi^H*$ or $\Pi^F*$ only includes spending $g$ or $p$ respectively in its fixed costs.

Findings: As IPR enforcement increases (as $t$ decreases):

(i) Spending of the foreign firm $p^*$ always increases $dp^*/dt < 0$.

(ii) Spending of the home firm $g^*$ always decreases $dg^*/dt > 0$.

(iii) The spillover ratio $s^*$ always decreases.

(iv) The home firm’s profit decreases, while the foreign firm’s profit increases.
The effects of IPR enforcement on the equilibrium spending can be analyzed by the comparative static of \( dg^*/dt \) and \( dp^*/dt \). Total differentiation of the first order conditions (4-18) and (4-19) yields:

\[
\Pi_{gg}^H dg^* + \Pi_{gp}^H dp^* + \Pi_{g}^H dt = 0
\]  
(4B-1)  
\[
\Pi_{pg}^F dg^* + \Pi_{pp}^F dp^* + \Pi_{p}^F dt = 0
\]  
(4B-2)

where a subscript \( t, g \) or \( p \) denotes derivative with respect to \( t, g \) or \( p \), respectively.

\[
\Pi_{gg}^H = \frac{4}{9b} (c^0 - c^\bar{c}) (s_{gt}(a - 2(1 - s^*) c^0 + (1 - 2s^*) c^\bar{c}) + 2s_{gt}(c^0 - c^\bar{c})) > 0
\]  
(4B-3)  
\[
\Pi_{pp}^F = -\frac{2}{9b} (c^0 - c^\bar{c}) (s_{pt}(a + (1 - s^*) c^0 - (2 - s^*) c^\bar{c}) - s_{pt}(c^0 - c^\bar{c})) < 0
\]  
(4B-4)  
\[
\Pi_{gg}^H = \frac{4}{9b} (c^0 - c^\bar{c}) (s_{gg}(a - 2(1 - s^*) c^0 + (1 - 2s^*) c^\bar{c}) + 2s_{gt}(c^0 - c^\bar{c})) < 0
\]  
(4B-5)  
\[
\Pi_{pp}^F = -\frac{2}{9b} (c^0 - c^\bar{c}) (s_{pp}(a + (1 - s^*) c^0 - (2 - s^*) c^\bar{c}) - s_{pp}(c^0 - c^\bar{c})) < 0
\]  
(4B-6)  
\[
\Pi_{gp}^H = \frac{4}{9b} (c^0 - c^\bar{c}) (s_{gp}(a - 2(1 - s^*) c^0 + (1 - 2s^*) c^\bar{c}) + 2s_{gt}(c^0 - c^\bar{c})) < 0
\]  
(4B-7)  
\[
\Pi_{pp}^F = -\frac{2}{9b} (c^0 - c^\bar{c}) (s_{pg}(a + (1 - s^*) c^0 - (2 - s^*) c^\bar{c}) - s_{pg}(c^0 - c^\bar{c})) < 0
\]  
(4B-8)

where \( s_t > 0; s_{pt} > 0; \) and \( s_{gt} > 0 \).

These equations (4B-1) and (4B-2) can be put in matrix form and solved using Cramer’s rule:
\[
\frac{dg^*}{dt} = (\Pi_H^{H} \Pi_F^{F} + \Pi_F^{H} \Pi_F^{H}) / D > 0 \tag{4B-9}
\]

\[
\frac{dp^*}{dt} = (\Pi_F^{H} \Pi_F^{F} + \Pi_H^{H} \Pi_F^{F}) / D < 0 \tag{4B-10}
\]

where \( D = \Pi_H^{H} \Pi_F^{F} - \Pi_F^{H} \Pi_H^{F} > 0 \) from the stability conditions.

From (4B-3), (4B-4), (4B-6) and (4B-7), \( \frac{dg^*}{dt} = 0 \) because \( \Pi_H^{H} > 0, \Pi_F^{F} < 0, \Pi_F^{H} < 0, \Pi_F^{F} < 0 \), and \( \Pi_H^{H} < 0 \). From (4B-3), (4B-4), (4B-5) and (4B-8), \( \frac{dp^*}{dt} < 0 \) because \( \Pi_F^{H} < 0, \Pi_F^{F} < 0, \Pi_F^{H} > 0, \Pi_F^{F} < 0 \).

These results confirm \( ds^*/dt > 0 \):

The effects of spending \( g \) and \( p \) on the spillover ratio at the equilibrium can be analyzed by the comparative static of \( ds^*/dt \). Total differentiation of the function of the spillover ratio \( s = s(g, p) \) yields:

\[
ds^* = s_g \frac{dg^*}{dt} + s_p \frac{dp^*}{dt} + s_t \frac{dt}{dt} \tag{4B-11}
\]

The effects on the spillover ratio can be obtained, dividing both sides of (4B-11) by \( dt \) :

\[
\frac{ds^*}{dt} = s_g \frac{dg^*}{dt} + s_p \frac{dp^*}{dt} + s_t > 0 \tag{4B-12}
\]

From (4B-9) and (4B-10), the sign of \( ds^*/dt \) is positive, because \( \frac{dg^*}{dt} > 0 \) and \( \frac{dp^*}{dt} < 0 \). This interprets that as IPR is enforced, the equilibrium spillover ratio \( s^* \) decreases, where the equilibrium spending of the home firm \( g^* \) decreases and the equilibrium spending of the foreign firm \( p^* \) increases.
APPENDIX 4C

PROOF OF PROPOSITION 4.2

Total differentiation of the profit function of the foreign firm with respect to a multiplier $t$ yields:

$$d\Pi^F_t = \Pi^F_t \ dt + \Pi^F_s \ ds + \Pi^F_p \ dp + \Pi^F_g \ dg$$  \hspace{1cm} (4C-1)

$$\frac{d\Pi^F_t}{dt} = \Pi^F_t + \Pi^F_s \ \frac{ds}{dt} + \Pi^F_g \ \frac{dg}{dt} < 0$$  \hspace{1cm} (4C-2)

where $\Pi^F_t = 0$; $\Pi^F_s = -\frac{2}{9b} (a + (1-s^*) \ c^0 - (2-s^*) \ c^F) (c^0 - c^F) s_t < 0$;

$$\Pi^F_s = -\frac{2}{9b} (a + (1-s^*) \ c^0 - (2-s^*) \ c^F) (c^0 - c^F) < 0; \ \frac{ds}{dt} > 0;$$

$$\Pi^F_g = -\frac{2}{9b} s g (a + (1-s^*) \ c^0 - (2-s^*) \ c^F) (c^0 - c^F) - 1 < 0; \text{ and } \frac{dg}{dt} > 0.$$

Since (4C-2) is negative, as IPR is enforced, the profits of the foreign firms with FDI increase. However, the profits of the foreign firm without FDI do not change. Therefore, as IPR is enforced, the lower limit of the foreign entry conditions lowers.
Comparing an exporting equilibrium and an FDI equilibrium, changes in consumer surplus and in home producer surplus from FDI can be expressed:

\[ \Delta CS = \frac{1}{18b} \{(c^x - c^F)(4a - 2c^0 - c^x - c^F) + s^*(c^0 - c^F)(4a - 2c^0 - 2c^F + s^*(c^0 - c^F))\} \quad (4D-1) \]

\[ \Delta PS = \frac{1}{9b} \{(c^F - c^x)(2a - 4c^0 + c^F + c^x) + 4s^*(c^0 - c^F)(a - 2c^0 + c^F + s^*(c^0 - c^F))\} - g^* \quad (4D-2) \]

Taking derivative with respect to a multiplier \( t \) yields:

\[ \frac{\Delta CS}{t} = \frac{1}{9b} s_t (c^0 - c^F)(2a - (1 - s)c^0 - (1 + s)c^F) > 0 \quad (4D-3) \]

\[ \frac{\Delta PS}{t} = \frac{4}{9b} s_t (c^0 - c^F)(a - 2(1 - s)c^0 + (1 - 2s)c^F) - \frac{dg^*}{dt} > 0 \quad (4D-4) \]

(4D-4) is positive from (4-17). From (4D-3) and (4D-4), as IPR is enforced, both changes in both the profits of the home firm \( \Delta PS \) and consumers’ welfare \( \Delta CS \) decrease as the equilibrium spillover ratio \( s^* \) decreases.

Welfare changes by the foreign firm’s entry when it was previously unprofitable can be analyzed using (4D-1) and (4D-2). \( \Delta CS \) is positive even though \( c^x \) and \( s^* \) become smaller. \( \Delta PS \) is ambiguous because the first term \( (c^F - c^x)(2a - 4c^0 + c^F + c^x) \) is negative. The second term \( (4s^*(c^0 - c^F)(a - 2c^0 + c^F + s^*(c^0 - c^F))/(9b) - g^* \) is positive, otherwise the home firm would not spend \( g^* \). Adding the first terms of \( \Delta PS \) and \( \Delta CS \) gives:

\[ \frac{1}{18b} \{(c^x - c^F)(3(c^0 - c^F) + 3(c^0 - c^x))\} > 0 \quad (4D-5) \]

where \( (c^0 - c^x) > 0 \) at the lower limit of \( c^x \).
Since positive effects dominate negative effects in the profits of the home firm, $\Delta W = \Delta PS + \Delta CS > 0$. Therefore, home welfare increases with new FDI.
REFERENCES


CHAPTER 5
CONCLUSION

Foreign direct investment (FDI) from developed countries to developing countries plays a significant role in the economic growth of developing countries. Especially, technology spillovers from the foreign technologies of FDI are accomplished by the means of imitation. Firms in developing countries can gain the existing technologies of the foreign firms in developed countries by imitation. Therefore, technology transfer and spillovers of FDI in developing countries may act as a stepping stone to the economic growth of the third world.

5.1 Technology Spillovers and Welfare

This study examines the strategic interaction between the foreign firm and the home firm that determines technology spillovers through FDI in developing countries. The foreign firm is willing to spend to prevent technology spillovers while the home firm is willing to spend to gain spillovers. It also provides theoretical insight for the positive and negative empirical spillover results of FDI on productivity of local firms.

It must be attractive enough for the foreign firms to have FDI in developing countries. The technology gap is found to have an impact on the spillover equilibrium and local welfare. The analyzed results of the endogenous spillover equilibrium in an oligopoly approach are:

(1) As the technology gap between the foreign and home firms increases from a small initial level, technology spillovers increase. However, when the technology gap
exceeds a certain critical level, further increases lead to smaller spillovers.

(2) Since the foreign entry conditions are lowered as the technology gap increases, the likelihood of FDI increases.

(3) Home welfare always increases due to the FDI if the foreign firm has a cost advantage over the home firm prior to the FDI. If the spillover ratio increases as the technology gap increases for the smaller technology gap, home welfare always increases with the FDI.

5.2 Technology Transfer, Spillovers, and Growth

This study provides that the growth of capital accumulation, consumption, and income depends on the conditions of the population growth, the rate of return on capital, and the net FDI inflow. The analysis of the endogenous growth model concludes the following results:

(1) For a developing country to sustain endogenous economic growth, the required conditions are the higher rate of return on investment and positive net FDI inflow.

(2) In order to have positive net FDI inflow, the developing country needs to promote FDI by improving the investment climate or key determinants of growth, such as political stability, education, health, and infrastructure.

(3) In order to increase technology spillovers from available foreign technologies, local firms need to have high absorptive capacities.

The best policy package for the developing country is to promote FDI to increase the net foreign capital inflow, and to support R&D activities of local firms to increase their absorptive capacities.
5.3 The Effects of IPR Protection on Spillovers and Welfare

I have analyzed policy implications of IPR protection using the oligopoly model. IPR protection changes the behaviors of the foreign firm and the home firm. As a result, it changes technology spillovers and local welfare. The findings of the effects of IPR enforcement on the spillover equilibrium and local welfare are:

(1) Private enforcement of the foreign firm’s spending to prevent technology spillovers is complementary to public enforcement of IPR protection. In other words, stronger public enforcement of IPR leads to higher spending by the foreign firm to further prevent technology spillovers.

(2) On the contrary, stronger public enforcement of IPR hinders the home firm’s efforts to gain technology spillovers and thereby leads to lower spending on those efforts.

(3) As a result of these effects on the firms’ strategic behavior, stronger IPR enforcement lowers the level of technology spillovers.

(4) A decrease in technology spillovers leads to reduction in consumers’ welfare as well as in the profits of the home firm.

(5) However, stronger IPR protection increases the foreign firm’s profits from FDI and thereby increases the likelihood that FDI occurs. The host country can benefit from strengthening its IPR protection if this serves to attract FDI that would not otherwise occur.
5.4 Future Research

There are a number of ways to extend my theoretical models. My first two models can be used as base models for further research applications. By changing some assumptions, these models can be extended to analyze other situations of FDI in developing countries. Using these developed theoretical models, extensive policy analyses become possible, as shown in Chapter 4. These theoretical results including policy implications can be also tested empirically. Other possible research applications using these models are to analyze additional and related problems in developing countries, such as sustainable development, environmental, and poverty issues.