



Technology Spillover and Productivity Growth under R&D Consortia Policy

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Technology Spillover and Productivity Growth under R&D Consortia Policy

ABSTRACT

This present research studies the effect of the R&D consortia policy on the productivity growth and technology spillover through FDI in the Southeast Asia region using a system dynamics approach. Thailand, Malaysia, and Vietnam are selected as the representative countries in the Southeast Asia region. The R&D consortia policy has not been implemented in these three countries. However, the effect of the R&D consortia policy on the selected countries is examined through the Japanese case which successfully utilizes the R&D consortia policy. The study shows that Thailand, Malaysia, and Vietnam gain benefits from the R&D consortia policy by having higher productivity. Increase in the country's productivity also improves the average income of the population in that country. By having more income per person, the country can attract more FDI which in turn increases the technology spillover and productivity of the country. Through sensitivity analysis, the country can gain more benefits by shortening the policy implementation duration. However, these benefits are the short-term benefits instead of the long-term benefits. The negative reaction of foreign firms toward the implementation of the R&D consortia policy also shows insignificant effect on the productivity of the country and the GDP per capita although it lowers the level of FDI. The effect of the R&D consortia policy on the improvement of the productivity growth, country's economy, and foreign investment varies due to the economic situation and the risk of the country. The country with mature economy gains more productivity growth but acquires less additional FDI from the policy while the country with a rapidly growing economy receives less benefit in terms of country productivity but acquires more benefits in terms of FDI. The country which is perceived by foreign investors as a high risk

country requires a longer period until the effect of the R&D consortia policy on the increase in FDI takes place.

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CHAPTER 1: INTRODUCTION

Foreign Direct Investment (FDI) is one of the key factors that drive the economy of the FDI recipient countries. Foreign enterprises provide more jobs with higher compensation to local workers (Bandick, 2004; Conyon, Girma, Thompson, & Wright, 2002; Fu & Balasubramanyam, 2005; Girma & Görg, 2007; Heyman, Sjöholm, & Tingvall, 2007; Lipsey & Sjöholm, 2004; Martins, 2004; McDonald, Tüselmann, & Heise, 2002; Williams, 1999) and also transfer technology and operational practices from the multinational firms' headquarters to their local subsidiaries which increase the country's production output (Baranson, 1970; Contractor & Sagafi-Nejad, 1981). Moreover, the presence of foreign firms in the industry also makes the productivity of domestic firms in the related industries increase even though they have no direct interaction with the foreign firms, which also improves the welfare of the host countries (Sawada, 2005). This phenomenon is called "technology spillover".

Technology spillover is perceived as a method to reduce the productivity capability gap between developing countries and developed countries. Therefore, a lot of research has been thoroughly conducted on technology spillovers through FDI including the existence of technology spillover (for example, see Blomström and Sjöholm (1999), Chuang and Lin (1999), Liu (2002), and Cheung and Lin (2004)), the determinant of technology spillover through FDI (Blomström & Sjöholm, 1999; Chuang & Lin, 1999; Kohpaiboon, 2006; Sawada, 2005; Sermcheep, 2006; Wang, 1997), and the effect of

public policy on technology spillover (Bozeman, 2000; Derwisch, Kopainsky, & Henson-Apollonio, 2009; Sawada, 2005; Stoneman & Diederer, 1994). However, most of the research approaches the problem based on a static perspective which treats the problems as a snapshot picture instead of a change during a period of time. Moreover, they assume that the level of technology spillover has no effect on the level of FDI which is not realistic. Besides, the delay of the effect between each factor and the technology spillover are also neglected. These are the major flaws that this dissertation aims to solve. Therefore, this dissertation will study the dynamics of productivity growth from technology spillover through FDI. For parsimony, the study will focus on the Southeast Asia region and Thailand, Malaysia, and Vietnam will be used as the case studies.

Although technology transfer and technology spillover provide benefits to the FDI recipient countries, this rarely happens without the assistance from public sectors through public policy. Public policy has been considered an important factor to facilitate the technology transfer and technology spillover because the technology market is not a perfect competition market (Bozeman, 2000; Stoneman & Diederer, 1994). As a result, many policies have been studied in terms of their ability to assist the technology transfer. One of such policies is the intellectual property rights which many scholars present as a type of policy that prevents, instead of encouraging, the technology spillover (Derwisch, et al., 2009; Sawada, 2005). The R&D consortia policy is, on the other hand, a policy that has been examined and proved that it stimulates the technology transfer and spillover (Evan & Olk, 1990; Lin, Fang, Fang, & Tsai, 2009; Ouchi & Bolton, 1988).

The R&D consortium is an inter-organization cooperation to conduct R&D together. This policy can stimulate technology and knowledge transfer between firms in

the consortium and with the research institutes that participate with the consortium. The success story of the R&D consortia policy starts in the semiconductor industry of Japan in 1961 which makes Japan one of the global leaders (Ouchi & Bolton, 1988; Sakakibara, 1997; Watanabe, Kishioka, & Nagamatsu, 2004). In the U.S., the R&D consortia policy was implemented after the U.S. semiconductor industry lost its competitiveness to Japan (Aldrich & Sasaki, 1995; Evan & Olk, 1990). Besides Japan and the U.S., the R&D consortia policy has also been implemented in Europe, South Korea, and Taiwan (Lin, et al., 2009; Mathews, 2002; Mothe & Quélin, 2000; Sakakibara & Cho, 2002)

Even though the implementation of the R&D consortia policy has been done in many countries, there is no research showing the use of this policy in countries in the Southeast Asia region, which have the problem of limited technology capacity (NSTDA, 2007). Therefore, this research is worth studying because it focuses on the effect of using the R&D consortia policy on technology spillover in developing countries in Southeast Asia, focusing on Thailand, Malaysia, and Vietnam.

Objective

Based on the above mentioned issues, there is a room for further examination of the dynamics of productivity growth from technology spillover through FDI when considering the feedback effect from the productivity level to the level of FDI and also the effect of the R&D consortia policy on the technology spillover and improvement in the productivity of developing countries. Therefore, this dissertation aims to:

Objective 1: Examine the productivity growth from technology spillover whether there is a feedback effect from the level of improvement in productivity and technology spillover to the FDI level

Even though Sawada (2005) claims that multinational firms have higher costs if the degree of technology spillover is high due to the investment to prevent the technology leakage which will affect the investment decision in the future and Derwisch, Kopainsky et al. (2009) study the effect of Intellectual Property Rights on the technology spillover from FDI in the agricultural sector with the feedback effect from technology spillover to the level of FDI, there is no strong evidence showing that the feedback effect from productivity improvement and technology spillover to the level of FDI exist. Therefore, this research will study whether there is a feedback effect from the productivity improvement and technology spillover to the level of FDI by considering the causality between these two variables and also comparing the simulation results when the feedback effect is incorporated with the actual data.

Objective 2: Study the dynamics of productivity growth from technology spillover through FDI in a short-term and long-term period when incorporating the feedback effect from the productivity improvement and the level of technology spillover to the FDI

The existing research on the dynamics of technology spillover from FDI is limited and does not incorporate the feedback effect from the technology spillover to the FDI into an equation (for example, see Hur and Watanabe (2002)). Moreover, the productivity

growth from technology spillover through FDI needs to be considered in both a short run and long run in order to understand the overall effect because the benefits in the short run can become the problem in the long run (Samii & Teekasap, 2009). Therefore, if the study's first objective shows a positive result, we will then study the dynamics of productivity growth from technology spillover through FDI considering the feedback effect from the improvement of productivity to the FDI in a short-term and a long-term.

Objective 3: Examine the effect of the R&D consortia policy on the productivity growth from technology spillover through FDI in Thailand, Malaysia, and Vietnam

The R&D consortia policy is a successful policy that has been implemented in developed countries such as the United States and Europe and works as a key policy in transforming developing countries into developed countries as happened in Japan, Taiwan, and South Korea (Aldrich & Sasaki, 1995; Mathews, 2002; Mothe & Quélin, 2000; Sakakibara & Cho, 2002). However, there is no evidence of using this policy to encourage the technology spillover in countries in Southeast Asia. Moreover, there is no study on the dynamics of implementing an R&D consortia policy. Therefore, this dissertation will bring to light the dynamics of the effect of the R&D consortia policy on the productivity growth from technology spillover through FDI in Thailand, Malaysia, and Vietnam.

Contribution of this research

Most of the existing literature on productivity growth and technology spillovers through FDI has mainly considered the effect of FDI on the technology spillover (for example see Wang (1997) and Sermcheep (2006)). These studies treat the level of FDI as an exogenous factor that is not affected by the degree of technology spillover. However, Sawada (2005) presents that the multinational firms invest to prevent the technology spillover. Based on this reasoning, high level of technology spillover will increase the operating cost of the firms which then discourage the inflow of FDI. Therefore, considering FDI as an exogenous variable which is not affected by the technology spillover make these studies oversimplified and does not illustrate the real situation. This study will tackle this problem by examining the dynamics of productivity growth from technology spillover through FDI under the closed-loop feedback relationship between FDI and the productivity improvement.

How public policy affects the level of technology spillover from FDI has also been studied for many years. One of the policies that had been successfully implemented is the R&D consortia policy. The R&D consortia policy has been adopted and effectively enhanced the technology transfer in Japan, United States, Taiwan, Korea, and Europe (Aldrich & Sasaki, 1995; Mathews, 2002; Mothe & Qu  lin, 2000; Sakakibara, 1997; Sakakibara & Cho, 2002). However, there is neither a study on the implementation of the R&D consortia policy in developing countries in Southeast Asia nor about the dynamics of productivity growth from technology spillover through FDI under the R&D consortia policy. For that reason, this research will study the dynamics of productivity growth from

technology spillover through FDI under the R&D consortia policy in Thailand, Malaysia, and Vietnam.

In summary, this research is different from the existing research because this research will study the dynamics, instead of the statics, of productivity growth from technology spillover through FDI when incorporating the feedback effect under the R&D consortia policy. Such policy if successfully implemented can transform developing countries into developed countries in the East Asia region but there is no academic evidence of such implementation in developing countries in Southeast Asia especially in Thailand, Malaysia, and Vietnam.

CHAPTER 2: LITERATURE REVIEW

Productivity can be improved from the technology spillover through the presence of foreign firms. However, even though there is no foreign investment, the performance of local firms still varies from firm-to-firm based on other factors. Therefore, we need to understand those factors that affect the productivity of the firms in order to eliminate their influence to the change in productivity when studying the pure effect of FDI on productivity growth from technology spillover.

Determinants of productivity

Productivity is affected by many factors. Based on the existing literature, we can summarize the factors into three levels of analysis, which are country level, industry level, and firm level.

Country level

When we consider the productivity at the country level, it is measured by the gross domestic product (GDP) or aggregate demand per employment which presents the monetary value of the outcome that each employment can produce on average. There are two main methods to calculate a country's productivity: the aggregate demand method and the production function.

The aggregate demand calculation is one of the early developments in economics by John Maynard Keynes in his famous book “The General Theory of Employment, Interest, and Money” (Keynes, 1936). The aggregate demand is derived from the summation of consumption, investment, government spending, and net export. Even though this equation is widely accepted, it is mainly used to explain the conceptual idea of which factors affect the GDP instead of a framework for an empirical research because of the difficulties in gathering the data. Moreover, in order to forecast the aggregate demand, many variables require behavioral analysis which is complicated.

Another approach which is more applicable for empirical work is the production function developed by Cobb and Douglas (1928). Cobb and Douglas presented that the production P is affected by the amount of man-hour of labor L and fixed capital K as shown in equation 1. This equation was tested with U.S. data during 1889 and 1992. The results show a small deviation between the equation and the actual data.

$$P = bL^k K^{1-k} \quad (1)$$

However, technology change or “technical change” also affect to the production (Solow, 1957). Besides the capital and labor, Solow (1957) added the time into the function to capture “technical change” which includes any kind of shift in the production function. Therefore, the equation becomes as shown in equation 2. From that, we can take the special form with $A(t)$ as a multiplicative factor as shown in equation 3.

$$P = F(K, L; t) \quad (2)$$

$$P = A(t)f(K,L) \quad (3)$$

The above model is the standard production function of a neoclassical model. $A(t)$ represents the output gain from other factors besides labor and capital which change over time such as technology development, innovation, and new management practices.

Industry Level

The previous section focuses on the factors that affect the productivity at the macro level. In this section, we concentrate on the industry level because the industrial characteristics can also affect the productivity of the firms.

Chuang and Lin (1999) studied the factors that affect the productivity in Taiwan's manufacturing industry. The productivity value is measured from the total factor productivity which is collected from the firms' total factor productivity under constant returns to scale and variable returns to scale assumption. Chuang and Lin studied both firm-level factors and industry-level factors. However, the results on firm-level factors are discussed in the next section.

The industry-level factors that are studied in Chuang and Lin's research include industry's concentration ratio, which is measured from the market share of four largest firms in the industry, and the market openness, which is the share of exports to total industry output. The regression results show that both factors are significant to the change in productivity but in an opposite way. Market concentration has a negative effect while the market openness has a positive effect on the productivity.

Kohpaiboon (2006) also studied the determinant of productivity by focusing on the Thai manufacturing industry. The dependent variable is the labor productivity of local firms. The independent variables include the effect of foreign presence and firm-level characteristics which is discussed in the following section. For the industry-level factors, Kohpaiboon studied the effect of trade policy regime and market concentration which is also studied by Chuang and Lin (1999). The results contradict Chuang and Lin (1999) findings that the market concentration significantly supports the productivity due to a competition effect. However, the industrial trade policy does not significantly affect the productivity.

From the research discussed above, we can conclude that competition, through market openness in Chuang and Lin (1999) and market concentration in Kohpaiboon (2006), improve the productivity of local firms.

Firm level

The effects of firm-level factors on the firm's productivity are likely to be studied together with the effect of the industry-level factors. Therefore, we refer to the studies by Chuang and Lin (1999) and Kohpaiboon (2006) that we have reviewed in the industry-level section.

Chuang and Lin (1999) studied the effect of the labor quality, firm's size, and firm's share of export to total output on the productivity. Labor quality is measured from the employment share of white-collar workers, the ratio of skilled to unskilled labor, and the relative wage of white to blue-collar workers. The results show a significant positive

effect of the production scale of a firm, share of exports, and labor quality on the productivity of the firms.

Kohpaiboon (2006) integrated a part of Chuang and Lin (1999) research with the Cobb-Douglas production function by using the firm's capital-labor ratio, capital stock of the firm, and the labor quality. Instead of measuring the labor quality as Chuang and Lin (1999) did, Kohpaiboon used the ratio of supervisory and management workers to total industry employment to represent the labor quality. The results support Cobb and Douglas (1928)'s findings but contradict the results of Chuang and Lin (1999) because he found a significant positive relationship between the firm's capital-labor ratio and firm's capital stock with the productivity of the firms while the relationship between labor quality and the productivity is not significant.

Sermcheep (2006) also studied the factors that affect the productivity of the Thai manufacturing industry by focusing mainly on the presence of foreign firms and the firm-level factors. The factors included in her study are the capital per employee, material per employee, education level of workers, firm's training program, R&D intensity, firm size, export intensity, and import intensity. The R&D intensity is measured by the ratio of R&D expenditures to total sales. The size of the firms is measured by the number of employee and the total assets of the firms. The export and import intensity is quantified by the ratio of exports to total sales and the ratio of import materials to total materials.

The results from Sermcheep (2006) show the significant contribution of capital per employee and material per employee on the firm's productivity, which supports the finding from Cobb and Douglas (1928). The education level of workers, training programs, and the R&D intensity alone do not show a significant effect on the

productivity of the firm but the education level and training combined have a significant relationship with the productivity. However, the finding about the effect of firm's size contradicts Chuang and Lin (1999) findings since Sermcheep found insignificant relationship between the firm size and the productivity. However, the relationship between the export and import intensity with the productivity is also significant.

In summary, the variables that are significantly related to the productivity of the firms and should be controlled when studying the effect of foreign direct investment on technology spillover are: fixed capital, labor, material, export intensity, import intensity, and industry concentration. There are other variables that provide inconclusive findings on how they affect productivity due to the contradictory results in different papers but should also be included as control variables when firm-level analysis is conducted. These variables are the labor quality and the size of the firm.

Evidence of productivity growth from technology spillover

In the previous section, we described how the productivity of the firms varies based on many factors that are not related to foreign investment. Thus, the next important question to be examined is whether there is a technology spillover or not. There are many studies showing the existence of technology spillover in different environments. In general, the existing research identifies the relationship between the presence of foreign firms and an improvement of productivity of the local firms as an evidence of technology spillover.

We start with the study by Chuang and Lin (1999). In this study, they focused on the productivity change from the spillovers in Taiwan's manufacturing industry. The

authors used linear regression to find the relationship between the presence of a foreign firm, measured from the share of foreign assets at the industry level, and the productivity of local firms represented by the local firms' total factor productivity. They found a positive relationship between the share of foreign assets and the firms' total factor productivity which can imply that there is a technology spillover in the manufacturing industry in Taiwan.

In the same year, Blomström and Sjöholm also published a paper to show the productivity growth from technology spillover in Indonesia (Blomström & Sjöholm, 1999). Instead of using the share of foreign assets at the industry level as Chuang and Lin (1999), they used the foreign share in the foreign affiliate. Moreover, they also studied the effect of foreign presence on productivity of both the foreign affiliate and the local firms in the same industry by using the labor productivity, measured from the value added per labor ratio, as a dependent variable. The regression results indicate that the foreign share has a positive significant effect on the productivity of both foreign affiliate and local firms which also shows the same result as Chuang and Lin (1999) that the technology spillover exists.

Liu (2002) revisited this issue again and expanded the existing literature by examining the technology spillover effect within the same industry and also between different industries. Not only the relationship between FDI and the productivity was studied, he also examined the relationship between FDI and the growth rate of productivity. This study was based on data from 29 manufacturing industries in the Shenzhen Economic Zone of China during 1993 and 1998 using a log-log regression model which is developed from the production function by Cobb and Douglas (1928).

The results do not show a significant relationship between FDI and productivity and the productivity growth for the overall industry but it shows a positive relationship in the component industries. Moreover, other industries also get benefits from the foreign investment which denotes that the spillover effect is not limited only to the same industry but also affects other industries.

Cheung and Lin (2004) also studied the existence of spillover effect in China. However, they differentiate their research by focusing on the effect of FDI on innovation measured by the number of patent applications instead of the productivity or value-added and using the provincial data instead of industrial data. They used a pooled time-series cross-sectional regression to include data from all provinces during 1995 and 2000. The results indicate that the FDI spillover effect on local innovation is positive and significant.

In summary, the productivity growth from technology spillover through FDI exists which is proved by the positive relationship between the degree of foreign investment and the productivity, productivity growth, and innovation of local firms. In addition, not only the local firms within the same industry receive the spillover effect, but also the local firms in other industries gain benefits from FDI.

Determinants of technology spillover through FDI

Even though it has been shown in the previous section that there is a significant effect of FDI on improving the productivity of domestic firms, the degree of spillover in each environment is different. In general, the factors that affect the degree of spillover

can be grouped into four categories which are characteristic of the recipient country, industry, domestic firms, and foreign firms.

Recipient country characteristics

The attribute of the recipient country affects the decision making of foreign investment (Dunning, 1998) and also the degree of technology spillover from foreign investment to local firms as indicated in the study of Wang (1997) and Meyer and Sinani (2009).

Wang (1997)'s study focuses on the international technology transfer and spillover from U.S. multinationals during 1980s. The degree of technology transfer is measured by the amount of royalties and license fee payments to the U.S. The attributes that he focused on are trade openness which is measured from the difference in U.S. exports to the recipient country and the U.S. exports to U.S. foreign affiliates in that country and the quality of human capital which is quantified by the number of years of education. Wang found that both trade openness and the quality of human capital have a significant positive influence on the degree of technology spillover.

Another paper that concentrates on the country characteristics and the level of spillover is Meyer and Sinani (2009). This paper used a meta-regression method and utilized the data from published and unpublished existing literature on technology spillover. They focused on the effect of host country's level of development, which is divided into the level of per capita income, level of human capital, and level of institutional development, and the effect of trade openness on the technology spillover. The GDP per capita is used for the per capita income. The level of human capital is

indicated by the gross enrollment ratio in tertiary education, R&D expenditure as a percentage of GDP, and the ratio of the number of patents granted to host country residents per GDP. For the level of institutional development, the Economic Freedom Index from the Heritage Foundation and the Corruption Perception Index by Transparency International are used. The trade openness is measured by the sum of exports and imports divided by the GDP.

The results show that the level of development of host countries, which is the composite of per capita income, human capital, and institutional development, and the degree of technology spillover has a curvilinear with U-shaped pattern while the trade openness has a positive linear relationship with the technology spillover.

The rational behinds the curvilinear relationship can be explained based on Chen (1996)'s awareness-motivation-capability framework. For low-income countries, the foreign investment aims to access to low labor cost resources and mainly for export-oriented purposes. Therefore, there is no direct competition between foreign firms and domestic firms. Domestic firms also are not aware of the competition with foreign firms because of the low similarity between the characteristics of domestic and foreign firms. However, domestic firms can learn non-proprietary knowledge from demonstration effects because the technology gap between foreign firms and domestic firms is high. For the case of middle-income countries, a foreign firm invests to access both a new market and for labor opportunities. Thus, foreign firms and domestic firms are likely to have a direct competition. Although the domestic firms are aware of the threat, they don't have the capability to protect their territory. The demonstration effect is unlikely to provide substantial benefits because domestic firms already know the non-proprietary knowledge

and foreign firms do not share their proprietary technology. Therefore, the productivity of domestic firms is low. In high-income economies, local firms and foreign firms have a strong head-to-head competition. In high-income countries, as opposed to middle-income economies, domestic firms have the capability and experience in dealing with aggressive competition. At the end of the struggle, weak firms will leave the industry and only the strong firms survive. Therefore, the average productivity of domestic firms increases.

The market openness stimulates the development of productivity of local firms because it creates a higher competitive market environment and also provides an opportunity for domestic firms to learn new knowledge and technology from foreign investment.

In summary, per capita income, quality of human capital, and trade openness of the FDI recipient countries affect the level of technology spillover.

Industry characteristics

Sermcheep (2006) considered the type of industry whether it is a low-, medium-, or high-technology industry and the productivity growth from technology spillover through FDI. The results indicate that firms in the low- and medium-technology level can gain higher benefits from the presence of foreign enterprises than the local firms in high-technology industries because of the difference between the technological capability between domestic firms and foreign firms in the low- and medium-technology industries is small enough for the local firms to absorb. However, the technology in high-technology industries is mainly a proprietary knowledge and the absorptive capability of the domestic firms is not enough to acquire all the technology from foreign firms.

Kohpaiboon (2006) also studied the effect of each industry-level variable on the technology spillover by using a two-step least square regression. The first regression is to find the relationship between each variable and the foreign investment. The second regression is the relationship between foreign investment and the productivity of domestic firms. The result of the second equation shows that the presence of foreign firms significantly reduces the productivity of local firms, which contradicts the findings of many researchers who have been referenced above. The factors that are considered in the first equation are labor productivity, market size, trade policy, and labor quality. Interestingly, the results indicated that labor productivity, market size of the industry, and trade policy have a significant negative relationship with the foreign investment while labor quality significantly supports the foreign investment. Therefore, based on the two regressions, an industry with high labor productivity, large market size, and a high rate of protection is likely to have higher technology spillover while the labor quality will reduce the technology spillover.

Domestic firm characteristics

One of the firm's attributes that affects the technology spillover is the technology gap between domestic firms and foreign firms. Sawada (2005) developed a theoretical model based on the game theory approach that domestic firms will invest to increase the technology spillovers while foreign firms also have an incentive to invest to prevent the technology spillover. From his model, an increase in the technology gap will increase the technology spillover due to the demonstration effect. However, when the technology gap

increases over the critical level, the technology spillover will decrease because the benefits of a technology spillover are less than the cost to acquire the technology.

Sermcheep (2006) considered the effect of firm size and the market orientation on the productivity growth from technology spillover. Small firms are likely to have a positive productivity growth while the spillover level is reduced and becomes negative for the large firms due to the direct competition effect. Large firms tend to compete in the same market as foreign firms. Therefore, when foreign firms invest in Thailand, large domestic firms lose their market share to the foreign firms. However, small- and medium-size domestic firms gain benefits from the technology spillover without the competition effect due to a different target market. Moreover, domestic firms that are export oriented are likely to gain less benefit from the technology spillover than the domestic firms that focus on the domestic market because export-oriented domestic firms can access the technology from interacting with international markets and international competitors whereas the domestic-oriented local firms cannot.

Foreign firm characteristics

Instead of looking at the characteristics of domestic firms, Buckley, Clegg, and Wang (2007) focused on the relationship between the nationality of ownership of foreign firms and the technology spillover. They studied the case of foreign investment in China by overseas Chinese firms, including firms from Hong Kong, Macau, and Taiwan, by comparing them with the investment from firms from Western countries. The results show that the relationship between the presence of overseas Chinese firms and the productivity of domestic firms in low-technology industries is curvilinear with an inverse

U-shaped pattern while the relationship between the presence of overseas Chinese firms and the productivity in high-tech industries and the presence of Western firms and productivity of domestic firms in all industries is positive and linear. A curvilinear relationship occurred because the overseas Chinese firms and domestic firms are likely to have a direct competition which creates a market stealing and crowding-out effect. In the case of high-technology industries, overseas Chinese firms need to compete with the firms from Western countries. Therefore, the overseas Chinese firms and Western firms are considerably equal. In the case of an investment from Western firms, the investment is mainly focused on a different market segment. Therefore, domestic firms can gain the benefits from technology spillover without a negative effect from the competition.

FDI, technology spillover and the host country welfare

The effect of FDI and technology spillover on the welfare of the host country is ambiguous. On one hand, consumers gain benefits from the FDI and the technology spillover because of lower price and increased productivity. On the other hand, local firms may suffer from the competition with the foreign firms as shown in Figure 1.

Based on the Cournot Nash Equilibrium model, Sawada (2005) suggested that whether the host country's welfare is better or worse should be considered from the marginal cost of local firms and foreign firms before and after the FDI and the technology gap. If the marginal cost of foreign firms before FDI is lower than the marginal cost of local companies, FDI always supports host country's welfare. Moreover, if the difference between the marginal costs of the foreign firms before and after the FDI is less than double of the technology gap, the host country still benefits. However, if the

difference is more than double of the technology gap, the spillover becomes negative and the change in host country's welfare becomes ambiguous.

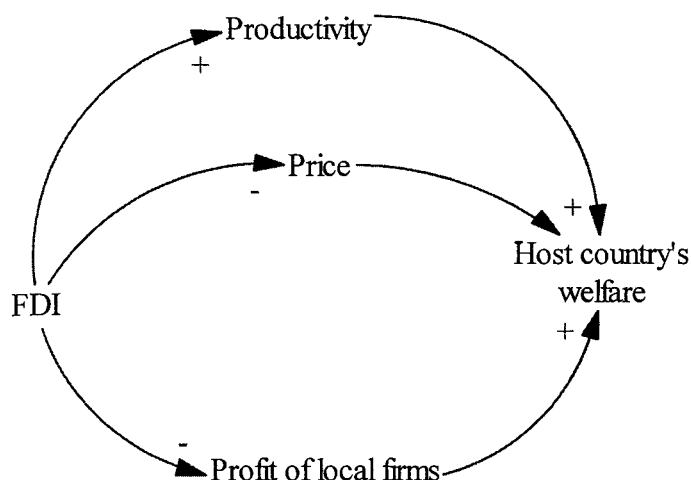


Figure 1: Effect of FDI on host country's welfare

Public policy and technology spillover

Acquiring advanced technology is always desired by domestic firms in order to improve their competitive position in the market. However, technology does not have the same behavior as a public good in the sense that everyone benefits from acquiring it (Contractor & Sagafi-Nejad, 1981). Even though technology spillover provides significant benefits for local firms, it comes at the expense of losing competitive advantage for foreign firms (Sawada, 2005). Therefore, in order to stimulate technology spillover, especially in developing countries, the governments need to come up with a public policy that increases the absorptive capability of local firms and provides incentives for foreign firms to ease their technology spillover barrier (Bozeman, 2000).

In addition, Stoneman and Diederer (1994) also suggested that a public policy is required because the technology market is imperfect. If the technology market were a perfect market, technology should be developed, traded, transferred, and spilled until it reaches equilibrium whereas the marginal benefits from adopting the technology are equal to the marginal social cost of producing the capital goods that embody that technology. The technology market is imperfect because of the imperfect information, market power, and externalities.

Information on the benefits of new or advanced technology is unknown to the technology adopters until they already adopt it. The technology providers also have an incentive to provide only information they prefer others to know. The limitation in the number of suppliers and customers also creates a market failure. When the number of customers is small, sales of one technology supplier are the lost sales of other suppliers. Therefore, technology providers will push to sell their technology faster than the optimal point. Another factor is the externalities. When the benefit of adopting one technology is dependent on the number of users of that technology, the system can be locked-in into an inferior technology (Arthur, 1994; Sterman, 2000). This situation makes the technology providers drive their customers to adopt the technology before the optimal time.

Public policy is required for technology spillover, but not every policy reaches that goal. Contractor and Sagafi-Nejad (1981) published a literature review on government policies that stimulate technology transfer and spillover. One type of public policy is to enact a law to facilitate and control foreign investment such as the Mexican Law of 1972. These types of control have a range that goes from bureaucratic decisions to published criteria such as a limit on royalties paid. However, these rules, most of the

time, cannot achieve their purpose. For example, foreign firms can create other forms of payment in order to attain the same returns on technology. In some cases, the government can provide an exception if the technology is strongly required.

In many cases, public policies create a counterintuitive result due to many limitations. For example, local content policy aims to encourage foreign firms to establish local plants and utilize local resources, which provides benefits in lowering unemployment, increasing productivity, and lowering the product price. However, due to the limitations in the number and quality of potential suppliers, they face the problem of poor quality, scheduling delays, and higher costs (Contractor & Sagafi-Nejad, 1981).

The previous example illustrates the failure of a public policy. Therefore the question becomes what types of policies should be implemented. Stoneman and Diederer (1994) recommend public policies that can relieve the market imperfection problem. One way is to provide a channel for the technology recipient to gain essential information which can be done through a public subsidy on technology monitoring and technology consulting activities. Another way is to transfer the risk of imperfect information into government sectors such as a government R&D program. The third method to solve imperfect information is to set up standards. However, as discussed above, a rigid standard may not be able to achieve its goal.

Another public policy on technology spillover that has been studied extensively is the intellectual property rights. Intellectual Property Rights is the ability of the inventors to acquire the proprietary rights of that knowledge. Based on game theory, Sawada (2005) suggest that intellectual property rights prevent the technology spillover from foreign firms to domestic firms because foreign firms have an incentive to invest more on

spillover prevention while domestic firms are discouraged by that. Because of reduced technology spillover, local firms lose their competitiveness while an investment from foreign firms is likely to increase due to lowered competition.

Derwisch, Kopainsky, and Henson-Apollonio (2009) also study the effect of intellectual property rights on foreign investment and technology spillover in the agriculture industry by using a system dynamics approach. In their paper, the intellectual property rights are assumed to have a low or no spillover effect as suggested by Sawada (2005). The results indicate that if the technology gap between the foreign firms and local firms is large, domestic enterprises cannot survive without the technology spillover. However, if the technology gap is small, domestic firms can still compete with the foreign firms.

In summary, intellectual property rights prevent the technology spillover from foreign investment and are likely to provide benefits for foreign firms instead of local firms. There is another public policy that has been used in developing countries such as Japan, South Korea, and Taiwan and has resulted in the transformation from low-labor cost industries to technology-advanced industries and has provided the ability to compete face-to-face with developed countries. This policy is the R&D consortia policy.

R&D consortia policy

The R&D consortia policy is a public policy that stimulates the cooperation of the research and development activities of the firms in the same and related industries to innovate new and advanced technology which can change the competitiveness of the firms in the industries. The firms who join the R&D consortia can gain economies of

scale, share the risks of an innovation, set the standards for a new technology, and share complementary knowledge (Evan & Olk, 1990). The R&D consortia policy has been used in many countries and regions including the U.S., Europe, Japan, South Korea, and Taiwan. However, in most cases, the knowledge is transferred and spillovered within the domestic firms. How the R&D consortia policy affects the spillover from foreign firms to domestic firms has not been studied before. This knowledge gap is what this dissertation targets to do.

The R&D consortia, as defined above, contradicts the law of competition. How can two direct competitors conduct research together and come up with the same product offering to the same customers at the same time? If it happens, we would call it a cartel instead of competition. Therefore, only some types of technology and knowledge are appropriate for the R&D consortia. Ouchi and Bolton (1988) divide intellectual property into three types: private property, public property, and leaky property. Private property is the intellectual property that the private party legally has a full right to appropriate and transfer to others. Public property is the knowledge that inventors cannot appropriate even for a short period of time. Leaky property is the knowledge that inventors can appropriate for a short period of time.

Even though only the private property is worth conducting R&D, all types of knowledge are essential. Ouchi and Bolton (1988) recommended that the government sector, public-funded universities, and not-for-profit research organizations should produce public property. For leaky property, the incentive for inventors is less than the benefit they can get from the knowledge. However, with the collaboration of the parties

who will gain benefits from that knowledge such as the R&D consortia, the return for each party on researching on leaky property is positive.

Another challenge is how to manage and hold the collaboration when every member has an incentive to defect, as in the prisoner's dilemma situation. Arend (2005) suggests that all parties must signal the truthful expectation of the value of their joint work and provide the penalties for defecting in order to have the R&D collaboration. However, most R&D consortia do not have the same characteristics as the suggestion.

Determinants of knowledge transfer through R&D consortia

Even though the R&D consortia have been implemented for many years in many countries, the study on which factors create successful R&D consortia is very limited. Lin, Fang, Fang and Tsai (2009) focus on the effect of network embeddedness on technology transfer in the R&D consortia in Taiwan. They conducted a survey about government-supported R&D consortia in Taiwan. The results show that the technology transfer is better if the consortia are concentrated and have strong network ties, mutual trust, and shared norms. They also found that technology transfer between firms and institutions such as universities is better than with other firms because of there is no conflict of interest.

R&D consortia in Japan

Japan was the first country to implement an R&D consortia policy which resulted in the big jump in its competitive position in the global market. The most successful project was the very large scale integrated circuits (VLSI) project.

The R&D consortia in Japan were triggered by the Mining and Industrial Technological Research Association Law of 1961, issued by the Ministry of International Trade and Industry (MITI). This law encourages Japanese firms to set up an association to conduct joint research. Due to the collectivism culture in Japan, MITI focused on encouraging cooperative activities between the firms rather than being concerned about the anti-competitive situation (Aldrich & Sasaki, 1995).

The collaboration under the R&D consortia had actually started since 1956 under the term “Technology Research Association” which was modeled on a British World War I program that allowed small and medium sized firms who could not afford to run their own R&D to do collaborative research. However, the key goal for the British Research Association was to solve the technical problems instead of conducting R&D. The R&D consortia in Japan received funding from the government in either a research contract, in which the government owned the research and licensed to the association, or a forgivable loan, in which the association owned the result and repaid the money to the government if the project was successful.

One of the early associations was the VLSI Technology Research Association. The formation of VLSI technology research association was established from the introduction of the fourth generation of the semiconductor technology. The first generation was the vacuum tube, the second generation was the transistor, and the third generation was based on the integrated circuit. In 1975, the fourth generation which was based on the very large scale integrated circuits (VLSI) was just introduced. In order to advance from third generation into the fourth generation technology, new manufacturing processes and equipments were required. The companies had two choices: they could

conduct the research individually and come up with their own standards which would require unique equipment and tooling, or they could conduct the research together to create this new generic knowledge and set the same standards throughout the industry. It was clear that in order to compete with the U.S., the second choice was not just a choice, it was a necessity. Thus, five large semiconductor-computer companies, which were NEC, Toshiba, Hitachi, Fujitsu, and Mitsubishi, and the Electro-Technical Laboratory (ETL) of MITI joined together into the VLSI Technology Research Association.

The structure of the association was divided into two major units – the joint laboratory and the group laboratories. The joint laboratory consisted of 100 scientists; five from the ETL and the rest were from the other members. For the group laboratories, the association set up two groups which were the CDL group (Fujitsu, Hitachi, and Mitsubishi) and the NTIS group (NEC and Toshiba). The joint laboratory worked on generic and basic R&D projects for which the technology would equally benefit to all members. The group laboratories undertook the application research which was not appropriate for the joint lab. The later phases of product development and manufacturing were conducted exclusively by each company on its own.

The research was also categorized into “add vectors” projects and “principal vector” projects. “Add vectors” projects were the projects that each party could add equal value and which required the exchange of information or small joint experiments, but required no major capital expenditure. “Principal vector” projects, on the other hand, required major capital expenditures. “Add vector” projects included two or three scientists from each member while “principal vector” projects included eight to ten scientists from one company, two or three from one or two additional companies, and

none from the remaining companies. However, all intellectual property was immediately available for licensing to all members.

The VLSI association was a very successful project which can be measured by the achievement of the goal of developing process technology for 256K DRAM and the 1,000 gate logic, several industry standards were set up, 600 patents were awarded and 1,000 patent applications were filed. The benefits from the association were not limited only to the association members but it also spilled over the entire Japanese industry, which made the Japanese semiconductor and electronic appliance industry dominate the world market (Ouchi & Bolton, 1988).

The VLSI Technology Research Association was a very successful story, but it is also a rare case. Sakakibara (1997) studied the pattern and the benefits of R&D consortia in Japan by surveying the R&D managers of 237 R&D consortia in Japan. In general, there is no clear linkage between the competitiveness of the industry, measured by the export share, and the number of R&D consortia. The results from the survey show that the goal of R&D consortia has shifted from near commercialization stage to basic research due to a shift in the business focus from overseas competition to new business venturing. Along with the change in business focus, firms join the R&D consortia mainly to access complementary knowledge instead of sharing the R&D cost or catching up the overseas and non-participating competitors. Moreover, managers found that R&D consortia encourage more R&D spending for each firm, on average 38% increase in private R&D spending compared to the spending without R&D consortia. However, the surveys show that perceived benefits from R&D consortia are intangible such as

researcher training and increased awareness of R&D instead of tangible benefits such as valuable knowledge.

The perceived intangible benefits can be explained by the type of research. Because the research mainly focuses on basic knowledge, it is hard to translate this intellectual property into monetary value. Even if it could be justified, it would be a very small amount compared to the near commercialization research. Nevertheless, the R&D consortia policy is still widely used in many industries in Japan.

R&D consortia in the U.S.

R&D consortia in the U.S. started in 1984; 23 years after the Japanese government approved the Mining and Industrial Technological Research Association Law. Before 1984, firms in the U.S. could not conduct any joint research due to the Sherman Antitrust Act of 1890 which prevented U.S. firms to join efforts to pursue their collective interest (Evan & Olk, 1990). However, because of the success of the VLSI Technology Research Association which made the Japanese semiconductor and computer companies leapfrog American manufacturers and compete with U.S. products in the U.S. market and the announcement of the Japanese fifth-generation computer project, the U.S. microelectronics and computer technology industry sent a signal to the government. An initiation of R&D consortia was started by William Norris, the founder of Control Data Corporation. The representatives from twenty companies in microelectronics and computer technology had an initial meeting in February 1982. In December 1982, twelve founding companies established the Microelectronics and Computer Technology Corporation (MCC) as a Delaware corporation, and the U.S. Department of Justice

announced its intention not to challenge the collaborative formation. The research operation started in Austin, Texas, in September 1983. About 20 months later, the Department of Justice issued the final approval to the MCC within the framework of the National Cooperative Research Act of 1984. The MCC became the first major R&D consortia in the U.S. (Ouchi & Bolton, 1988).

The MCC had the goal of attacking technical problems while reducing the technical risks on seven streams which included Artificial Intelligence/Knowledge Based Systems, Database Management Systems, Human Interface Systems, Parallel Processing Architecture, VLSI Computer Aided Design, Semiconductor Packaging/Interconnect, and Expert Systems Software Technologies.

The organizational formation of the MCC was different from the VLSI association. The MCC hired technical staffs who were experienced, specialized, and elite scientists with significantly higher wages than the comparable positions in the leading U.S. industrial research laboratories. Scientists from member companies were not utilized because member companies were afraid of losing their qualified scientists. The budget came from the member companies. All members were required to fund at least one of the research streams for an initial period of three years in order to maintain continuity. Each member was able to access only the intellectual products from its funded programs. Information exchange between programs could occur only after the program managers executed arm's-length agreements.

All the research activities were conducted in the MCC-owned laboratories and performed only R&D necessary to produce a working prototype. The commercial-scale volume production was performed individually by each member. All intellectual property

rights belonged to the MCC, not the member companies. However, those firms which had funded a research project had immediate licensing rights. The board of directors was able to grant the licenses to other member firms. Three years after the first license, all the MCC members would have automatic access to all licenses and the board had the right to grant licenses to non-MCC member companies (Ouchi & Bolton, 1988).

Another case of R&D consortia is the Pump Research and Development Company (PRADCO). The story started when five companies which dominate the specialized high-volume pump industry submitted a research proposal for a major research contract with the Electric Power Research Institute (EPRI) but the contract was awarded to a Swiss company who entered a key product market for a first time. From this loss, U.S. firms realized that their technology was behind other competitors. In September 1983, three months after the contract announcement, these five companies initiated a collaborative R&D unit driven by the director of technology of each member. PRADCO applied to the Department of Justice for approval in October 1983 and received approval in June 1985.

PRADCO's organizational structure was also different from both MCC and VLSI project. PRADCO operated as a holding company without any laboratory or scientist. The research activities were conducted at each member's laboratories with its own scientists. The technical committee drawn from all of the partners was set up to supervise each project. Information sharing between each project was done through visits by research managers from one company to another, quarterly review meetings, and sharing of the working papers.

Besides these two R&D consortia, there were 135 more consortia registered as of August 1989. These consortia were formed in many industries such as agriculture, automotive, and biotechnology industries. At least twenty consortia consist of foreign members and some US companies also are members of foreign consortia.

The difference between R&D consortia in Japan and the U.S.

Even though the U.S. and Japan have put the R&D consortia policy into an action, there were significant differences in the operational patterns. Japanese research organizations were run as term projects with predetermined termination dates while in the U.S. collaboration worked as open entities. The research goals for Japanese R&D consortia were more focused than U.S. consortia ones. The relationship between members in the Japanese organization was less formal without extensive rules and detailed contract than in U.S. Moreover, U.S. consortia received the research budget from members while the Japanese research association acquired it from the government (Ouchi & Bolton, 1988).

The differences between Japanese R&D consortia and the U.S. R&D consortia did not occur only in the major projects as described above. Aldrich and Sasaki (1995) conducted a survey on the characteristics of R&D consortia which included 39 U.S. consortia and 54 Japanese consortia. Japanese consortia conducted their research by using only member facilities while U.S. consortia also use joint facilities such as universities. The research of U.S. consortia focuses on many stages of innovation whereas Japanese consortia are likely to concentrate on particular steps.

CHAPTER 3: RESEARCH QUESTION

This dissertation aims to understand the dynamics of productivity growth from technology spillover through FDI in the Southeast Asia region under the R&D consortia. This research targets to reproduce the historical data based on the relationship between each variable and apply it as a framework for policy analysis. Hypothesis testing, thus, is not applicable in this research. In order to reach this goal, the key question to be answered is:

Key Research Question: What is the effect of the R&D consortia policy on the productivity growth from technology spillover through FDI in Thailand, Malaysia, and Vietnam in the short term and the long term?

This key research question consists of three main parts. The first is the effect of the R&D consortia policy on productivity growth from technology spillover. To answer this part, we will study the effect of the R&D consortia policy on productivity growth from technology spillover in a country that was economically similar to the current economic situation in Thailand, Malaysia, and Vietnam at the time the R&D consortia policy was implemented such as Japan. The second part is the effect of the R&D consortia policy on productivity growth from technology spillover in Thailand, Malaysia, and Vietnam. These three countries are selected as a representative sample for the

Southeast Asia region because these three countries represent around 38% of the total inward FDI in the Southeast Asia region and around 88% if Singapore is excluded¹. The last part is to study the effect in both short term and long term. In order to understand the dynamics of technology spillover, the observation of the change over time of the effect of the R&D consortia policy on technology spillover is required. Both short term and long term scenarios are included in the study because in many cases short term benefits come with a long term pain (Sterman, 2000) such as that the high FDI growth rate will increase FDI in the short run but it makes FDI drops faster in the long run (Samii & Teekasap, 2009).

In order to answer the key research question, these sub questions need to be examined.

Sub Research Question 1: Which factors affect the productivity growth from technology spillover through FDI?

This sub question is covered in the literature review on productivity growth and determinants of technology spillover. Even though the factors that affect the technology spillover can be found from previous literature, most of the research uses regression techniques which show only the correlation between the factors and the technology spillover, not the causality. The correlation can only show the relationship between two variables within a fixed environment during a fixed period of time. However, the

¹ Calculated from the data of inward FDI for each country from 2001 to 2006 by IMF International Financial Statistics

correlation can be changed when the time period is changed or the environment is different. Thus, causality is more essential when simulating a situation that has not happened before such as implementing the R&D consortia policy in Thailand, Malaysia, and Vietnam. Therefore, the next sub question is:

Sub Research Question 2: What is the relationship between each factor that affects the productivity growth from technology spillover through FDI and the technology spillover?

To answer this question, we create a model based on the causality assumption and simulate the model. The causality assumption is accepted if the simulation can trace the actual change in each variable in the model. Actual data for Thailand, Malaysia, and Vietnam will be used to validate the causality, thus the effect of the R&D consortia policy on the technology spillover is not included in the model. The next question is how the R&D consortia policy affects the system.

Sub Research Question 3: What is the effect of the R&D consortia policy on each variable in the model?

The model which is developed to answer sub question 2 does not include the effect of the R&D consortia policy. The effect of the R&D consortia policy can be studied when the model is applied to a country that already implemented such a policy which is Japan. The causality assumption between the R&D consortia policy and the system is tested and will be accepted if the simulation can trace the actual change of

variables in the country that uses the R&D consortia policy during the period of policy implementation and after the policy is in effect.

After the effect of the R&D consortia policy on productivity growth from technology spillover through FDI is understood, we will implement the effect of the R&D consortia policy on the model of Thailand, Malaysia, and Vietnam which has been developed in sub question 2 to answer the key research question.

CHAPTER 4: RESEARCH METHODOLOGY

To study the dynamics of productivity growth from technology spillover through FDI under the R&D consortia policy, the system dynamics method is applied. System dynamics is a tool that has been developed from feedback control system and mathematical simulation (Sterman, 2000) to simulate the problem. System dynamics is appropriate for this research because it can show the dynamics of the systems based on the feedback and non-linear causality relationship between each variable with time delays. Examples of applications are the dynamics of cluster development (Teekasap, 2009) and the oil market (Samii & Teekasap, 2010). System dynamics has also been implemented in a policy analysis because it can show the potential effect of the policy when the policy has not yet been implemented such as the FDI policy effect on the employment in a host country (Samii & Teekasap, 2009)

Variables and data sources

This dissertation adopts the same measurement of productivity growth from technology spillover as most existing research (for example see Chuang and Lin (1999), Blomström and Sjöholm (1999) and Liu (2002)) which considers the change in productivity of local firms when foreign firms are in the country as the technology spillover. This dissertation also focuses on the macro level, instead of the industry or the firm level. Therefore, the production function is used to explain the change in

productivity (Cobb & Douglas, 1928; Solow, 1957). From the production function, production P is the function of Labor L , the Fixed Capital K , and time t . Thus, productivity p which is the production P per Labor L is the function of the capital per labor k which is the fixed capital K divide by Labor L and time t .

$$P = F(K, L; t) \quad (4)$$

$$p = A(t)f(k) \quad (5)$$

The Cobb-Douglas production function is applied in both micro- and macroeconomic situations and has been used widely by neoclassical economists (for example see Solow(1957)). However, there was a debate between the economists from the University of Cambridge which pointed out the drawback of the production function. The determination of capital is highly affected by the rate of profit or the gap between the price and the cost whereas the neoclassical assumption is based on the perfect competition in which the price is determined by the demand and supply. Besides, without any mathematical restrictions, the integration of the production function of each sector is not equal to the production function as a whole (Cohen & Harcourt, 2003; Harcourt, 1972; Stiglitz, 1974).

The measurement of a country's labor productivity is the GDP per employment which is also used by the OECD (OECD, 2008). The OECD measures productivity using GDP per hour work. However, due to the data limitation in obtaining the number of working hours, we assume that the average working hour per worker is constant and equal in all the countries in the sample. The amount of fixed capital can be calculated

from the gross fixed capital formation which is the change of fixed capital each year. Even though the data on actual fixed capital for each year is not available, we can assume an initial fixed capital in an earlier year and add up the gross fixed capital formation in the later year. After adding the gross fixed capital formation for each year and deducting the depreciation, the initial fixed capital does not significantly affect the current fixed capital (Samii, 1975). The amount of foreign investment depends on the economic situation of the country measured by the GDP. Another factor is the technology gap between foreign firms and local firms. Based on the definition of technology spillover stated before, technology gap can be referred to as the productivity gap. Therefore, the productivity gap which is the difference between GDP per employment between the home countries and host countries is used.

The trade openness of the country which is indicated by the percentage of exports and imports is also affected the amount of technology spillover (Meyer & Sinani, 2009; Wang, 1997). However, this dissertation focuses only on the technology spillover through FDI. Therefore, the effect of exports and imports is excluded from the model. The type of industry also affects the level of technology spillover. Hi-tech industries have lower technology spillover compared to low-tech industries (Sermcheep, 2006). However, because this dissertation focuses on Thailand, Malaysia, and Vietnam where the industries are labor intensive and low-technology, the type of industry is not considered.

FDI flows into a country mainly because of two reasons - market seeking and low labor cost seeking - which can be justified by the GDP per capita. When FDI comes into a country, not only the productivity increases, the income of workers in that country also increases which leads to higher GDP per capita. However, in the case of low labor cost

seeking which applies to Thailand, Malaysia, and Vietnam, an increase in workers' income discourages FDI in the long run. The jump in salary starts when the number of working population almost reaches the limit or ,in other words, when the unemployment pool dries out (Samii & Teekasap, 2009). Therefore, unemployment is also a factor that should be included in the model.

In sum, the list of variables that will be included in the model as endogenous variables (variables that affect and are affected by the system), exogenous variables (variables that affect the system but are not affected by the system) and the variables which are important but are not included in the model are shown in Table 1. The data of each variable can be obtained by the source as shown in Table 2 through the Thomson DataStream database.

Table 1: Model boundary

| Endogenous | Exogenous | Excluded |
|----------------------------------|---------------------------------|------------------------|
| GDP per employment | GDP per employment (Foreign) | Company-level factors |
| GDP | Time | Industry-level factors |
| Fixed gross capital formation | Non-Workforce | Export/Import |
| Foreign Direct Investment | | |
| Employment | | |
| Unemployment | | |

Table 2: Source of data

| Name | Measurement | Data source |
|----------------------------------|----------------------------------|--|
| Country Productivity | GDP/Employment | |
| | GDP | Economist Intelligence Unit |
| | Employment | IMF International Financial Statistics |
| GDP per Capita | GDP/Population | |
| | Population | IMF International Financial Statistics |
| FDI | FDI | IMF International Financial Statistics |
| Gross Fixed Capital Formation | Gross Fixed Capital Formation | IMF International Financial Statistics |
| Employment | Employment | IMF International Financial Statistics |
| Unemployment | Unemployment | IMF International Financial Statistics |

CHAPTER 5: TECHNOLOGY SPILLOVER MODEL

The technology spillover model is created to simulate the productivity growth from technology spillover through FDI. Factors which are included in the model consist of FDI, local investment, fixed capital, employment, and productivity. This chapter is organized into two sections: the conceptual model and the detailed model. The conceptual model section provides the framework of the model and aims for the readers to understand the conceptual interaction between each factor in order to have good idea on the structure underneath the simulation results which are shown in the following chapters. For readers who have a technical background or wish to see the details of the model, the detailed model section provides the complete model with detailed calculations. The complete lists of equation and symbol used in the model are in Appendix 1 and Appendix 3.

Conceptual model

The conceptual model shows the causal linkage framework between each factor in the system that explains the dynamic of productivity growth from technology spillover by the foreign direct investment. First, the productivity is calculated based on the production function with the effect of the productivity gap and the shift of production factors which is represented by time (Solow, 1957). We add the productivity gap to represent the technology gap between foreign firms and local firms to account for the effect of

transfer and technology spillover because the technology absorptive capability of local firms increases (Meyer & Sinani, 2009; Sawada, 2005). Increase in technology spillover will enhance the country's productivity as shown by Reinforce Loop 1 (R1): Increase Learning Capability in Figure 2.

An increase in country productivity will amplify real GDP and real GDP per capita. Larger GDP per capita will encourage foreign investment due to a better market opportunity. A portion of FDI will invest in fixed capital which enlarges the country's fixed capital (Krkoska, 2001) and also boosts the capital per employment. Based on the production function, larger capital per employment will drive up the country's productivity as shown by R2: Foreign Investment in Figure 2. The equation for R2 is:

$$Y = p * L \quad (8)$$

$$y = Y/N \quad (9)$$

$$FDI = f(y) \quad (10)$$

$$K_F = f(FDI) \quad (11)$$

$$K = K_F + K_L \quad (12)$$

$$k = K/L \quad (13)$$

Given Y is a real GDP; L is the number of labor or employment; y is the real GDP per capita; N is the population; FDI is the inward foreign direct investment; K_F is the fixed capital investment by foreign firms; K_L is the fixed capital investment by local firms; and K is total fixed capital.

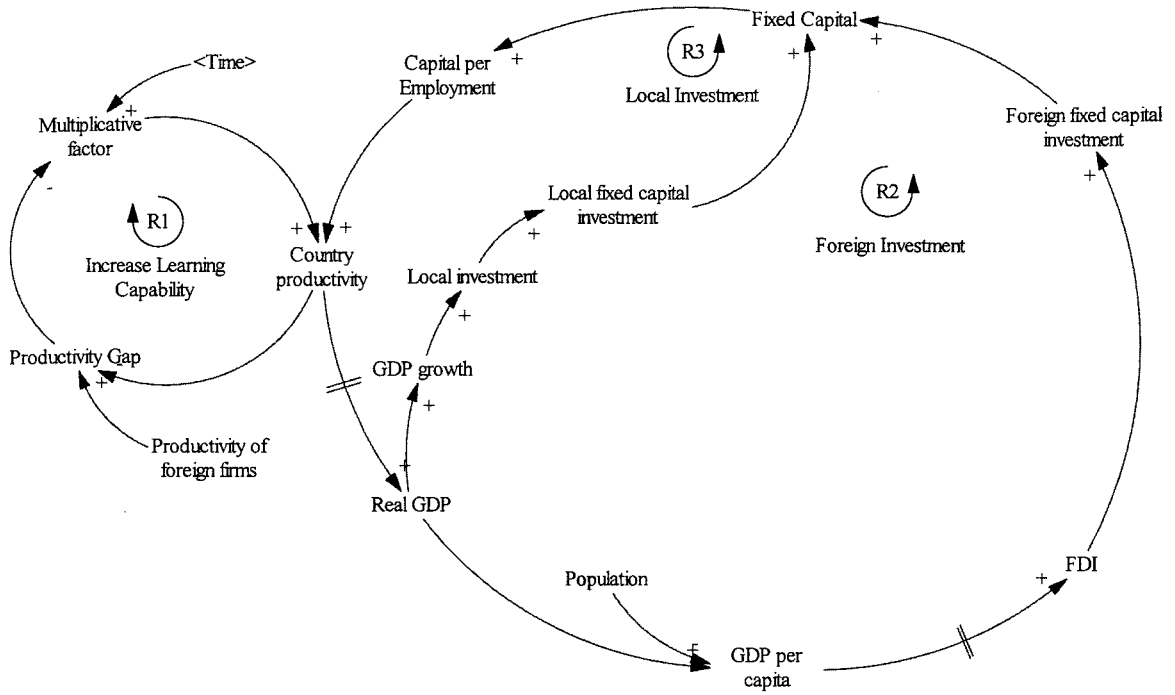


Figure 3: Conceptual model with local investment

Fixed capital investment does not come only from foreign companies. Local investment also contributes to an increase in fixed capital. Local investment growth is assumed to be at the same rate as the GDP growth. Local investment also acts as a positive feedback which enlarges the real GDP over a period of time as shown by R3: Local Investment in Figure 3. The equations for local investment are:

$$\%Y = (Y_t - Y_{t-1})/Y_{t-1} \quad (14)$$

$$\Delta D = D * \%Y \quad (15)$$

$$K_L = f(\Delta D) \quad (16)$$

Given %Y is the GDP growth; D is the local investment; and ΔD is the change in local investment.

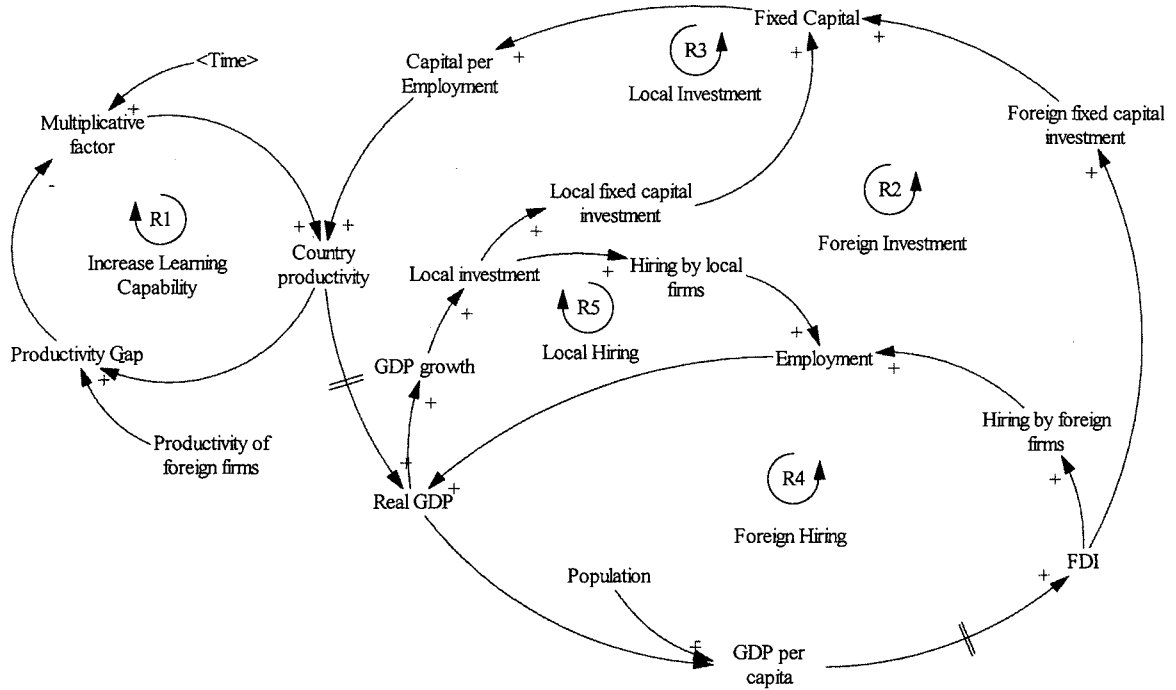


Figure 4: Conceptual model with hiring from foreign and local firms

Local and foreign investment does not only increase the fixed capital. They also increase the employment which drives up the real GDP as shown by R4: Foreign Hiring and R5: Local Hiring in Figure 4. The equations for employment by local and foreign firms are:

$$\Delta L = H_L + H_F \quad (17)$$

$$H_L = f(D) \quad (18)$$

$$H_F = f(FDI) \quad (19)$$

Given ΔL is the change in employment; H_L is the hiring rate by local firms; and H_F is the hiring rate by foreign firms.

Increase in real GDP will encourage foreign and local investment which in turn increases employment as discussed above. However, increase in employment will dilute the capital per employment which in turn reduces the real GDP as indicated by Balancing loop 1 (B1): Diluted Capital per Employment in Figure 5.

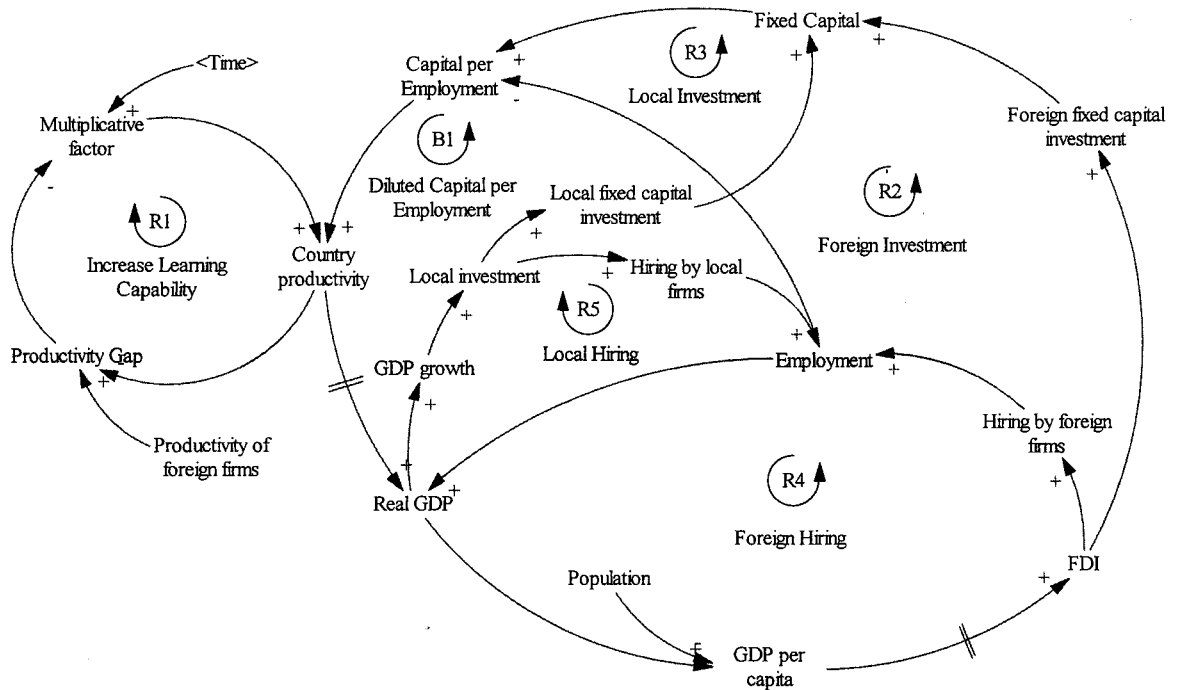


Figure 5: Full conceptual model

Detailed model

The model shown in the conceptual model section provides the basic framework of the model. However, in order to make a model which can simulate and trace the actual data, we need to add more detail into the model. The complete detailed model is shown in

Figure 6 and all the equations are listed in Appendix 1 with the list of symbol in Appendix 3.

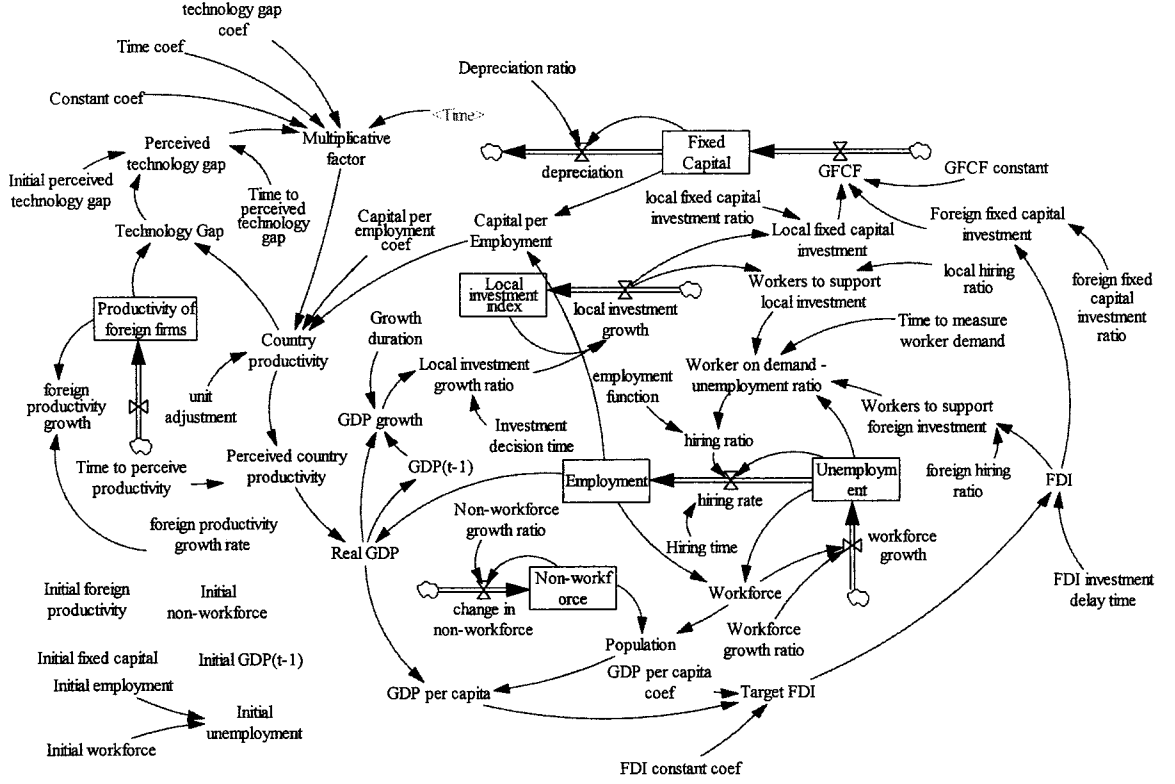


Figure 6: Full detailed model

First, we start with the productivity and production function as shown in Figure 7. The country productivity is calculated from a multiplicative factor and the capital per employment. Developed from the conceptual equation 5, the equation to calculate the productivity is:

$$p = \alpha k^{\beta k} \quad (20)$$

Given α is the multiplicative factor and β_k is the coefficient of capital per employment.

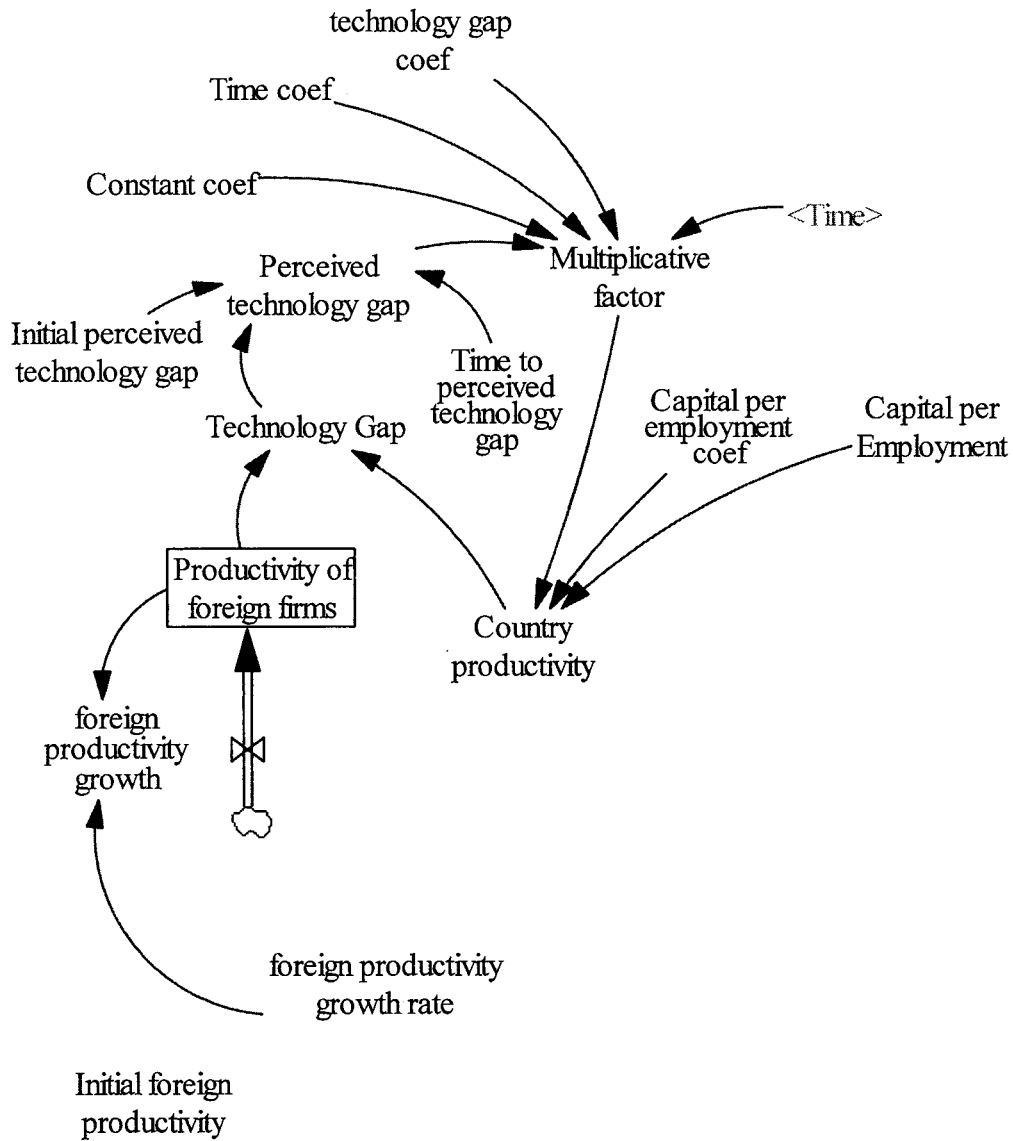


Figure 7: Detailed model with production function

The multiplicative factor α accounts for the effect of the technology gap Λ and the time-dependent technical shift on the productivity. We follow the equation used by Solow (1957) and Kohpaiboon (2006). Thus, the equation of the multiplicative factor is:

$$\alpha = \beta_{\alpha} e^{(\beta_t t + \beta_{\Lambda} \Lambda)} \quad (21)$$

Given β_{α} is the constant coefficient; β_t is the time coefficient; and β_{Λ} is the technology gap coefficient.

However, the technology gap used in the equation is the perceived technology gap, not the actual technology gap. The perceived value is the delayed value based on the publication duration and the people's perception which is anchored by the historical value (Sterman, 2000). In this case, the productivity data is delayed by the publication duration. Thus, the equation for multiplicative factor is:

$$\alpha = \beta_{\alpha} e^{(\beta_t t + \beta_{\Lambda} \bar{\Lambda})} \quad (22)$$

Given $\bar{\Lambda}$ is the perceived technological gap.

The perceived technology gap is the exponential smooth of the technology gap. People perceive the value of a variable based on the historical value. For example, we perceive a product is \$5 if the product's price has been set at \$5 for a period of time. If the price jumps to \$7, we still perceive that its price should be at \$5. The perception is changed to \$7 if the price jumps and stays at \$7 for a period of time. The perceived value is calculated from adding the current perceived value to the difference of the actual value

and perceived value divided by the duration people used in order to perceive the change of the value. Thus, the equation for the perceived technological gap is:

$$\bar{\Lambda} = \int \left(\frac{\Lambda - \bar{\Lambda}}{t_{\Lambda}} \right) dt \quad (23)$$

Given t_{Λ} is the duration to perceive the technology gap.

The technology gap is the difference between productivity of foreign firms and the country productivity. However, the productivity of foreign firms is not constant but increases over time. From the empirical data the productivity of a foreign firm has an exponential growth with the foreign productivity growth rate. Therefore, the equations are:

$$p_F(t+1) = p_F(t) * (1 + g_{pF}) \quad (24)$$

Given g_{pF} is the growth rate of foreign productivity.

After we have the production function, we expand the model to include the foreign investment and the fixed capital as shown in Figure 8. Starting with the country productivity, it has a time delay due to the data collection duration, publication duration, and the time that people take to perceive the data. Perceived country productivity is created to represent the delayed country productivity data under the exponential smoothing method. The equation for perceived country productivity is:

$$\bar{p} = \int \left(\frac{p - \bar{p}}{t_p} \right) dt \quad (25)$$

Given t_p is the duration to perceive the country productivity.

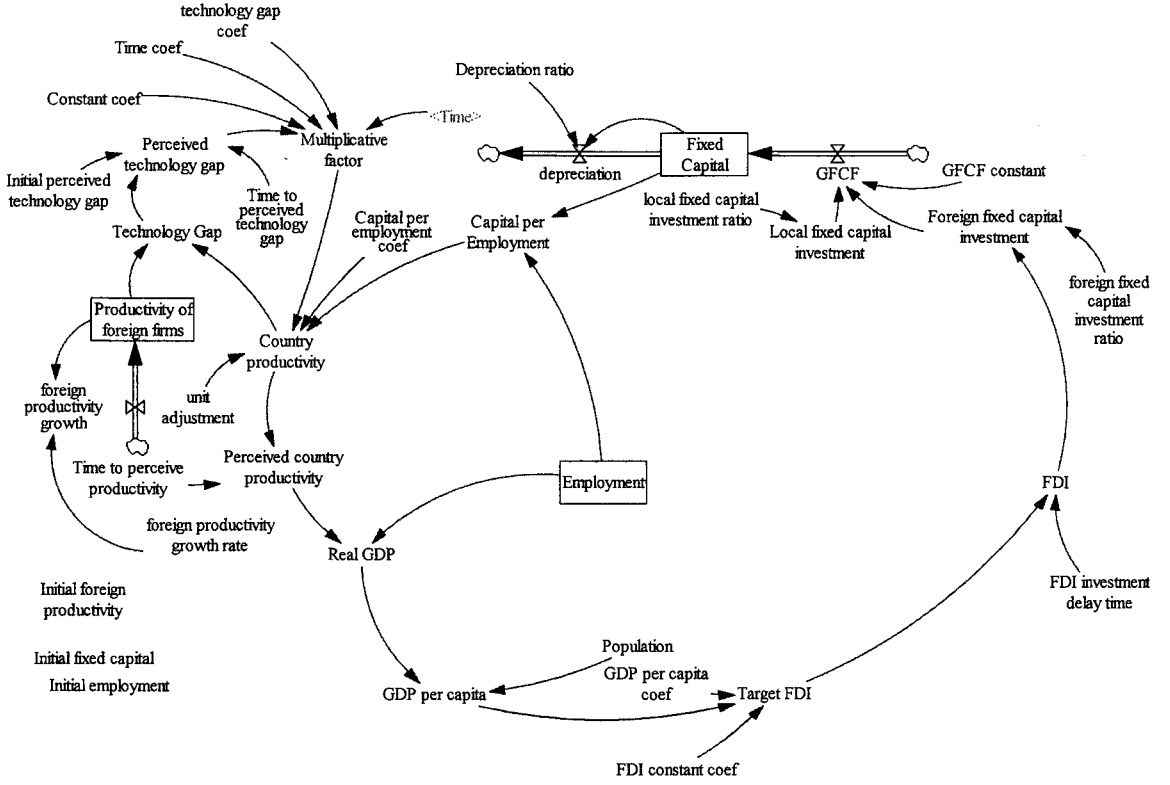


Figure 8: Detailed model with the foreign investment

Based on the definition of productivity as the real GDP per employment (OECD, 2008), the real GDP can be calculated from the multiplication of country productivity by the number of employment. We use the equation 8 and 9 which are:

$$Y = p * L \quad (8)$$

$$y = Y/N \quad (9)$$

Foreign investment mainly aims for either low labor costs or market opportunities. For both types of FDI the objective can be justified by real GDP per capita. We assume that FDI and real GDP per capita have a linear relationship and thus we use the linear regression model to calculate the FDI from the GDP per capita. However, FDI also has a time delay because firms are usually conservative when making an investment in an unfamiliar environment (Sterman, 2000). Therefore, we call it Target FDI to represent the level that FDI should be at without a decision delay and FDI is the target FDI after accounting for a FDI investment decision delay time. We use a 3-step exponential delay method as recommended for an investment decision making (Sterman, 2000). Therefore, the equations are:

$$\widehat{FDI} = \beta_{FDI} + \beta_y y \quad (26)$$

$$FDI = \int [(\Psi_2 - FDI)/DL] dt \quad (27)$$

$$\Psi_2 = \int [(\Psi_1 - \Psi_2)/DL] dt \quad (28)$$

$$\Psi_1 = \int [(\widehat{FDI} - \Psi_1)/DL] dt \quad (29)$$

$$DL = t_{FDI}/3 \quad (30)$$

Given \widehat{FDI} is the target FDI; β_{FDI} is the constant coefficient; β_y is the coefficient for GDP per capita; t_{FDI} is the FDI delay time.

Foreign investment will invest a portion of the total investment in a fixed asset. An annual increase in fixed capital is called Gross Fixed Capital Formation (GFCF). We assume that the GFCF that comes from foreign investment and the local investment have

a linear relationship. Thus, we use the linear regression model to calculate the relationship between GFCF and FDI. The equations are:

$$\sigma = \beta_{\sigma} + \sigma_F + \sigma_L \quad (31)$$

$$\sigma_F = FDI * \gamma_F \quad (32)$$

Given σ is the GFCF; β_{σ} is the constant coefficient; σ_F is the foreign fixed capital investment; σ_L is the local fixed capital investment; γ_F is the foreign fixed capital investment ratio.

The accumulative fixed capital is the integration of GFCF every year after deducting the depreciation. We assume a fixed depreciation ratio. Therefore, the equation for fixed capital is:

$$K(t+1) = K(t) + \sigma - K(t) * \delta \quad (33)$$

Given δ is the depreciation ratio.

Fixed capital is used to calculate the capital per employment, which is used in the production function. We use equation 13 to calculate the capital per employment.

$$k = K/L \quad (13)$$

Figure 9 shows the detailed model with local investment. Local investment is assumed to grow at the same rate as the GDP growth rate. However, because we do not

have the data on local investment, the local investment index is set to represent the local investment with the value of an initial year as 100. First, we use the equation 14 to calculate the GDP growth rate which is:

$$\%Y = (Y_t - Y_{t-1})/Y_{t-1} \quad (14)$$

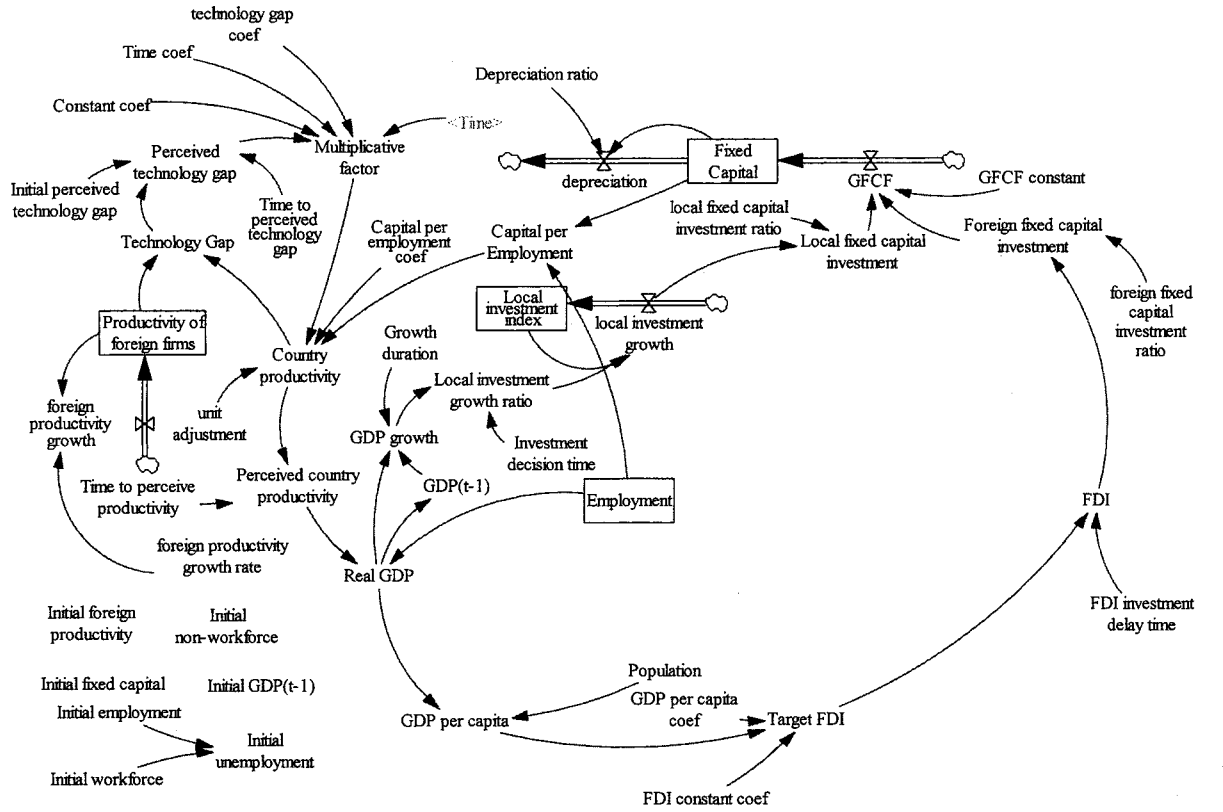


Figure 9: Detailed model with local investment

The local investment is delayed due to the investment decision process. Therefore, we create the Local investment growth ratio as a delayed variable of the GDP growth using an exponential smoothing function. A portion of the local investment

contributes to the fixed capital which in turn increases the productivity of the country.

The equations for local investment are:

$$\%D = \int [(\%Y - \%D)/t_D] dt \quad (34)$$

$$D(t+1) = D(t) * (1 + \%D) \quad (35)$$

$$\sigma_L = D * \gamma_L \quad (36)$$

Given $\%D$ is the local investment growth ratio; t_D is the duration to make a local investment decision; γ_L is the local fixed capital investment ratio.

The last part of the model is the hiring rate from local and foreign firms as shown in Figure 10. New investment from both local and foreign firms will hire additional workers. However, the number of workers to be hired is limited by the number of unemployed in the country. In this model, we create “Worker on demand – unemployment ratio” to represent the ratio between demand and supply of additional workers. The equations are:

$$H_L = \Delta D * \lambda_L \quad (37)$$

$$H_F = FDI * \lambda_F \quad (38)$$

$$\Xi = [(H_L + H_F) * t_L]/U \quad (39)$$

Given λ_L is the local hiring ratio; λ_F is the foreign hiring ratio; Ξ is the ratio between the demand workers and the unemployment; t_L is the unemployment coverage duration; U is the unemployment

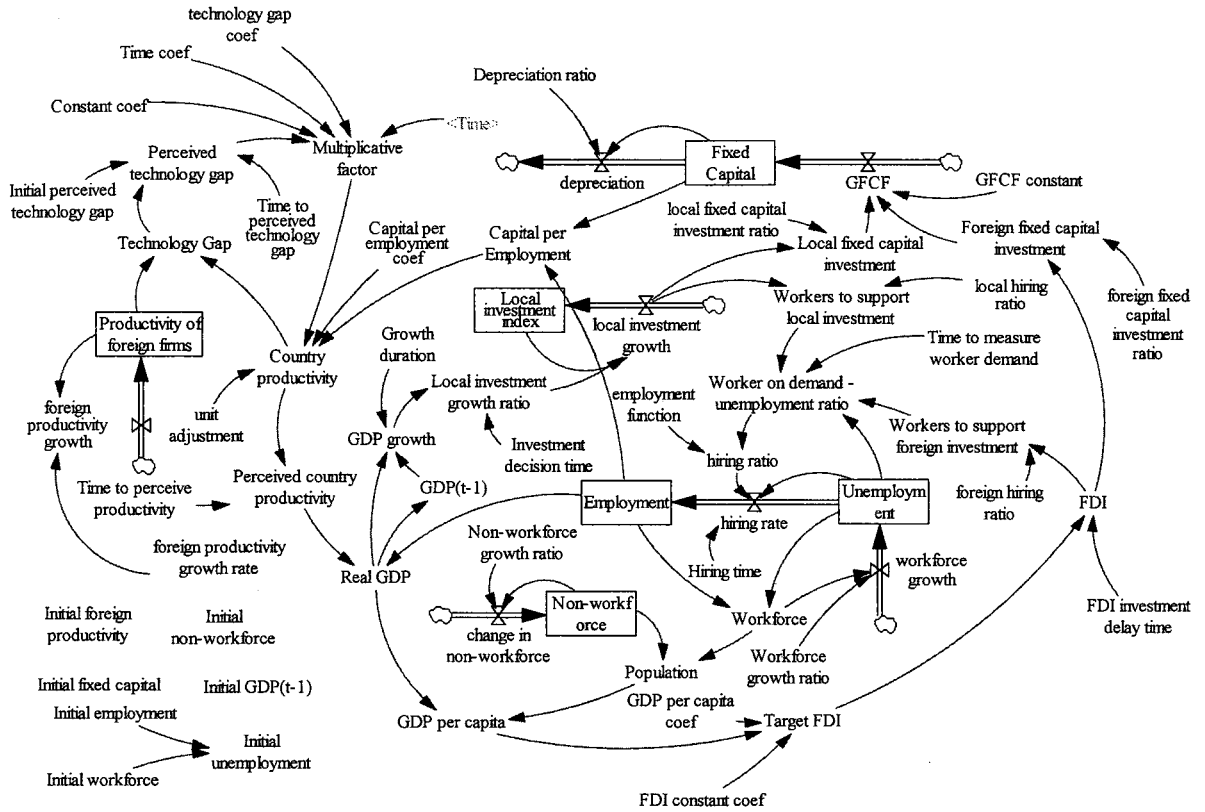


Figure 10: Detailed model with local and foreign hiring

In general, the worker demand – unemployment ratio is equal to the percentage of unemployment that is hired if the work demand-unemployment ratio is between 0 and 1. However, if the demand of additional workers almost reaches the number of unemployment, the hiring ratio is lower than the worker demand-supply ratio because there is a possibility that the qualification of unemployed may be lower than the firms' requirement. When the worker demand-supply ratio is almost zero, the hiring ratio is higher than the demand-supply ratio because there are some industries that still need additional workers while other industries do not. The employment function is the

function that indicates the hiring ratio from worker demand – unemployment ratio and it is shown in Figure 11. Therefore, the equations for the hiring rate are:

$$H = U * f(\Xi) / t_H \quad (40)$$

$$L(t+1) = L(t) + H \quad (41)$$

Given H is the hiring rate; t_H is the hiring duration.

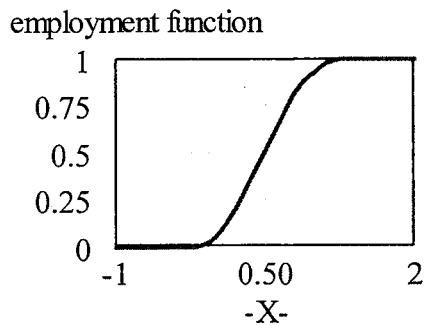


Figure 11: The relationship for the employment function

The workforce grows continuously. The new workforce starts from being unemployed and are hired later. The number of workforce plus number of non-workforce is the number of total population.

$$W = L + U \quad (42)$$

$$U(t+1) = U(t) - H(t) + w(t) \quad (43)$$

$$w = W * g_w \quad (44)$$

$$N = W + O \quad (45)$$

$$O(t+1) = O(t) * (1+g_O) \quad (46)$$

Given W is the number of workforce; w is the workforce growth rate; g_w is the workforce growth ratio; O is the number of non-workforce; g_O is the growth ratio of non-workforce

CHAPTER 6: MODEL VALIDATION

Model validation is required when creating any model to check the correctness, accuracy, and robustness of the model in order to ensure that the simulation results from the model are reliable. Many methods have been recommended to check the reliability of the model (Forrester & Senge, 1980; Sterman, 2000). However, in this paper, we validate the model by using the dimension consistency method, the behavior reproduction test, the family member method, the extreme condition test, and the model forecastability method.

Dimension consistency method

The dimension consistency method tests the unit consistency of each variable in the model to ensure that the units of all the key-in variables and all the calculated ones are consistent throughout the entire model and the model does not add apples with oranges and comes out with banana. Besides, the unit check is also useful in checking variables with strange combinations of units which do not represent the actual situation such as Dollar/(Person²*Year).

This model has been checked for dimension accuracy by using the Vensim's built-in function for dimension consistency check. This function tests the unit uniformity by examining every equation in the model. The test result indicates that the model has unit consistency. The list of units and equations of all the variables are shown in Appendix 1.

Behavior reproduction test

The behavior reproduction test is used to determine how well the model can reproduce the actual change of each variable. The test is conducted by comparing the simulation data with the empirical data using statistical tools such as the R^2 and the Mean Absolute Percentage Error (MAPE). The model can reproduce the behavior well if the R^2 is high and the MAPE is low.

This research has conducted the behavior reproduction test by replicating the change of each variable of Thailand, Malaysia, Vietnam, and Japan. The details of the test and the test results are shown in Chapter 7 and Chapter 8. In general, the results show that the model can significantly reproduce the change of variables related to FDI and productivity growth from technology spillover.

Family member test

The family member test assesses the ability of the model to reproduce the result in the other systems which are similar to the system the model was built for. This test can check if all key variables are included in the model.

The model in this research has been tested for the family member test by applying the model to Thailand, Malaysia, and Vietnam. These three countries are similar in terms of the relationship between FDI and productivity growth from technology spillover. The results, described in detail in Chapter 7, show that the model can considerably replicate the behavior of FDI and productivity growth from technology spillover in Thailand, Malaysia, and Vietnam.

Extreme condition test

The extreme condition test if the model can handle an extreme situation. An extreme situation is a situation that rarely happens but the result of that situation could be predicted theoretically.

In this research, we test the robustness of the model by assuming that the FDI flow into the country is stopped. This situation is not a usual situation but happened to Malaysia during the 1997 Asian Financial Crisis. In 1998, Malaysia imposed a strong capital flow control to cope with the Asian Financial crisis which almost eliminated the inflow of investment. However, the Malaysian economy did not collapse from the lack of foreign investment but still grew due to the domestic drives. However, theoretically, even though the economy was still growing without FDI, it would have grown at a slower rate because of the limiting capital. Therefore, we expect to see the slower growth of GDP when FDI is blocked.

We use Thailand's model (the parameters of the model is explained in Chapter 7) as the study case. We assume that the inflow of FDI has been stopped since 1990. However, the foreign firms which had already invested in the country are not affected by the loss of FDI.

Figure 12 compares the real GDP of Thailand if the inflow of FDI had been stopped since 1990 with the base case which foreign investment volume did not change. The simulation result presents that the real GDP when the inflow of FDI is blocked is significantly lower than the base case which follows the theoretical assumption. Therefore, the model passes the extreme condition test.

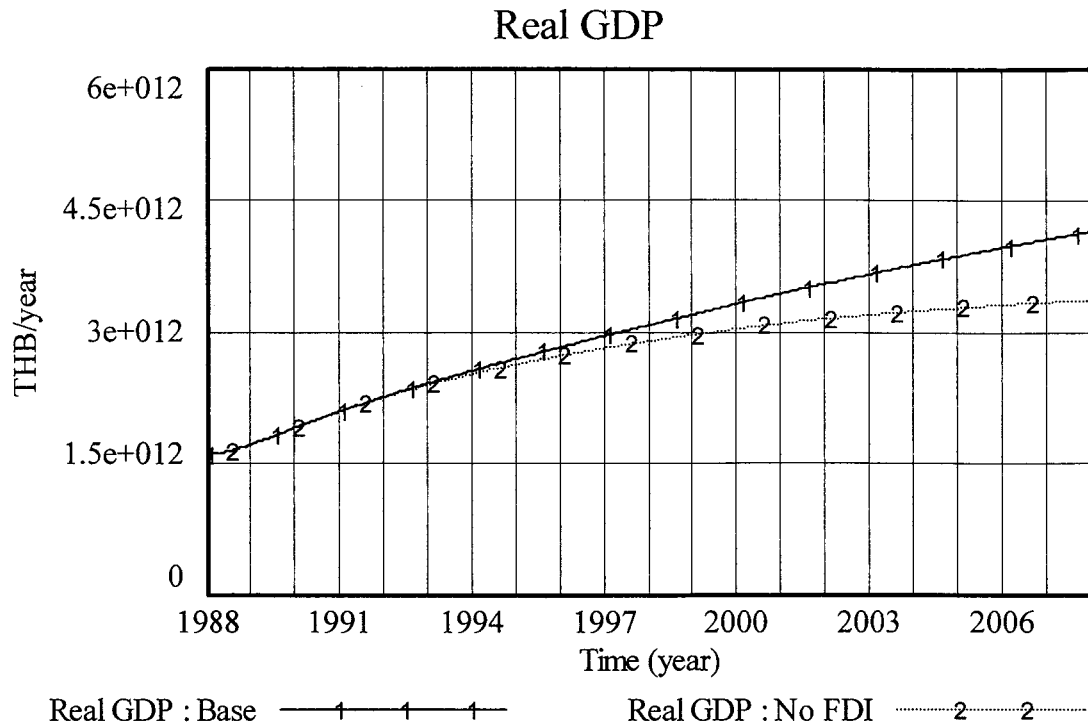


Figure 12: Result of the surprise behavior test

Model forecastability test

The model forecastability test examines if the model can determine the data in the next time period based on the historical data. The model forecastability test is conducted by removing the data of the last year and then simulating the model based on the coefficients which is obtained from the existing data. The comparison between empirical data and simulation is compared using statistical method.

We use Thailand as the case study for the model forecastability test. We use data from 1988 to 2008 in the model. To test for forecastability, we simulate the model by using the coefficients determined from the data from 1988 to 2000 to forecast the data of 2001. Then we simulate the model using the coefficients determined from the data from

1988 to 2001 to forecast the data of 2002. We continue the process until the data of 2008 is forecasted. In this section the explanation is focused on the details of this test. The detailed calculation of the coefficient determination is explained in Chapter 7.

The result of the model forecastability test on the country productivity, GDP per capita, and FDI is shown in Table 3. From the results, the simulation can trace the historical data of the country's productivity, GDP per capita, and FDI. Therefore, the model can significantly forecast the value one year ahead.

Table 3: The results of the model forecastability test

| | R² | MAPE |
|----------------|----------------------|-------------|
| Productivity | 0.7748 | 4.65% |
| GDP per capita | 0.7822 | 4.23% |
| FDI | 0.5277 | 19.15% |

Note: MAPE = Mean Absolute Percentage Error

In summary, the developed model has been tested using the dimension consistency method, the behavior reproduction test, the family member test, the extreme condition method, and the forecastability test. The test results indicate that the model is moderately robust. Therefore, this model is used for the study of productivity growth from technology spillover through FDI under the R&D consortia policy in the Southeast Asia region in the following chapters.

CHAPTER 7: MODEL PARAMETERIZATION

The model described in Chapter 5 is used to replicate the actual data of Thailand, Malaysia, and Vietnam in order to validate the model and provide the foundation structure to analyze the R&D consortia policy. The raw data for Thailand, Malaysia, and Vietnam is listed in Appendix 2. The model is simulated using local currencies because the real GDP and GFCF data are only available in the local currencies. In addition, due to the availability of the empirical data, the simulation period for Thailand and Malaysia is from 1988 to 2008 and for Vietnam is from 1996 to 2008. The required parameters to simulate the model are the coefficient for workforce, non-workforce, productivity of foreign firm, country productivity, FDI, GFCF, and hiring rate.

Thailand

Thailand has had a significant growth of inward FDI, productivity and GDP per capita since 1987, except for the Asian Financial Crisis period, as shown in Figure 13 and Figure 14. In this section, we determine the parameters used in the model to replicate the growth of Thailand's FDI, productivity, and GDP per capita based on the empirical data.



Figure 13: FDI and productivity of Thailand during 1987 – 2008

Source: IMF International Financial Statistics and Economist Intelligence Unit

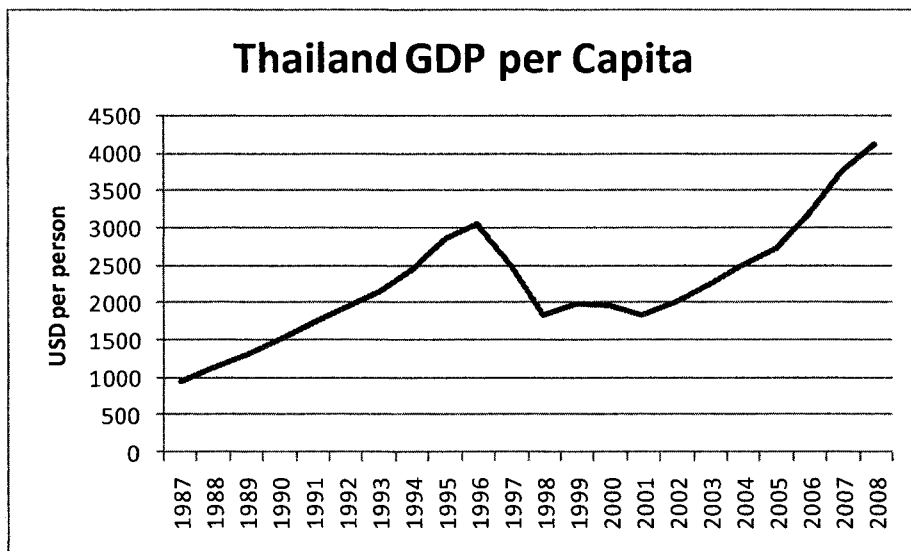


Figure 14: GDP per capita of Thailand during 1987 - 2008

Source: Economist Intelligence Unit

The first group of variables to be determined is the workforce, non-workforce, and foreign productivity. These variables grow exponentially without any effect from

other factors. Therefore, the required coefficient for these variables is the initial value in 1988 which is the start year and the growth rate. The general equations used to determine the coefficients are:

$$Y = Y_0(1+g)^t \quad (47)$$

$$\ln(Y) = \ln(Y_0) + t \cdot \ln(1+g) \quad (48)$$

Given Y_0 is the initial value at the starting year, g is the growth rate, and t is time.

The workforce is calculated from adding the number of employment and unemployment. The difference between the population and the workforce is the number of non-workforce. In terms of foreign productivity, Japan has the highest share of foreign investment by country in Thailand². Therefore, the productivity of Japan, which is calculated from the real GDP per employment, is used to represent the foreign productivity. Because the model is simulated under the Thai Baht currency, the productivity of Japan was converted from Japanese Yen (JPY) to Thai Baht (THB). The coefficient for each variable is shown in Table 4.

The next step is to calculate the coefficient for country productivity. Country productivity is calculated from capital per employment, time, and the technology gap. A regression model used to determine the coefficient is developed from equation 6 as shown below.

$$\ln(\text{Productivity}) = b_0 + b_1 \ln(\text{Capital per employment}) + b_2 \text{time} + b_3 \text{techgap} \quad (49)$$

² The Board of Investment of Thailand

Table 4: Coefficient for workforce, non-workforce, and foreign productivity for Thailand

| | Workforce | Non-workforce | Japan productivity |
|-------|------------------|----------------------|---------------------------|
| Y_0 | 30,571,000 | 24,616,000 | 1,240,000 |
| g | 0.00854 | 0.0114 | 0.0496 |
| R^2 | 0.9099 | 0.9323 | 0.8602 |

There is a possibility that the technology gap is a delayed variable because the technology transfer and spillover require a significant period of time to happen. Therefore, a model with a 1-year lag technology gap is also studied and compared with the equation without a time lag. The results shown in Table 5 indicate that the model with no time lag in the technology gap represents the actual data better. Thus, the coefficient of the model without time lag is used in the model. This result can be explained based on the delay of the technology gap data. The published technology gap data is the delay of actual data due to the data collection and publication process. The time delay of the data availability reduces the effect of the time shift between the technology gap and the productivity.

The next coefficient to be studied is the coefficient for FDI. The level of FDI is determined by the country's personal wealth which is indicated by the GDP per capita. We assume that the relationship between FDI and GDP per capita is linear. Therefore, the equation is:

$$FDI = b_0 + b_1 \text{GDP per capita} \quad (50)$$

Table 5: Coefficient for productivity for Thailand

| | Techgap | Techgap(-1) |
|----------------------------|----------------------------|------------------------|
| Constant | -27.86*** | -22.81* |
| ln(Capital per employment) | 0.3346*** | 0.2940*** |
| Time | 0.01766*** | 0.01533** |
| Technology gap | -8.45×10^{-8} *** | N/A |
| Technology gap (-1) | N/A | -3.17×10^{-8} |
| R ² | 0.9751 | 0.9583 |
| Adjusted R ² | 0.9707 | 0.9505 |

Remark: *** p < 0.01; **p < 0.05; *p < 0.1

However, an investment is likely to have a significant time delay because firms are likely to be conservative when making an investment decision in an unfamiliar environment (Sterman, 2000). Therefore, we compare the results from the model with no time lag, 1-year time lag, and 2-year time lag as shown in Table 6. The results indicate that the model with the 2-year lag has the highest adjusted R². Therefore, the coefficient of the 2-year time lag model is used.

The next step is to determine the coefficient for GFCF and employment hiring. Both variables share the same independent variables: FDI and change in local investment (LIC) as presented in equation 51 and 52.

Table 6: Coefficient for FDI for Thailand

| | No time lag | 1-year lag | 2-year lag |
|-------------------------|----------------------------|----------------------------|----------------------------|
| Constant | $-2.939 \times 10^{11}***$ | $-3.246 \times 10^{11}***$ | $-3.658 \times 10^{11}***$ |
| GDP per capita | $9.569 \times 10^6***$ | N/A | N/A |
| GDP per capita (-1) | N/A | $1.054 \times 10^7***$ | N/A |
| GDP per capita (-2) | N/A | N/A | $1.177 \times 10^7***$ |
| R ² | 0.6227 | 0.6894 | 0.7630 |
| Adjusted R ² | 0.6028 | 0.6722 | 0.7491 |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

$$\text{GFCF} = b_0 + b_1\text{FDI} + b_2\text{LIC} \quad (51)$$

$$\text{Hiring} = b_0 + b_1\text{FDI} + b_2\text{LIC} \quad (52)$$

We also study the model with a time delay in LIC because there is a significant time delay in the investment decision process. However, we do not study the delay of FDI because the FDI data comes from an international source which incurs a significant time delay from the actual FDI. The results for GFCF and employment hiring are shown in Table 7 and Table 8 consecutively. The 1-year lag model for GFCF is the best fit; however the model with no time lag is the best fit for Employment hiring. The reason why the no time lag model has the highest R² is that most foreign investment in Thailand is in labor intensive industries which do not require significant time to train workers. Therefore, the firms do not have to hire the workers in advance before investing. Therefore, the coefficients from these two models are used.

Table 7: Coefficient for GFCF for Thailand

| | No time lag | 1-year lag | 2-year lag |
|-------------------------|---------------------------|---------------------------|---------------------------|
| Constant | $7.685 \times 10^{11***}$ | $7.272 \times 10^{11***}$ | $9.684 \times 10^{11***}$ |
| FDI | $2.864***$ | $2.633***$ | $1.957**$ |
| LIC | $2.262 \times 10^{10*}$ | N/A | N/A |
| LIC(-1) | N/A | $3.402 \times 10^{10***}$ | N/A |
| LIC(-2) | N/A | N/A | $2.364 \times 10^{10**}$ |
| R ² | 0.4654 | 0.6352 | 0.4497 |
| Adjusted R ² | 0.4025 | 0.5896 | 0.3764 |

Remark: *** p < 0.01; **p < 0.05; *p < 0.1

Table 8: Coefficient for employment hiring for Thailand

| | No time lag | 1-year lag | 2-year lag |
|-------------------------|-----------------------|-----------------------|------------------------|
| Constant | -2.961×10^3 | 8.680×10^4 | 4.284×10^5 |
| FDI | 2.35×10^{-7} | 2.30×10^{-7} | -1.07×10^{-7} |
| LIC | $3.767 \times 10^4**$ | N/A | N/A |
| LIC(-1) | N/A | 2.245×10^4 | N/A |
| LIC(-2) | N/A | N/A | -7.660×10^3 |
| R ² | 0.2221 | 0.0875 | 0.0110 |
| Adjusted R ² | 0.1306 | -0.0266 | -0.1208 |

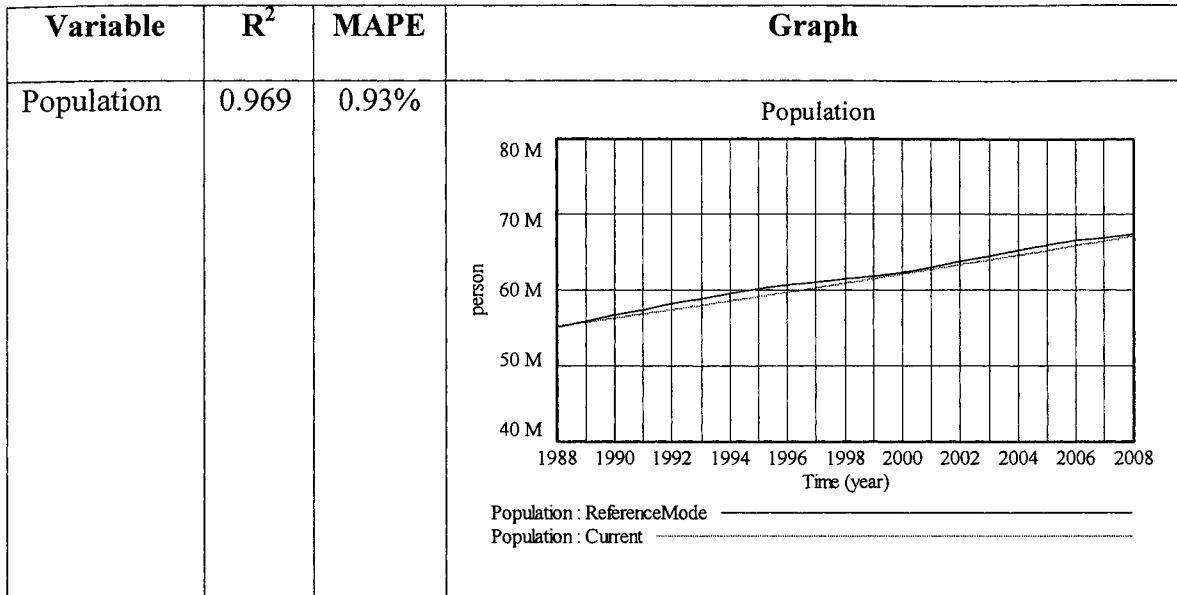
Remark: *** p < 0.01; **p < 0.05; *p < 0.1

The overall regression results support the assumption that there is a significant delay in the availability of the technology gap data and also in the investment decision making process. However, the decision making duration for foreign investment is longer than the decision period of the local investment because foreign investment endures higher risk stemming from the unfamiliar business environment. When the parameters are included into the model, the simulation can reproduce the change of actual data in various variables as shown in Table 9.

Table 9: Comparison between empirical data and simulation for Thailand

| Variable | R ² | MAPE | Graph |
|----------------------|----------------|--------|---|
| Foreign productivity | 0.757 | 10.15% | <p>Productivity of foreign firms</p> <p>THB/(person*year)</p> <p>Time (year)</p> <p>Productivity of foreign firms : ReferenceMode</p> <p>Productivity of foreign firms : Current</p> |
| Country productivity | 0.942 | 3.88% | <p>Perceived country productivity</p> <p>THB/(person*year)</p> <p>Time (year)</p> <p>Perceived country productivity : ReferenceMode</p> <p>Perceived country productivity : Current</p> |
| Real GDP | 0.932 | 5.36% | <p>Real GDP</p> <p>THB/year</p> <p>Time (year)</p> <p>Real GDP : ReferenceMode</p> <p>Real GDP : Current</p> |

| Variable | R ² | MAPE | Graph |
|---------------|----------------|--------|---|
| FDI | 0.758 | 52.05% | <p style="text-align: center;">FDI</p> <p style="text-align: center;">FDI : ReferenceMode FDI : Current</p> |
| Fixed capital | 0.924 | 11.18% | <p style="text-align: center;">Fixed Capital</p> <p style="text-align: center;">Fixed Capital : ReferenceMode Fixed Capital : Current</p> |
| Employment | 0.851 | 1.72% | <p style="text-align: center;">Employment</p> <p style="text-align: center;">Employment : ReferenceMode Employment : Current</p> |



Note: MAPE = Mean Absolute Percentage Error

Malaysia

Malaysia also has had a continuous high growth of GDP, GDP per capita, FDI, and productivity since 1987 except for the Asian Crisis period as shown in Figure 15 and Figure 16. Inward FDI into Malaysia significantly dropped during the Asian crisis due to strict financial controls and the denial to accept the IMF package. However, the level of FDI jumped back after the crisis period which indicates the strong economic foundation of Malaysia. In this section, we analyze the empirical data of Malaysia to determine the coefficient to be used in the model in order to simulate the FDI, GDP, and productivity of Malaysia.

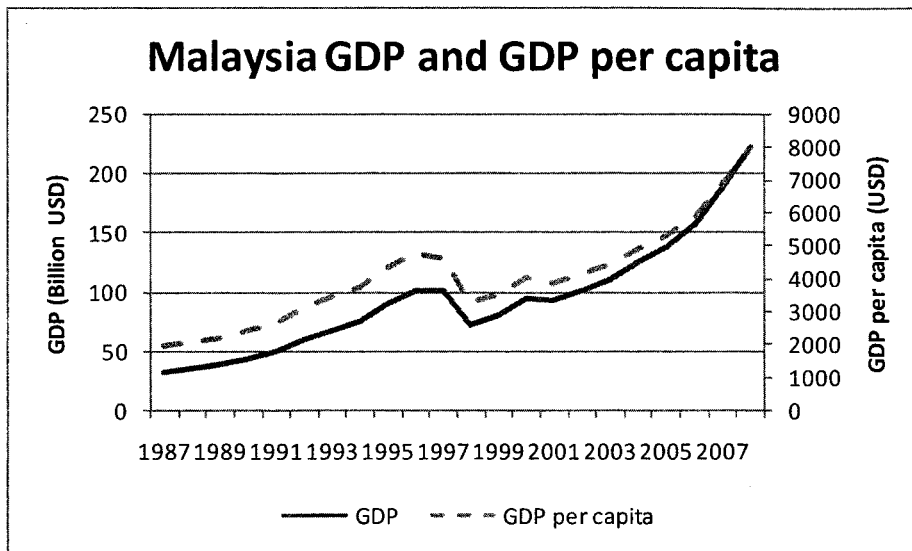


Figure 15: GDP and GDP per capita of Malaysia during 1987 – 2008

Source: Economist Intelligence Unit

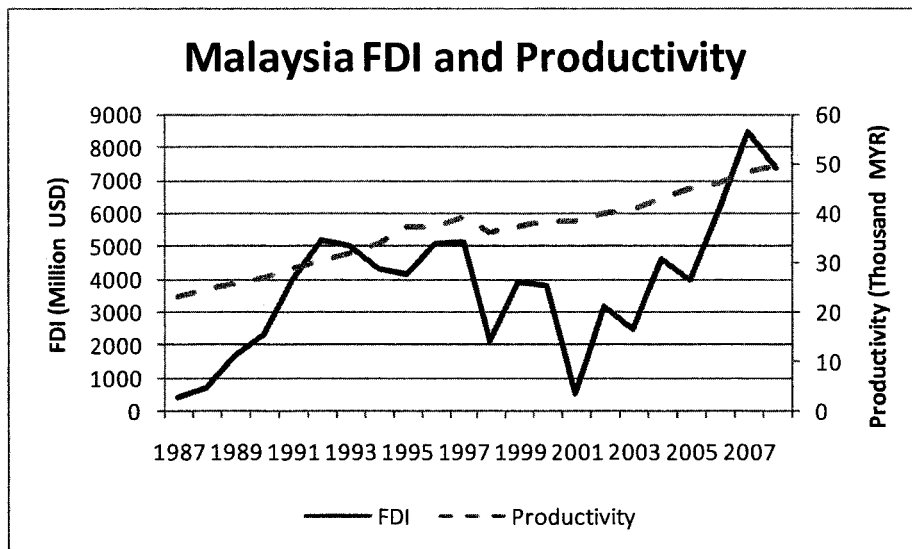


Figure 16: Inward FDI and productivity of Malaysia during 1987 – 2008

Source: IMF International Financial Statistics and Economist Intelligence Unit

The coefficient for Malaysia is determined using the same method as for

Thailand. The workforce, non-workforce, and foreign productivity are assumed to have an exponential growth and the coefficients for these three variables are shown in Table 10. Japan's productivity is used to represent the foreign productivity because Japan has the highest share of total investment in Malaysia³.

Table 10: Coefficient for workforce, non-workforce, and foreign productivity for Malaysia

| | Workforce | Non-workforce | Japan productivity |
|-------|---------------------|----------------------|---------------------------|
| Y_0 | 6.559×10^6 | 1.047×10^7 | 1.295×10^5 |
| g | 0.0266 | 0.0210 | 0.0435 |
| R^2 | 0.9779 | 0.9931 | 0.8781 |

The next step is to obtain the coefficient for the equation for productivity which we also used for Thailand as shown above in equation 49. The result is shown in Table 11.

The relationship between FDI and GDP per capita is studied using equation 50 which was used for Thailand as well. The models with no time lag, 1-year lag, and 2-year lag were compared because of the significant time delay from the investment decision making process. The results shown in Table 12 present a different outcome from Thailand. For Malaysia, the model with no time lag has the highest adjusted R^2 and it is the one used in the system dynamics model. This result indicates that foreign investors perceive that Thailand is riskier than Malaysia.

³ Malaysian Industrial Development Authority

Table 11: Coefficient for productivity for Malaysia

| | |
|----------------------------|---------------------------|
| Constant | -34.38*** |
| ln(Capital per employment) | 0.2915*** |
| Time | 0.0210*** |
| Technology gap | -9.88×10^{-7} ** |
| R ² | 0.9772 |
| Adjusted R ² | 0.9732 |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 12: Coefficient for FDI for Malaysia

| | No time lag | 1-year lag | 2-year lag |
|-------------------------|---------------------------|-------------------------|-------------------------|
| Constant | -1.08×10^{10} ** | -6.65×10^9 | -4.88×10^9 |
| GDP per capita | 1.651×10^6 *** | N/A | N/A |
| GDP per capita (-1) | N/A | 1.425×10^6 *** | N/A |
| GDP per capita (-2) | N/A | N/A | 1.358×10^6 *** |
| R ² | 0.5835 | 0.4286 | 0.3660 |
| Adjusted R ² | 0.5616 | 0.3968 | 0.3287 |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

The equations for GFCF and Hiring rate are the same as the ones used for Thailand which are equation 51 and 52. The models with no time lag, 1-year lag, and 2-year lag are also compared to check the investment delay. The result for GFCF shows

that the 1-year lag model has the highest adjusted R^2 as indicated in Table 13. Table 14 shows the results for employment hiring. The results for employment hiring for all time lag shows a negative coefficient for FDI which is not theoretically correct. Thus, we studied the model without a constant variable and the results show a positive coefficient which complies with the theory. Therefore, the model without a constant coefficient and time lag is selected.

Table 13: Coefficient for GFCF for Malaysia

| | No time lag | 1-year lag | 2-year lag |
|----------------|---------------------------|---------------------------|---------------------------|
| Constant | $7.685 \times 10^{11}***$ | $7.272 \times 10^{11}***$ | $9.684 \times 10^{11}***$ |
| FDI | 2.864*** | 2.633*** | 1.957** |
| LIC | $2.262 \times 10^{10}*$ | N/A | N/A |
| LIC(-1) | N/A | $3.402 \times 10^{10}***$ | N/A |
| LIC(-2) | N/A | N/A | $2.364 \times 10^{10}**$ |
| R^2 | 0.4654 | 0.6352 | 0.4497 |
| Adjusted R^2 | 0.4025 | 0.5896 | 0.3764 |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 14: Coefficient for employment hiring for Malaysia

| | Constant No lag | Constant 1-year lag | Constant 2-year lag | No constant No lag | No constant 1-year lag | No constant 2-year lag |
|----------------------------|------------------------|------------------------|-------------------------|--------------------------|------------------------------|------------------------------|
| Constant | $1.66 \times 10^5^*$ | $2.18 \times 10^5^*$ | $2.64 \times 10^5^{**}$ | N/A | N/A | N/A |
| FDI | -5.68×10^{-6} | 1.64×10^{-6} | 4.35×10^{-6} | 2.28×10^{-6} | 1.13×10^{-5} ** | 1.65×10^{-5} |
| LIC | $1.10 \times 10^4^*$ | N/A | N/A | $1.34 \times 10^4^{**}$ | N/A | N/A |
| LIC(-1) | N/A | -1.06×10^3 | N/A | N/A | 3.54×10^3 | N/A |
| LIC(-2) | N/A | N/A | -8.53×10^3 | N/A | N/A | -3.78×10^3 |
| R ² | 0.2094 | 0.0056 | 0.1675 | 0.0256 | -0.2212 | -0.1484 |
| Adjusted R ² | 0.1164 | -0.1186 | 0.0565 | -0.0285 | -0.2930 | -0.2202 |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

The results from the regression also support the assumption of a significant time delay of variables and the relationship between them. After inputting the parameter into the model, the simulation and the empirical data match to some extent as shown in Table 15.

Table 15: Comparison between empirical data and simulation for Malaysia

| Variable | R ² | MAPE | Graph |
|----------------------|----------------|-------|---|
| Foreign productivity | 0.812 | 8.08% | <p>Productivity of foreign firms</p> <p>Productivity of foreign firms : ReferenceMode Productivity of foreign firms : MY</p> |
| Country productivity | 0.936 | 3.70% | <p>Perceived country productivity</p> <p>Perceived country productivity : ReferenceMode Perceived country productivity : MY</p> |
| Real GDP | 0.981 | 3.14% | <p>Real GDP</p> <p>Real GDP : ReferenceMode Real GDP : MY</p> |

| Variable | R ² | MAPE | Graph |
|---------------|----------------|--------|---|
| FDI | 0.393 | 58.44% | <p style="text-align: center;">FDI</p> <p style="text-align: center;">Time (year)</p> <p>FDI : ReferenceMode FDI : MY</p> |
| Fixed capital | 0.970 | 9.74% | <p style="text-align: center;">Fixed Capital</p> <p style="text-align: center;">Time (year)</p> <p>Fixed Capital : ReferenceMode Fixed Capital : MY</p> |
| Employment | 0.965 | 2.26% | <p style="text-align: center;">Employment</p> <p style="text-align: center;">Time (year)</p> <p>Employment : ReferenceMode Employment : MY</p> |

| Variable | R ² | MAPE | Graph |
|------------|----------------|-------|---|
| Population | 0.972 | 2.07% | <p style="text-align: center;">Population</p> <p>Population : ReferenceMode Population : MY</p> |

Note: MAPE = Mean Absolute Percentage Error

Vietnam

The economy of Vietnam has been growing exponentially during the last couple years after Vietnam reduced the foreign investment barrier as observed by the comparatively stable FDI from 1996 to 2006, and then it significantly increased in the last two years as shown in Figure 18. However, even though FDI during the early period was limited, the GDP and the GDP per capita of Vietnam were gradually growing at a constant rate. Productivity grew constantly as well. In this section we aim to reproduce these empirical data by simulating the developed system dynamics model. The coefficients used in the model are determined from the regression equations similar to the ones used for Thailand and Malaysia.

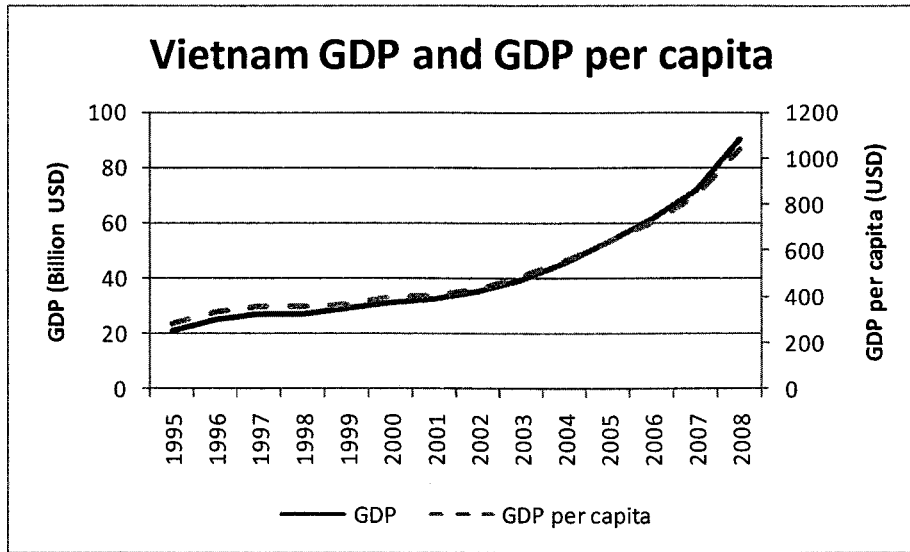


Figure 17: GDP and GDP per capita of Vietnam, 1995 – 2008

Source: Economist Intelligence Unit

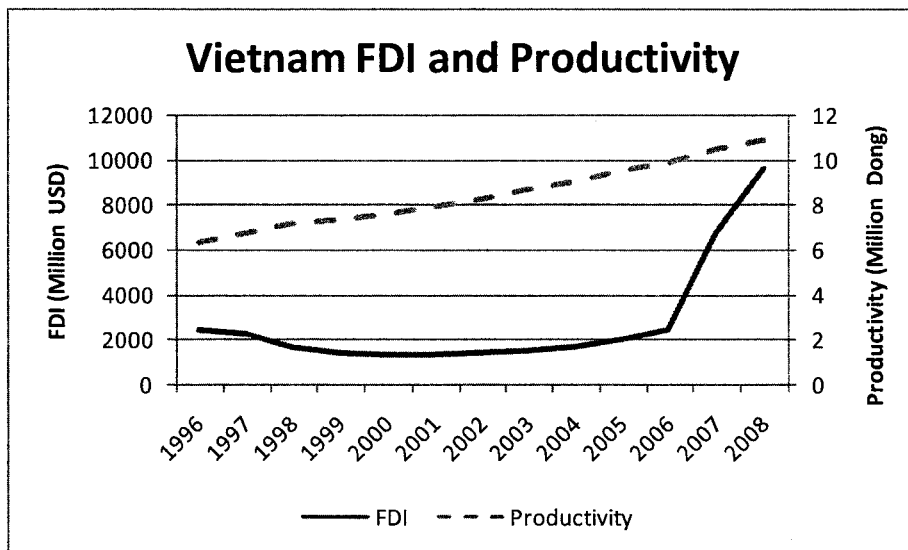


Figure 18: FDI and productivity of Vietnam, 1996 – 2008

Source: IMF International Financial Statistics and Economist Intelligence Unit

To determine the coefficients for Vietnam we use data from 1996 to 2008, instead of 1988 to 2008, because of the data availability limitation. Moreover, the data on

employment and unemployment are not available. However, the data on workforce and percentage of unemployment are available. Nevertheless, to prevent the rounding bias, we separate the growth of the workforce and the population. Therefore, the coefficient for population will be studied instead of non-workforce. The results are shown in Table 16.

Table 16: Coefficient for workforce, population, and foreign productivity for Vietnam

| | Workforce | Population | Japan productivity |
|-------|----------------------|----------------------|---------------------------|
| Y_0 | 3.4535×10^7 | 7.3464×10^7 | 7.211×10^8 |
| g | 0.0241 | 0.0135 | 0.0499 |
| R^2 | 0.9868 | 0.9984 | 0.8990 |

The productivity coefficient for Vietnam is calculated by using the same equation as we used for Thailand and Malaysia. The result is shown in Table 17.

Table 17: Coefficient for productivity for Vietnam

| | |
|--------------------------------------|-------------------------|
| Constant | -57.98*** |
| $\ln(\text{Capital per employment})$ | 0.0634 |
| Time | 0.02364*** |
| Technology gap | -5.26×10^{-11} |
| R^2 | 0.9980 |
| Adjusted R^2 | 0.9974 |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

The relationship between FDI and GDP per capita of Vietnam is not linear, but it is in an exponential form. From the empirical data, the FDI in last couple years jumped significantly above the early years. Therefore, the regression model used to determine the relationship between FDI and GDP per capita is:

$$\ln(\text{FDI}) = b_0 + b_1 * \text{GDP per capita} \quad (53)$$

We also compare the models with no time lag, 1-year lag, 2-year lag, and 3-year lag to determine the time delay of an investment. A model with a high degree of time lag is studied because Vietnam has recently opened the economy. Therefore, it is likely to have higher risk and uncertainty for foreign firms as compared to Thailand and Malaysia. A higher degree of decision time represents higher risk that foreign companies would perceive. The results in Table 18 show that the model with a 3-year lag can explain the change of FDI better than other models.

The next step is to study the equations for GFCF and employment hiring. The 1-year lag model of GFCF, shown in Table 19, has the highest adjusted R^2 compared to the other time lag models. This is the same as the results for Thailand and Malaysia. The equation for employment hiring has the same negative coefficient problem which we observed in the Malaysia model. The model with a 2-year lead shows a positive coefficient. Thus, the coefficient from the model with the 2-year lag shown in Table 20 is used.

Table 18: Coefficient for FDI for Vietnam

| | No time lag | 1-year lag | 2-year lag | 3-year lag |
|-------------------------|---------------------------|--------------------------|---------------------------|---------------------------|
| Constant | 28.63*** | 28.15*** | 27.49*** | 26.77*** |
| GDP per capita | 6.03×10^{-7} *** | N/A | N/A | N/A |
| GDP per capita (-1) | N/A | 7.5×10^{-7} *** | N/A | N/A |
| GDP per capita (-2) | N/A | N/A | 9.45×10^{-7} *** | N/A |
| GDP per capita (-3) | N/A | N/A | N/A | 1.19×10^{-6} *** |
| R ² | 0.6522 | 0.7327 | 0.8064 | 0.8512 |
| Adjusted R ² | 0.6206 | 0.7059 | 0.7849 | 0.8326 |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 19: Coefficient for GFCF for Vietnam

| | No time lag | 1-year lag | 2-year lag |
|-------------------------|---------------------------|---------------------------|--------------------------|
| Constant | -6.71×10^{13} ** | -7.18×10^{13} ** | -6.53×10^{13} |
| FDI | 2.013*** | 1.242*** | 1.221** |
| LIC | 1.94×10^{13} *** | N/A | N/A |
| LIC(-1) | N/A | 2.45×10^{13} *** | N/A |
| LIC(-2) | N/A | N/A | 2.66×10^{13} ** |
| R ² | 0.9678 | 0.9736 | 0.9571 |
| Adjusted R ² | 0.9606 | 0.9670 | 0.9448 |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 20: Coefficient for employment hiring for Vietnam

| | Constant No lag | Constant 1-year lag | Constant 2-year lag | No constant No lag | No constant 1-year lead | No constant 2-year lead |
|----------------------------|--------------------------|---------------------------|------------------------------|---------------------------|-------------------------------|-------------------------------|
| Constant | -1.38×10^5 | -1.65×10^5 | 1.07×10^5 | N/A | N/A | N/A |
| FDI | -4.69×10^{-9} | -8.87×10^{-9} | -8.68×10^{-9} ** | -4.37×10^{-9} | -1.18×10^{-8} | 3.83×10^{-9} |
| LIC | 1.19×10^5 ** | N/A | N/A | 1.06×10^5 *** | 1.27×10^5 *** | 9.35×10^4 |
| LIC(-1) | N/A | -1.45×10^5 ** | N/A | N/A | N/A | N/A |
| LIC(-2) | N/A | N/A | 1.39×10^5 ** | N/A | N/A | N/A |
| R ² | 0.5403 | 0.4120 | 0.5021 | 0.5325 | 0.3312 | -0.4133 |
| Adjusted R ² | 0.4381 | 0.2650 | 0.3598 | 0.4858 | 0.2569 | -0.5900 |

Remark: *** p < 0.01; **p < 0.05; *p < 0.1

Based on the results, Vietnam is considered by foreign firms as higher risk than Thailand and Malaysia which is shown by a longer foreign investment delay. In spite of this, Vietnam still attracts a significant number of foreign investments. The simulation results after parameterization are shown in Table 21. The results indicate that the simulation can explain the change of the actual data to some degree.

Table 21: Comparison between empirical data and simulation for Vietnam

| Variable | R ² | MAPE | Graph |
|----------------------|----------------|-------|--|
| Foreign productivity | 0.847 | 5.82% | <p>Productivity of foreign firms</p> <p>Productivity of foreign firms : ReferenceMode Productivity of foreign firms : VI</p> |
| Country productivity | 0.950 | 3.29% | <p>Country productivity</p> <p>Country productivity : ReferenceMode Country productivity : VI</p> |
| Real GDP | 0.969 | 4.58% | <p>Real GDP</p> <p>Real GDP : ReferenceMode Real GDP : VI</p> |

| Variable | R ² | MAPE | Graph |
|---------------|----------------|--------|---|
| FDI | 0.839 | 42.96% | <p style="text-align: center;">FDI</p> <p style="text-align: center;">Time (year)</p> <p>FDI : ReferenceMode FDI : VI</p> |
| Fixed capital | 0.874 | 25.25% | <p style="text-align: center;">Fixed Capital</p> <p style="text-align: center;">Time (year)</p> <p>Fixed Capital : ReferenceMode Fixed Capital : VI</p> |
| Employment | 0.912 | 2.62% | <p style="text-align: center;">Employment</p> <p style="text-align: center;">Time (year)</p> <p>Employment : ReferenceMode Employment : VI</p> |

| Variable | R ² | MAPE | Graph |
|------------|----------------|-------|---|
| Population | 0.934 | 1.27% | <p style="text-align: center;">Population</p> <p>Population : ReferenceMode Population : VI</p> |

Note: MAPE = Mean Absolute Percentage Error

Result comparison between Thailand, Malaysia, and Vietnam

The regression results of the relationship between the variables that affected the FDI and productivity of Thailand, Malaysia, and Vietnam show the similarities and the differences of these three countries. First, the results suggest that these three countries have a strong foundation to attract foreign investment as shown by the significant growth in FDI after the 1997 Asian Financial crisis. Furthermore, there are signs of the shift in industrial concentration from low labor cost industries to technology-based industries indicated by an increase in GDP per capita, FDI, and the productivity.

Even though Thailand, Malaysia, and Vietnam have a continuous FDI growth, Malaysia has the shortest FDI delay time whereas Vietnam's FDI delay time is the longest. This result can be interpreted that MNEs perceive Vietnam as a risky country comparing to Thailand and Malaysia. This explanation is supported by the Corruption

Perception Index (CPI)⁴ scores provided by Transparency International and Economic Freedom Index⁵ by The Heritage Foundation for which Vietnam has the lowest score and Malaysia has the highest score.

⁴ CPI 2009 Ranking for Vietnam is 120, Malaysia is 56, and Thailand is 84 out of 180 countries.

⁵ Economic Freedom Index 2010 Ranking for Vietnam is 144, Thailand is 66, and Malaysia is 59 out of 179 countries.

CHAPTER 8: EFFECT OF THE R&D CONSORTIA POLICY - CASE OF JAPAN

The effect of the R&D consortia policy on FDI and the technology spillover is studied through the case of Japan. Japan is similar to Thailand, Malaysia, and Vietnam in many ways. First, Japan is in East Asia which is geographically close to Thailand, Malaysia, and Vietnam which are in the Southeast Asia region. Then, Japanese culture is based on collectivism instead of individualism and so is the culture in Thailand, Malaysia, and Vietnam. Furthermore, Japan used to be a source of low labor cost which is the current situation that Thailand, Malaysia, and Vietnam have been facing. Therefore, Japan is used as a reference case to study the effect of the R&D consortia policy on FDI and technology spillover.

Japan model

The Japanese economy was based on the low skilled cheap labor. However, the R&D consortia policy, as well as other factors, shifted the core competitiveness of Japan from cheap labor into one of the world's technology leaders (Aldrich & Sasaki, 1995). The R&D consortia policy has been initiated by the Ministry of International Trade and Industry of Japan since 1961. However, we analyze the data from 1988 to 2008 due to the data availability limitation.

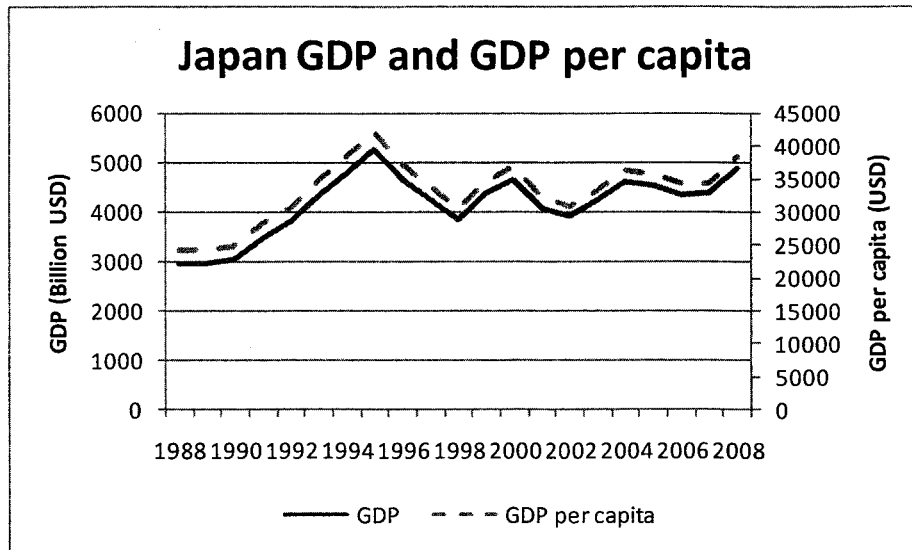


Figure 19: GDP and GDP per capita of Japan, 1988 - 2008

Source: Economist Intelligence Unit

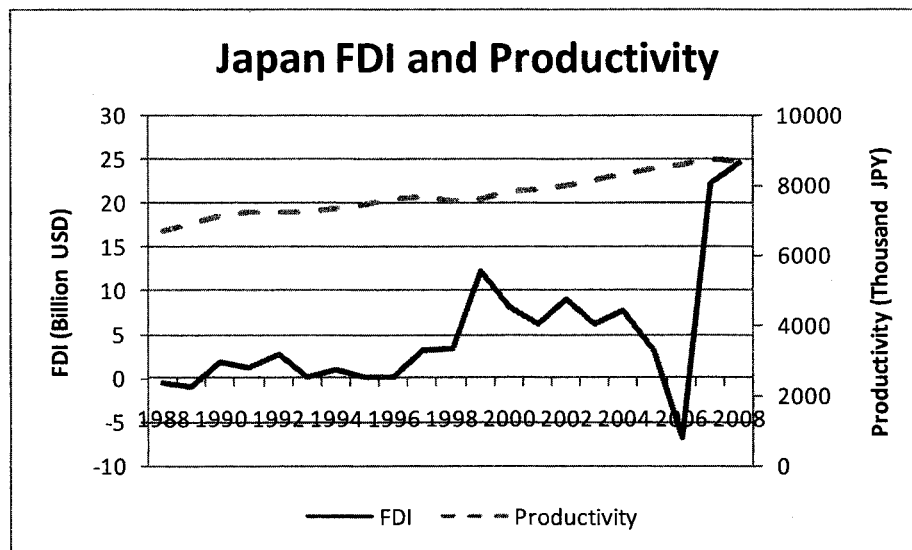


Figure 20: FDI and productivity of Japan, 1988 - 2008

Source: IMF International Financial Statistics and Economist Intelligence Unit

Japan has a fairly stable GDP and GDP per capita as shown in Figure 19. The inward FDI is considerably low compared to developing countries such as Thailand,

Malaysia, and Vietnam. However, the productivity has continuously increased as shown in Figure 20. In general, these graphs broadly present the difference of the relationship between FDI and productivity between Japan which has already implemented the R&D consortia policy and Thailand, Malaysia, and Vietnam which have not.

First, we determine the coefficient for foreign productivity. The U.S. productivity is used to represent the foreign productivity because the U.S. has the highest share of foreign investment in Japan⁶. Based on the data, the U.S. productivity grows exponentially. Therefore, the parameters for the U.S. productivity are estimated using the exponential model as shown in equation 48. The regression result is shown in Table 22.

Table 22: Coefficient for US productivity

| | US Productivity |
|-------|------------------------|
| Y_0 | 7,574,100 |
| g | 0.0180 |
| R^2 | 0.9903 |

Then the number of workforce and non-workforce is calculated. The data indicates the workforce and non-workforce have a 3rd-order polynomial pattern with 1988 given as year 1. Therefore, we use a 3rd-order polynomial function for workforce and non-workforce. The result is shown in Table 23.

⁶ Ministry of Finance, Japan

Table 23: Coefficient for workforce and non-workforce

| | Workforce | Non-workforce |
|----------------|---------------------|----------------------|
| Constant | 5.993×10^7 | 6.184×10^7 |
| t | 1.662×10^6 | 1.134×10^6 |
| t ² | 1.149×10^5 | 1.065×10^5 |
| t ³ | 2,410 | 2,605 |
| R ² | 0.9746 | 0.9226 |

The equation to determine the coefficient for Japan's productivity is the same as the one for Thailand which is equation 49. The regression result is shown in Table 24.

Table 24: Coefficient for productivity for Japan

| | |
|----------------------------|----------------------------|
| Constant | -19.17*** |
| ln(Capital per employment) | -0.0496** |
| Time | 0.0180*** |
| Technology gap | -6.69×10^{-8} *** |
| R ² | 0.9931 |
| Adjusted R ² | 0.9919 |

Remark: *** p < 0.01; **p < 0.05; *p < 0.1

The next step is to find the relationship between FDI and GDP per capita. We used equation 50 to determine the coefficients of FDI and the GDP per capita. We also studied the time delay between FDI and GDP per capita by examining regressions with

no time lag, 1-year lag, and 2-year lag. The results shown in Table 25 indicate that the model with 1-year lag has the highest R^2 . This can be interpreted that even though Japan is a developed country with less risk compared to Malaysia, Thailand, and Vietnam, foreign firms still require time to make an investment decision due to the fierce domestic competition. Therefore, the coefficient of the 1-year lag model is implemented in the system dynamics model.

Table 25: Coefficient of FDI for Japan

| | No time lag | 1-year lag | 2-year lag |
|---------------------|--------------------------|--------------------------|--------------------------|
| Constant | $-5.59 \times 10^{12**}$ | $-6.10 \times 10^{12**}$ | $-6.38 \times 10^{12**}$ |
| GDP per capita | $1.576 \times 10^6**$ | N/A | N/A |
| GDP per capita (-1) | N/A | $1.72 \times 10^6***$ | N/A |
| GDP per capita (-2) | N/A | N/A | $1.82 \times 10^6**$ |
| R^2 | 0.2967 | 0.3190 | 0.2990 |
| Adjusted R^2 | 0.2596 | 0.2812 | 0.2578 |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

The last two equations are the regressions to determine the coefficient for GFCF and Hiring rate which are equation 51 and 52. We studied the GFCF model with different time lags to estimate the fixed capital investment delay from foreign and local investment. The results show that the model with a 4-year lag provides the best fit compared to the other models as presented in Table 26. This result indicates that the local investment does not invest in fixed capital immediately. Local firms require a significant

amount of time to make a decision on fixed capital investment. For the employment model, the results show that the 2-year lead model provides the highest R^2 as presented in Table 27. It indicates that both local and foreign firms are likely to withhold human resource investment until they believe that the firms can operate the business and then they will hire workers.

Table 26: Coefficient of GFCF for Japan

| | No time lag | 1-year lag | 2-year lag | 3-year lag | 4-year lag |
|-------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Constant | $1.33 \times 10^{14}***$ | $1.30 \times 10^{14}***$ | $1.29 \times 10^{14}***$ | $1.27 \times 10^{14}***$ | $1.26 \times 10^{14}***$ |
| FDI | -6.311* | -6.224* | -6.034* | -6.078* | -5.248* |
| LIC | 1.27×10^{11} | N/A | N/A | N/A | N/A |
| LIC(-1) | N/A | 1.76×10^{12} | N/A | N/A | N/A |
| LIC(-2) | N/A | N/A | 2.06×10^{12} | N/A | N/A |
| LIC(-3) | N/A | N/A | N/A | $2.29 \times 10^{12}*$ | N/A |
| LIC(-4) | N/A | N/A | N/A | N/A | $2.23 \times 10^{12}*$ |
| R^2 | 0.1877 | 0.2793 | 0.3019 | 0.3360 | 0.3568 |
| Adjusted R^2 | 0.0922 | 0.1892 | 0.2089 | 0.2412 | 0.2578 |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 27: Coefficient of employment hiring for Japan

| | No time lag | 1-year lag | 2-year lag | 1-year lead | 2-year lead |
|----------------------------|---------------------------|---------------------------|------------------------|------------------------------|------------------------|
| Constant | -7.55×10^4 | -1.67×10^5 | 9.49×10^3 | -1.33×10^5 | -2.66×10^4 |
| FDI | -1.26×10^{-7} | -1.54×10^{-7} | -1.71×10^{-7} | N/A | N/A |
| FDI(-1) | N/A | N/A | N/A | -2.53×10^{-7} ** | N/A |
| FDI(-2) | N/A | N/A | N/A | N/A | -1.66×10^{-7} |
| LIC | 1.78×10^5 *** | N/A | N/A | N/A | N/A |
| LIC(-1) | N/A | 1.92×10^5 *** | N/A | 1.89×10^5 *** | N/A |
| LIC(-2) | N/A | N/A | 8.96×10^4 | N/A | 8.29×10^4 |
| R ² | 0.5446 | 0.6156 | 0.2565 | 0.6714 | 0.1933 |
| Adjusted R ² | 0.4910 | 0.5676 | 0.1574 | 0.6304 | 0.0857 |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

The simulation results after inputting the coefficient into the model indicate that the model can moderately reproduce the change in variables that relate to the FDI and technology spillover of Japan. The comparison between the empirical data and the simulation is shown in Table 28.

Table 28: Comparison between empirical data and simulation for Japan

| Variable | R ² | MAPE | Graph |
|----------------------|----------------|-------|---|
| Foreign productivity | 0.968 | 1.66% | <p>Productivity of foreign firms</p> <p>Productivity of foreign firms : ReferenceMode Productivity of foreign firms : JP</p> |
| Country productivity | 0.966 | 1.15% | <p>Perceived country productivity</p> <p>Perceived country productivity : ReferenceMode Perceived country productivity : JP</p> |
| Real GDP | 0.904 | 2.06% | <p>Real GDP</p> <p>Real GDP : ReferenceMode Real GDP : JP</p> |

| Variable | R ² | MAPE | Graph |
|---------------|----------------|--------|---|
| FDI | 0.285 | 720.8% | <p style="text-align: center;">FDI</p> <p style="text-align: center;">Time (year)</p> <p>FDI : ReferenceMode FDI : JP</p> |
| Fixed capital | 0.974 | 1.69% | <p style="text-align: center;">Fixed Capital</p> <p style="text-align: center;">Time (year)</p> <p>Fixed Capital : ReferenceMode Fixed Capital : JP</p> |
| Employment | 0.483 | 1.12% | <p style="text-align: center;">Employment</p> <p style="text-align: center;">Time (year)</p> <p>Employment : ReferenceMode Employment : JP</p> |

| Variable | R ² | MAPE | Graph |
|------------|----------------|-------|---|
| Population | 0.998 | 0.06% | <p style="text-align: center;">Population</p> <p>person</p> <p>Time (year)</p> <p>Population : ReferenceMode</p> <p>Population : JP</p> |

Note: MAPE = Mean Absolute Percentage Error

Result comparison between Japan and Thailand, Malaysia, and Vietnam

The coefficients for the model of Japan are different from those of the model of Thailand, Malaysia, and Vietnam in many ways. First, the coefficient to calculate the country productivity focuses on different factors. As shown in Table 29, the capital per employment has less impact on the productivity in Japan than in Thailand, Malaysia, and Vietnam. For the effect of the technology gap on the productivity, Japan, Thailand, and Malaysia utilize the technology gap at fairly the same level and at a significantly higher level than Vietnam.

The next calculation is the effect of the GDP per capita on FDI. We compare only between Japan, Thailand, and Malaysia because the model for Vietnam uses different equation. The results in Table 30 show that each country has a different time delay for foreign investment. Malaysia has no time lag while Thailand has a 2-year time lag. This result can be interpreted as Thailand being perceived by foreign firms as having higher

risk than Malaysia and thus they would require a longer period to collect the information and make an investment decision. Another explanation is because the process related to FDI in Thailand is more bureaucratic than that in Malaysia. Therefore, foreign firms require longer time to initiate the business. Japan has a 1-year time lag which can be explained through the local competition dimension. The local companies in Japan are technologically advanced and hold a strong foothold in the market. Therefore, to invest in Japan, foreign companies need to compete head-to-head with Japanese firms. For this reason, foreign firms are likely to withhold an investment to gather information before investing in Japan.

Table 29: Comparison between the coefficients of the productivity between countries

| | Japan | Thailand | Malaysia | Vietnam |
|----------------------------|---------------------------|---------------------------|---------------------------|-------------------------|
| Constant | -19.17*** | -27.86*** | -34.38*** | -57.98*** |
| ln(Capital per employment) | -0.0496** | 0.3346*** | 0.2915*** | 0.0634 |
| Time | 0.0180*** | 0.01766*** | 0.0210*** | 0.02364*** |
| Technology gap | -6.69×10^{-8} ** | -8.45×10^{-8} ** | -9.88×10^{-7} ** | -5.26×10^{-11} |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

The decision to invest in fixed capital is also different among countries. Japanese firms are likely to hold back the fixed capital investment as indicated by having a long time delay while the local firms in Thailand, Malaysia, and Vietnam require on average 1 year for a fixed capital investment. Moreover, foreign investment in Japan reduces,

instead of increasing, the fixed capital investment. It is because of the direct competition effect that foreign firms and local firms in Japan target the same market and both types of firms are strong. Therefore, if foreign firms successfully invest in Japan, they will take a portion of the market share from Japanese firms and some local firms may not be able to survive. Therefore, the coefficient of FDI on gross fixed capital formation is negative.

Table 30: Comparison of the coefficient of FDI between countries

| | Japan | Thailand | Malaysia |
|---------------------|--------------------------|----------------------------|--------------------------|
| Constant | $-6.10 \times 10^{12**}$ | $-3.658 \times 10^{11***}$ | $-1.08 \times 10^{10**}$ |
| GDP per capita | N/A | N/A | $1.651 \times 10^6***$ |
| GDP per capita (-1) | $1.72 \times 10^6***$ | N/A | N/A |
| GDP per capita (-2) | N/A | $1.177 \times 10^7***$ | N/A |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

The hiring pattern in each country is also different. Thailand and Malaysia do not have a time delay while Japan has a 1-year delay and Vietnam has a 2-year delay. This indicates that in Japan and Vietnam, firms are not likely to make a commitment by hiring workers immediately but they wait for a period of time to gather information and observe the business environment and then hire the workers. In addition, FDI in Japan reduces employment which can be explained through a competition model. In other words, foreign firms are likely to have direct competition with local firms which may push some local firms out of business and thus the employment is reduced.

Table 31: Comparison of the coefficient of GFCF between countries

| | Japan | Thailand | Malaysia | Vietnam |
|----------|--------------------------|---------------------------|---------------------------|--------------------------|
| Constant | $1.26 \times 10^{14}***$ | $7.272 \times 10^{11}***$ | $7.272 \times 10^{11}***$ | $-7.18 \times 10^{13}**$ |
| FDI | -5.248* | 2.633*** | 2.633*** | 1.242*** |
| LIC | N/A | N/A | N/A | N/A |
| LIC(-1) | N/A | $3.402 \times 10^{10}***$ | $3.402 \times 10^{10}***$ | $2.45 \times 10^{13}***$ |
| LIC(-2) | N/A | N/A | N/A | N/A |
| LIC(-3) | N/A | N/A | N/A | N/A |
| LIC(-4) | $2.23 \times 10^{12}*$ | N/A | N/A | N/A |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 32: Comparison of the coefficient of employment hiring between countries

| | Japan | Thailand | Malaysia | Vietnam |
|----------|--------------------------|-----------------------|-----------------------|-----------------------|
| Constant | -1.33×10^5 | -2.961×10^3 | N/A | N/A |
| FDI | N/A | 2.35×10^{-7} | 2.28×10^{-6} | N/A |
| FDI(-1) | $-2.53 \times 10^{-7}**$ | N/A | N/A | N/A |
| FDI(-2) | N/A | N/A | N/A | 3.83×10^{-9} |
| LIC | N/A | $3.767 \times 10^4**$ | $1.344 \times 10^4**$ | N/A |
| LIC(-1) | $1.89 \times 10^5***$ | N/A | N/A | N/A |
| LIC(-2) | N/A | N/A | N/A | 9.35×10^4 |

Remark: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

CHAPTER 9: EFFECT OF R&D CONSORTIA POLICY ON THAILAND, MALAYSIA, AND VIETNAM

In previous chapters, we have explained the model structure to study the relationship between FDI and productivity growth through technology spillover. Then we applied the model to Thailand, Malaysia, and Vietnam to replicate the empirical data in order to use the model as the foundation for policy analysis. Subsequently, we studied the FDI and productivity growth from technology spillover in Japan which had already implemented the R&D consortia policy in order to analyze the effect of the policy on the variables related to the FDI and the technology spillover. In this chapter, we will apply the effect of the R&D consortia policy on the relationship between FDI and productivity growth from the technology spillover which is acquired from Japan's model to the model of Thailand, Malaysia, and Vietnam. This allows us to study the implications of the R&D consortia policy on the productivity growth from technology spillover in these countries.

This chapter focuses on the analysis of the R&D consortia policy on productivity growth from technology spillover through FDI in Thailand, Malaysia, and Vietnam. The study does not aim to forecast what would happen in the future but to show the effect of R&D consortia on the development of technology spillover in these countries since the simulation environment may change. Therefore, the simulation results are shown using the simulation iteration instead of the year to avoid the misunderstandings.

Implementing R&D consortia in Thailand, Malaysia, and Vietnam

Productivity growth from technology spillover can be studied through the calculation of the country's productivity in the model. Country productivity is determined by capital per employment and a multiplicative factor. Capital per employment is not related to the technology spillover therefore we focus on the multiplicative factor. The multiplicative factor consists of the effect of the technology gap and a time dummy variable representing the change in technology, innovation, and management technique. The R&D consortia policy affects both factors in a multiplicative factor because the R&D consortia policy is expected to reduce the technology gap between local and foreign firms and also stimulate technology and innovation research. Therefore, to implement the R&D consortia policy in Thailand, Malaysia, and Vietnam, the coefficient of the multiplicative factor is modified. Japan is used as the representative case of a country using the R&D consortia policy. Therefore, the coefficient of the multiplicative factor of Japan is used in the model for Thailand, Malaysia, and Vietnam when the R&D consortia policy is implemented.

We assume that the R&D consortia policy is implemented in 2008 which is the last year of the empirical data we have. The R&D consortia policy is modeled to be gradually implemented and to be fully implemented by 8 simulation iterations in order to observe the dynamics of the change of country productivity and technology spillover in Thailand, Malaysia, and Vietnam. The model is also simulated for 12 simulation iterations after 2008 to observe the effect of the R&D consortia policy during and after the implementation.

Effect of the R&D consortia policy on productivity growth from technology spillover in Thailand

When implementing the R&D consortia policy to Thailand, the productivity of Thailand increases significantly compared to the case without the R&D consortia policy as shown in Figure 21. This result indicates that the R&D consortia policy can improve the productivity growth from technology spillover in Thailand.

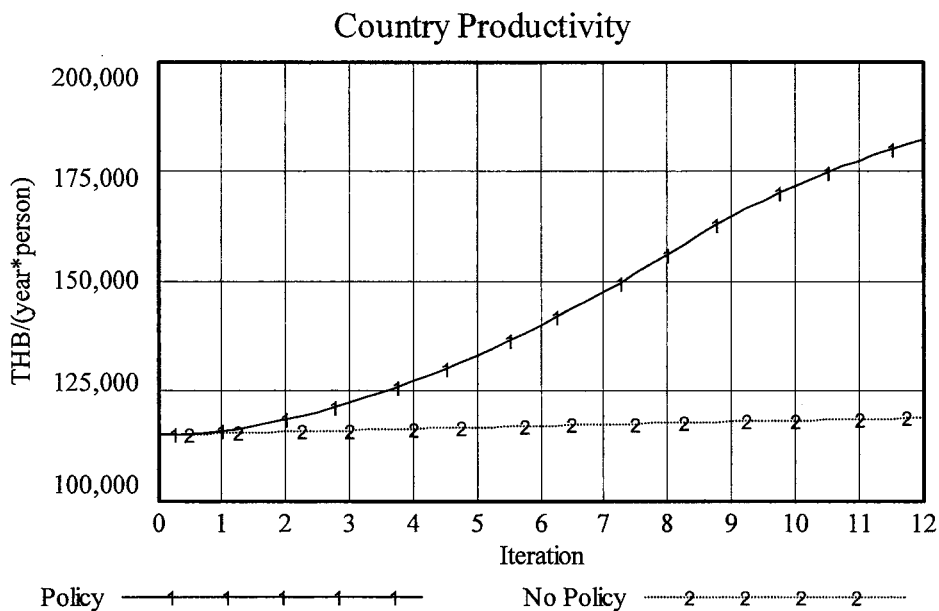


Figure 21: Comparison between the productivity of Thailand with and without the R&D consortia policy

The GDP per capita also increases extensively from the R&D consortia policy compared to the graph of the GDP per capita without the R&D consortia policy as shown in Figure 22. This result suggests that people in Thailand will gain benefits by having a

higher average income if the government uses the R&D consortia policy.

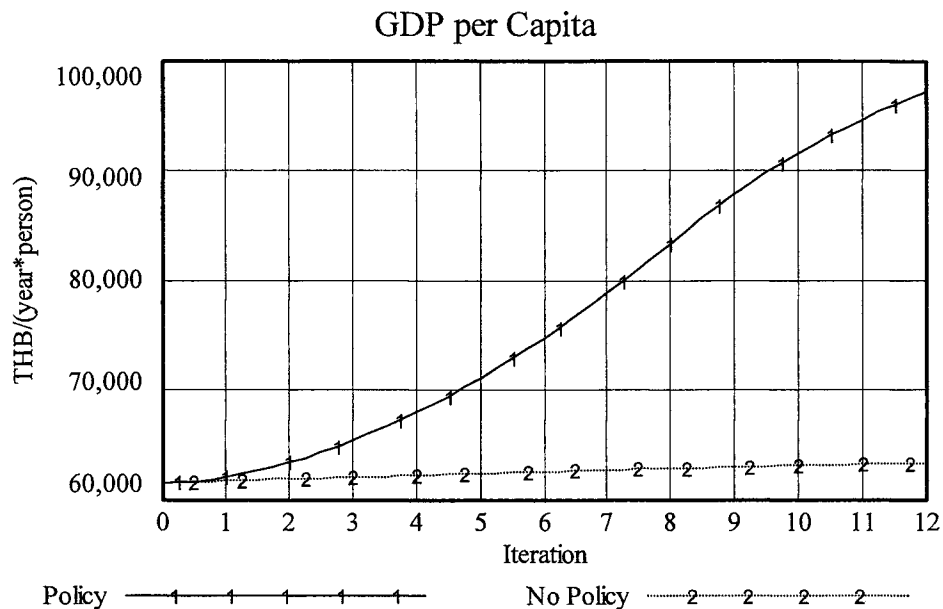


Figure 22: Comparison between the GDP per capita of Thailand with and without the R&D consortia policy

FDI also grow exponentially when Thailand implements the R&D consortia policy as presented in Figure 23. This result indicates that even though productivity and technology spillover in Thailand are high, foreign firms are still willing to invest in Thailand to gain market opportunity which is identified by the higher GDP per capita.

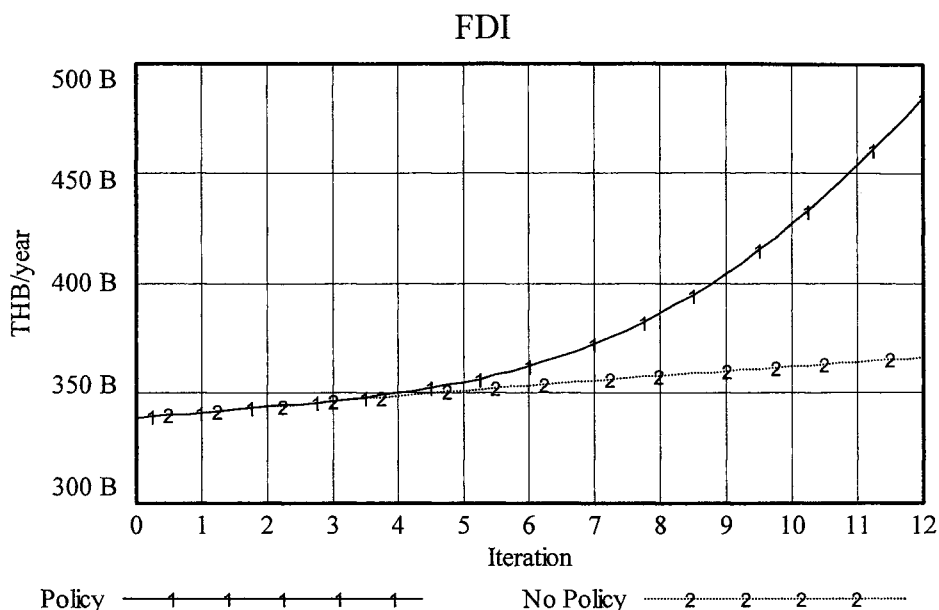


Figure 23: Comparison between the FDI of Thailand with and without the R&D consortia policy

In summary, the R&D consortia policy can encourage the productivity growth from the technology spillover through FDI as shown by a continuous increase in the productivity of Thailand. Increase in productivity also drives up the wealth of people in Thailand as indicated by a higher GDP per capita. With higher GDP per capita, Thailand becomes a market opportunity for foreign firms. Even though foreign firms are likely to lose their technology through technology spillover and have more direct competition with local firms due to the increase in productivity of the local firms, the country attractiveness from higher GDP per capita still outweighs the risk and results in an increase in FDI.

Effect of the R&D consortia policy on productivity growth from technology spillover in Malaysia

The R&D consortia policy improves the productivity, people's wealth, and also attracts more foreign investment in Malaysia. First, the productivity of Malaysia grows notably from the R&D consortia policy when compared with the case without the policy as shown in Figure 24. This result shows that the R&D consortia policy can improve the productivity growth from technology spillover through FDI in Malaysia.

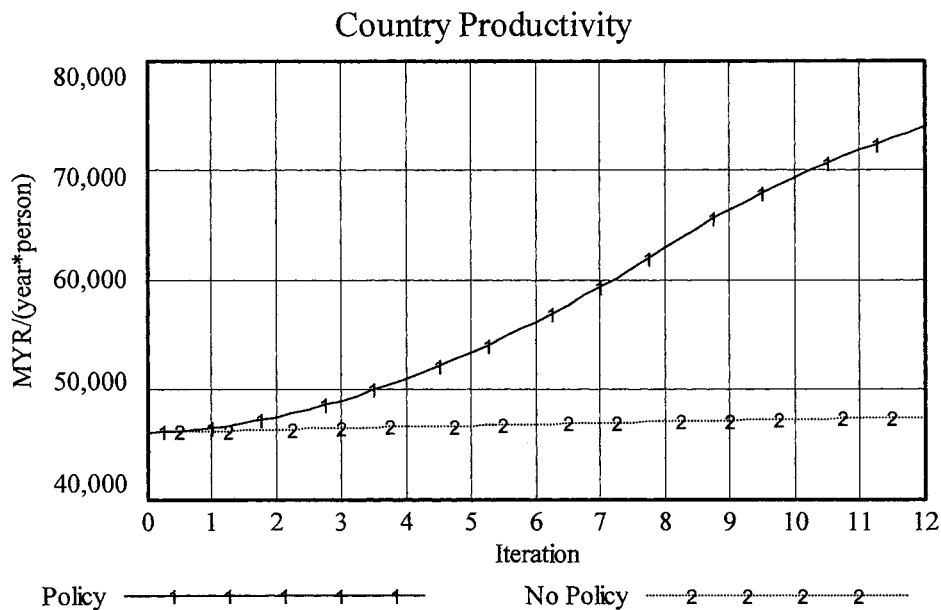


Figure 24: Comparison between the productivity of Malaysia with and without the R&D consortia policy

The wealth of people in Malaysia, measured by the GDP per capita, also increases significantly by the R&D consortia policy as presented in Figure 25. This result can be explained because the R&D consortia policy improves the productivity of the workers in

Malaysia, people in Malaysia on average gain higher income which is indicated by the higher GDP per capita.

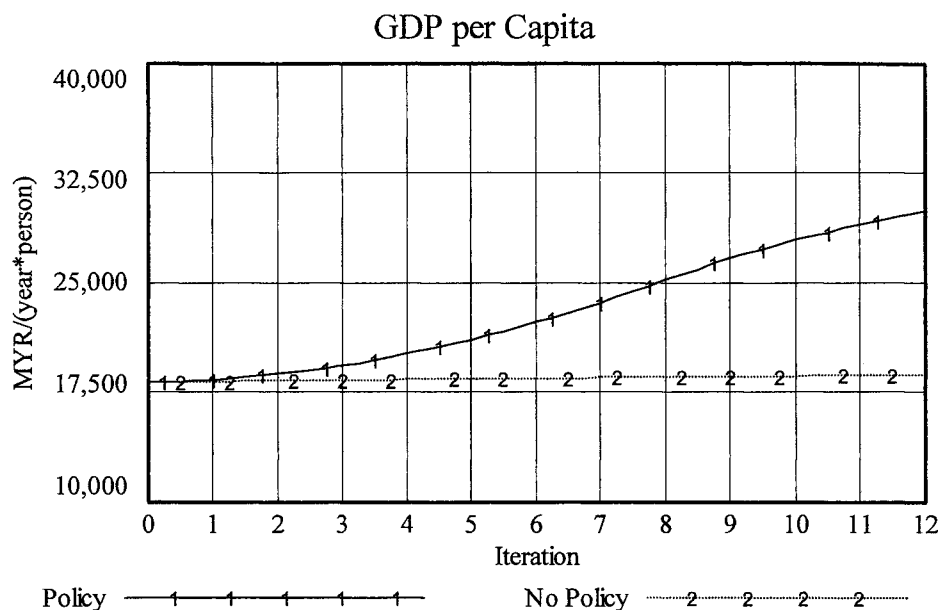


Figure 25: Comparison between the GDP per capita of Malaysia with and without the R&D consortia policy

Even though there is a debate that having higher technology spillover may discourage foreign investment (Sawada, 2005), the result in this study shows the opposite outcome. The foreign investment in Malaysia increases exponentially when the R&D consortia policy is initiated as presented in Figure 26. Foreign firms may be discouraged by higher technology spillover. However, higher technology spillover enlarges the GDP per capita of people in Malaysia which also increases the country attractiveness as a location for market opportunity. The benefits of providing a market opportunity outweigh the loss from technology spillover. Therefore, FDI in Malaysia increases.

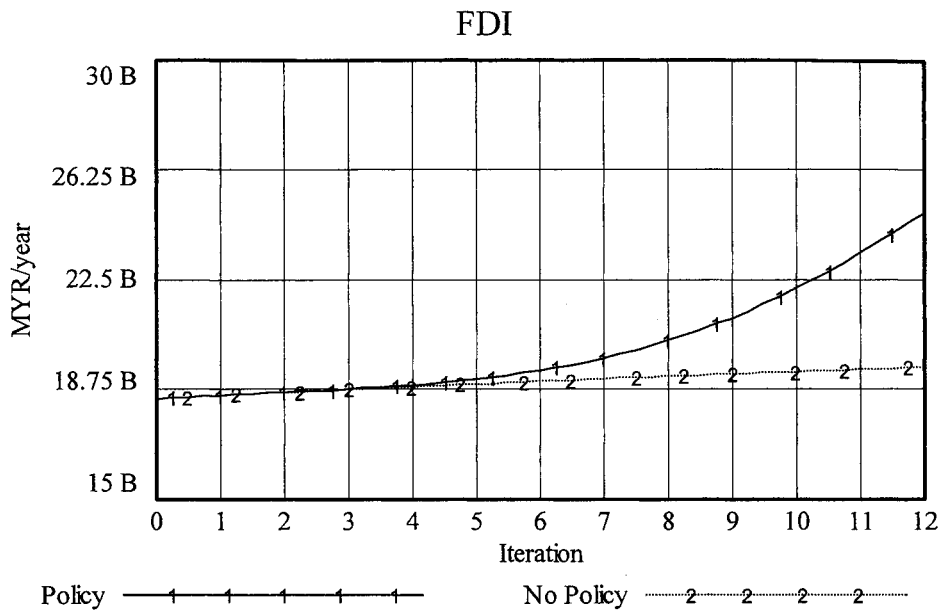


Figure 26: Comparison between the FDI of Malaysia with and without the R&D consortia policy

In summary, the R&D consortia policy supports the productivity growth from technology spillover through FDI in Malaysia. The higher productivity from the R&D consortia policy also increases the wealth of people in Malaysia indicated by the higher GDP per capita. With higher GDP per capita, Malaysia becomes more attractive to foreign investment as a growing market opportunity. Even though there is a risk of losing the proprietary technology through technology spillover, acquiring market opportunity is more essential. Therefore, the R&D consortia policy can also drive the FDI up.

Effect of the R&D consortia policy on productivity growth from technology spillover in Vietnam

The results also show an improvement in country productivity, GDP per capita, and FDI in Vietnam if the R&D consortia policy is utilized. In Figure 27, it shows that the R&D consortia policy can extensively increase the productivity of Vietnam. This result indicates that the R&D consortia policy can encourage the productivity growth from technology spillover through FDI in Vietnam.

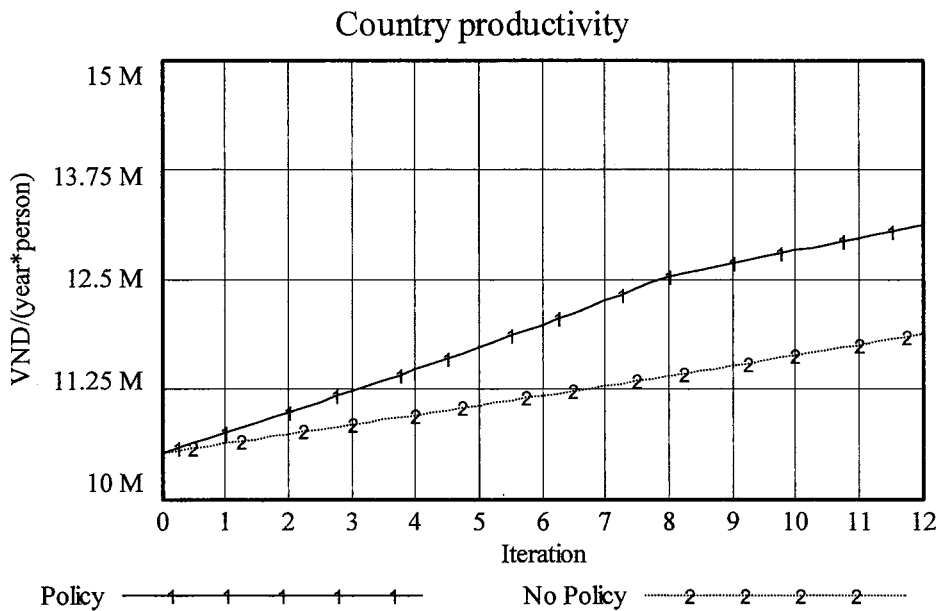


Figure 27: Comparison between the productivity of Vietnam with and without the R&D consortia policy

The GDP per capita of Vietnam is also driven up by the R&D consortia policy as shown in Figure 28. Because the R&D consortia policy supports the productivity in Vietnam, people in Vietnam can produce more output which then increases their average

income. Therefore, the GDP per capita of Vietnam when the R&D consortia policy is in place is enlarged.

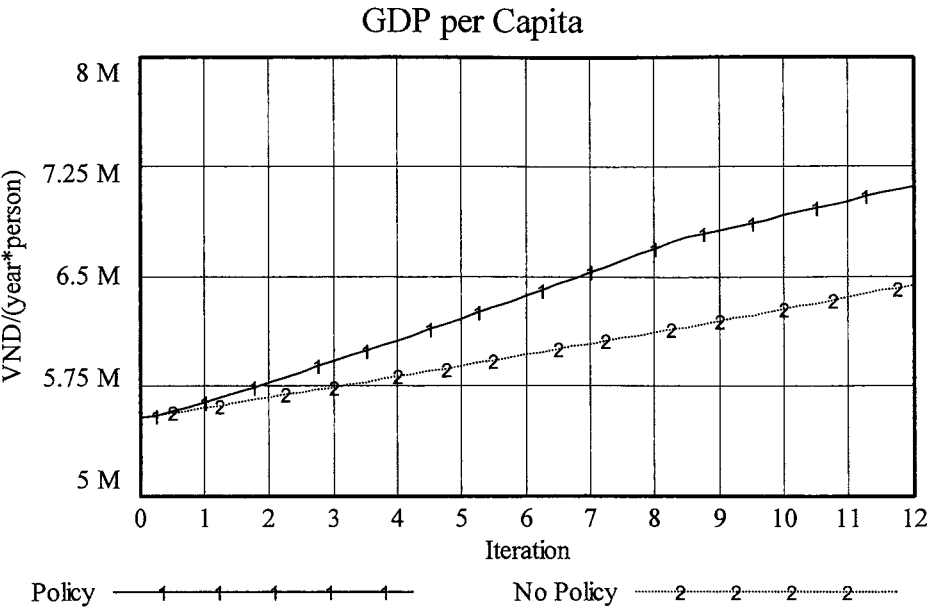


Figure 28: Comparison between the GDP per capita of Vietnam with and without the R&D consortia policy

FDI in Vietnam grows significantly from the R&D consortia policy as presented in Figure 29. FDI increases due to a notable improvement in the GDP per capita of Vietnam which is the result of a development in productivity from technology spillover. Therefore, even though the R&D consortia policy increases technology spillover which amplifies the risk of foreign firms losing their technology knowledge, an increase in GDP per capita still outweighs the risk.

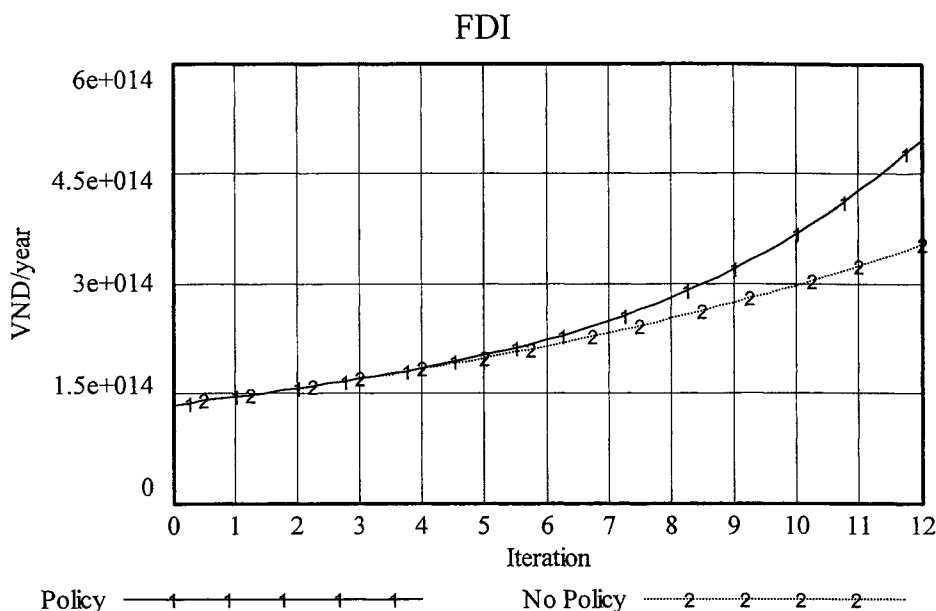


Figure 29: Comparison between the FDI of Vietnam with and without the R&D consortia policy

In summary, the R&D consortia policy can encourage the productivity growth from technology spillover through FDI in Vietnam. Increase in productivity enlarges the GDP per capita which in turn attracts more FDI into Vietnam.

Comparing the benefits of the R&D consortia policy between Thailand, Malaysia, and Vietnam

From the study, Thailand, Malaysia, and Vietnam gain significant benefits from implementing the R&D consortia policy in terms of increasing the country's productivity, GDP per capita, and the volume of FDI. However, the degree of the benefits each country obtains is different. When comparing the benefits the country would obtain from implementing the R&D consortia policy in terms of increasing in the productivity, GDP

per capita, and the volume of FDI between Thailand, Malaysia, and Vietnam at the 12th simulation iteration, Malaysia has the most benefits in terms of the productivity and the GDP per capita while Vietnam has the least benefits. However, when comparing the percentage gains in terms of FDI, Vietnam has the highest benefits follows by Thailand and Malaysia as shown in Table 33.

Table 33: Comparison of the benefits of the R&D consortia policy at the end of the simulation

| | Thailand | Malaysia | Vietnam |
|----------------|-----------------|-----------------|----------------|
| Productivity | 53.52% | 55.81% | 10.49% |
| GDP per capita | 53.54% | 60.27% | 10.50% |
| FDI | 32.24% | 27.05% | 40.73% |

The differences in the benefits each country obtain can be explained through the level of the economic development of the country and the risk perception of foreign investors toward the country. Vietnam has recently opened its economy which is indicated by the volume of inflow of FDI. The inflow of FDI into Vietnam jumped significantly from 2006 which suggests that there is a change in the investment environment that reduces the foreign investment barrier. Besides, Vietnam is perceived as a country with high corruption and low economic freedom which is indicated by the lowest score in Corruption Perception Index and Economic Freedom Index. With the perception of corruption and low economic freedom and the unfamiliarity for foreign investors, Vietnam is considered as the country with the highest investment risk compared to Thailand and Malaysia. However, because of the low labor cost in Vietnam,

Vietnam can attract significant FDI and became the country with the highest FDI growth since 2006 compared to Thailand and Malaysia.

Malaysia is on the opposite side of the spectrum. Foreign investment in Malaysia has grown steadily since 1988 which is the starting year of the simulation except during the 1997 Asian Financial Crisis period. Foreign investors perceive Malaysia as the country with low corruption and high economic freedom compared to Thailand and Vietnam which indicates by the highest rank in CPI and Transparency International and Economic Freedom Index among three countries. Thailand is in the middle between Malaysia and Vietnam. The FDI in Thailand is also gradually growing while the perception on corruption and transparency is lower than Malaysia.

Based on the simulation result, Malaysia gains the most benefits in term of an increase in country productivity from the R&D consortia policy, then Thailand and Vietnam has the least benefit from it. Vietnam benefits the least because Vietnam has many factors that support the growth of productivity from the economy expansion beside the R&D consortia policy while most factor that encourages the technology spillover in Thailand and Malaysia is matured.

Even though Malaysia gains more productivity advantage than Thailand and Vietnam, Thailand and Vietnam can attract more FDI from the R&D consortia policy. This is because economy of Thailand and Vietnam is still growing compared to Malaysia and foreign capital is required to drive the economic growth in these two countries. Therefore, the government of Thailand and Vietnam provides supporting infrastructure and environment to attract more FDI if the GDP per capita increases than Malaysia.

Although the FDI benefits in Vietnam and Thailand is higher than in Malaysia, it takes longer time until FDI significantly increases after the policy implementation. This is based on the risk perception of the foreign investors and the effectiveness of the bureaucratic process. Vietnam has the longest time lag between policy implementation and the effect on the FDI growth because Vietnam has the highest risk. With high risk, foreign investors take longer time to make an investment decision to collect more information. The ineffective FDI-related process also lengthens the FDI delay time.

Discussion on the effect of the R&D consortia policy on productivity growth from technology spillover through FDI in the Southeast Asia region

The R&D consortia policy is the policy that encourages local and foreign firms to conduct collaborative R&D. The R&D consortia policy increases the effectiveness and efficiency of R&D activities due to the knowledge sharing between firms and the economies of scale which also increase the technology skill of the firms. With better technology skills, local firms can increase their productivity. An increase in productivity means that the workers can produce more output in a year. Therefore, on average the population in that country can earn more income as measured by the GDP per capita if the R&D consortia policy is implemented. With higher average incomes, that country becomes a market opportunity for foreign firms and thus inflow of foreign investment increases. When the FDI increases, an investment in fixed capital also increases which feeds back into a productivity growth. Besides, the productivity growth also increases the competitiveness of local firms which drives up the local investment. With higher local investment, the fixed capital investment is also enlarged which becomes another support

to add up the productivity growth. In summary, the R&D consortia policy can increase the productivity, GDP per capita, and the volume of FDI of the implemented country.

Sawada (2005) argued that higher technology spillover will discourage foreign investment because foreign firms need to invest more to prevent the leakage of their technology. However, the results from this study show the missing part of his study. Technology spillover, by itself, may discourage FDI but technology spillover also increases the GDP per capita of that country which in turn increases the attractiveness for the market seeking FDI. The opportunities obtained from a higher GDP per capita outweigh the additional investment foreign firms have to invest to prevent technology spillover. This result also supports the findings of the U-shaped technology spillover discussed by Meyer and Sinani (2009) which indicates that productivity spillover increases if the average income of the host countries increases beyond the critical point. As the average income grows by an increase in productivity, technology spillover will increase if the country productivity is increased which are also the results of this study.

Besides, the model indicates that the fixed capital invested by both local and foreign firms is more significant than the additional employment. This is proved by the value of fixed capital per employment. As the FDI and local investment grow, the firms invest in fixed capital as well as hire additional workers. From the simulation, fixed capital per employment increases significantly over time. Thus, new investment would invest more in fixed capital than human capital. In other words, the new investment is capital intensive instead of labor intensive.

CHAPTER 10: POLICY ANALYSIS IF R&D CONSORTIA POLICY WAS IMPLEMENTED IN THE PAST

The previous chapter explains the benefits that Thailand, Malaysia, and Vietnam will acquire if the R&D consortia policy is implemented in 2008. However, there is one shortcoming of the analysis in the previous chapter. The policy analysis is studied by comparing two simulations – one simulation is the case that the R&D consortia policy is implemented and another case is not. In this chapter, we analyze the effect of R&D consortia if it were implemented in Thailand, Malaysia, and Vietnam in the past and compare the results with the historical data which is the situation that the R&D consortia policy was not implemented.

We assume that the R&D consortia policy is selected to be implemented by the government of Thailand, Malaysia, and Vietnam to recover the economy after the 1997 Asia Financial Crisis. The policy is assumed to be implemented in 2000 and fully implemented in 2002. The result of the simulation is compared with the empirical result and the simulation without the policy implementation.

Thailand

We assume that the R&D consortia policy was implemented in Thailand in 2000 and took 2 years to be fully implemented. The effect of the R&D consortia policy on the productivity of Thailand is shown in Figure 30. The result indicates that the productivity

of Thailand grew significantly if Thailand had implemented the R&D consortia policy in 2000.

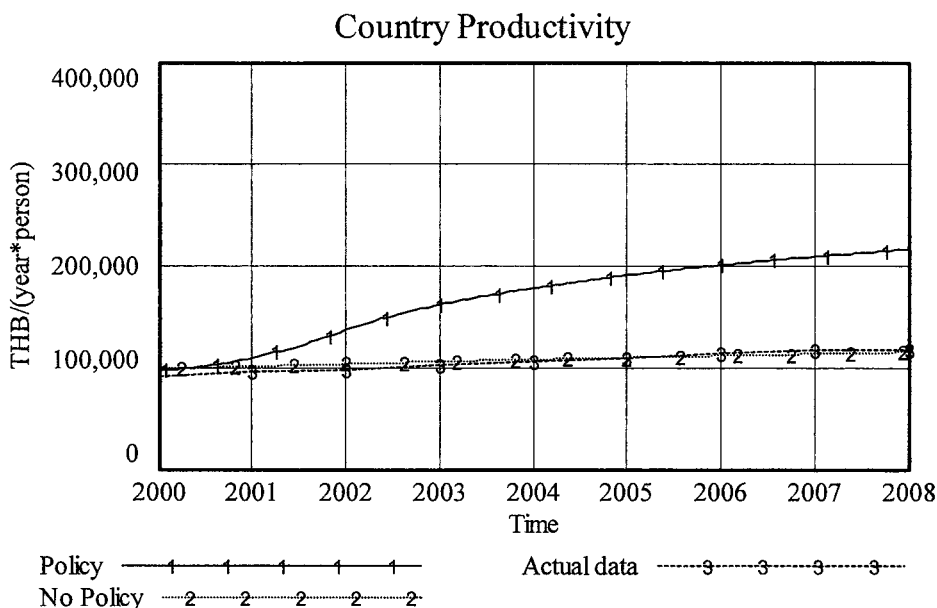
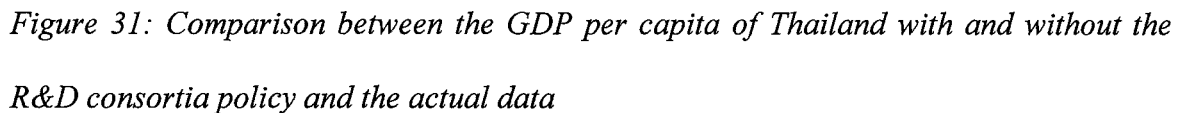


Figure 30: Comparison between the productivity of Thailand with and without the R&D consortia policy and the actual data

The result of the effect of the R&D consortia policy on GDP per capita as shown in Figure 31 provides the same result as the effect of the policy on Thailand's productivity. If Thailand had implemented the R&D consortia policy in 2000, the GDP per capita would have increased significantly and approximately doubled the actual GDP per capita in 2008.

Regarding FDI in 2008, if the R&D consortia policy had been implemented in 2000, FDI would be significantly higher than the actual one as presented in Figure 32. However, it took a couple years to notice the effect of the R&D consortia policy on the



protests from foreign firms as well as local agents who would lose their benefits from the policy.

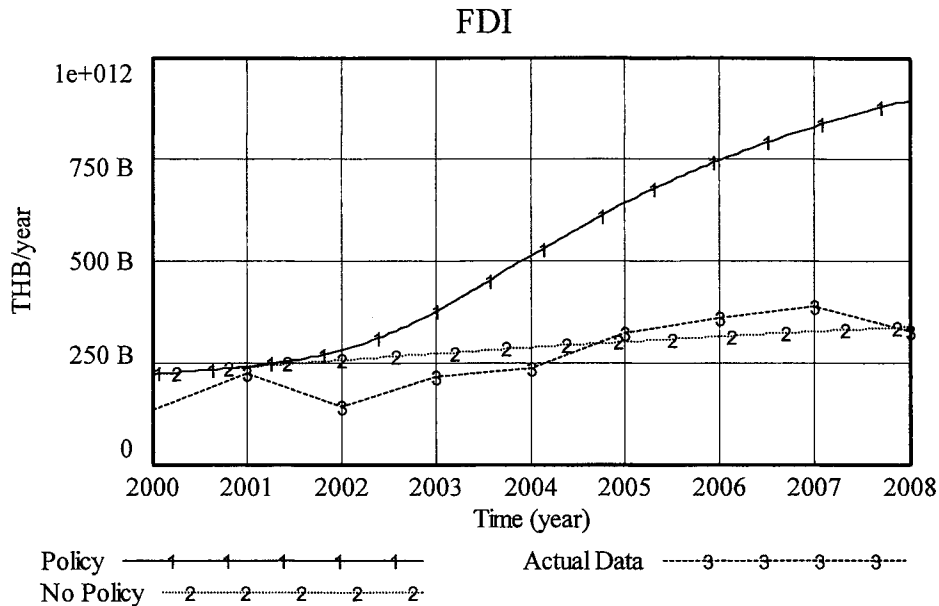


Figure 32: Comparison between the FDI of Thailand with and without the R&D consortia policy and the actual data

Malaysia

The effect of the R&D consortia policy on Malaysia if the policy had been implemented in 2000 is compared with the simulation if the policy was not implemented and the empirical data to determine the size of the consequences of the policy. First, the effect of the R&D consortia policy on the productivity of Malaysia is shown in Figure 33. The result is similar to the effect of the policy on the productivity of Thailand. The productivity of Malaysia would have increased significantly if the R&D consortia policy was implemented.

The GDP per capita in Malaysia would have also increased significantly if the R&D consortia policy was implemented as presented in Figure 34. This indicates that the R&D consortia policy can improve the wealth of people in Malaysia.

The effect of the R&D consortia policy on FDI of Malaysia has a smaller effect than in Thailand as presented in Figure 35. However, FDI in Malaysia would have still been higher than the actual situation if the R&D consortia policy had been implemented which shows that the R&D consortia policy increases the FDI attractiveness of Malaysia.

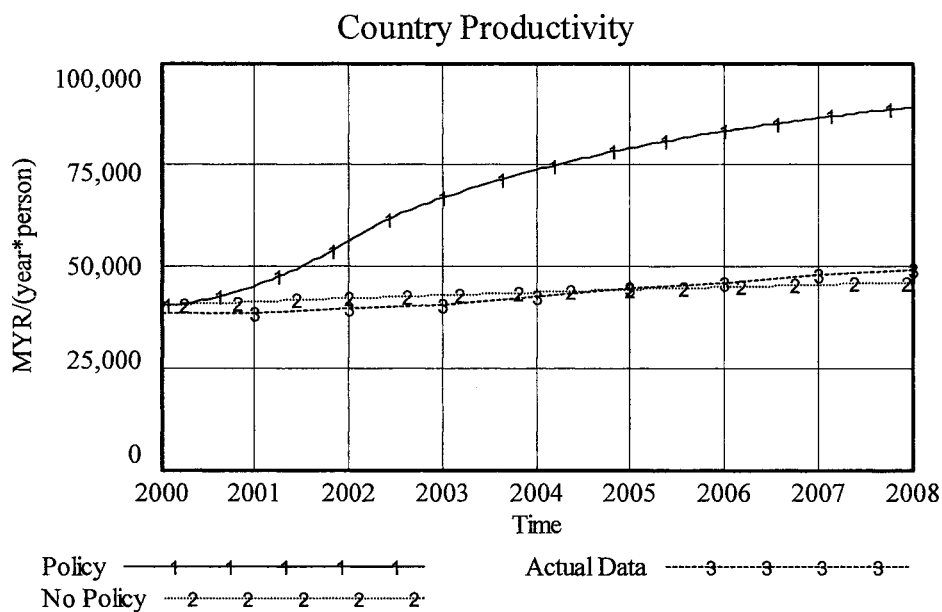


Figure 33: Comparison between the productivity of Malaysia with and without the R&D consortia policy and the actual data

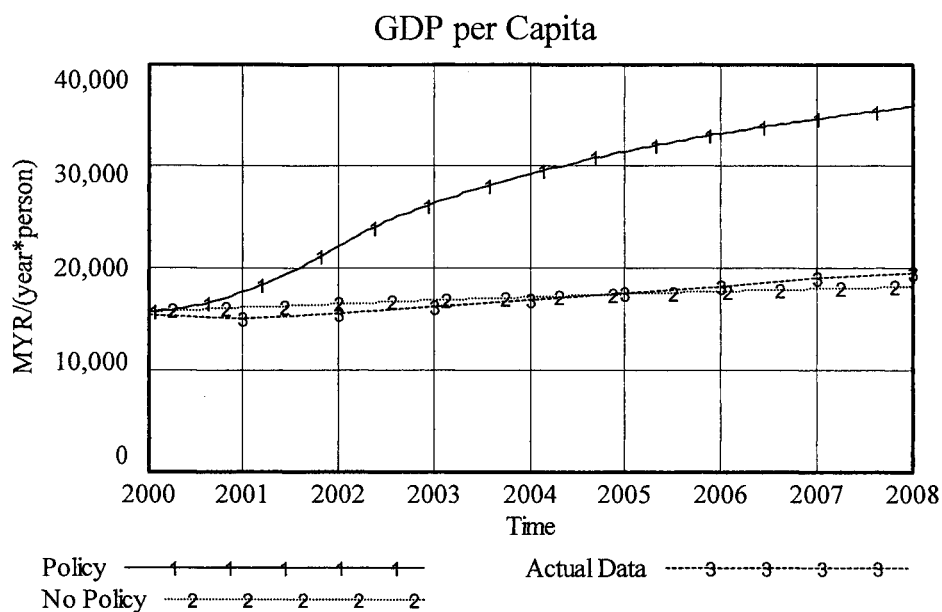


Figure 34: Comparison between the GDP per capita of Malaysia with and without the R&D consortia policy and the actual data

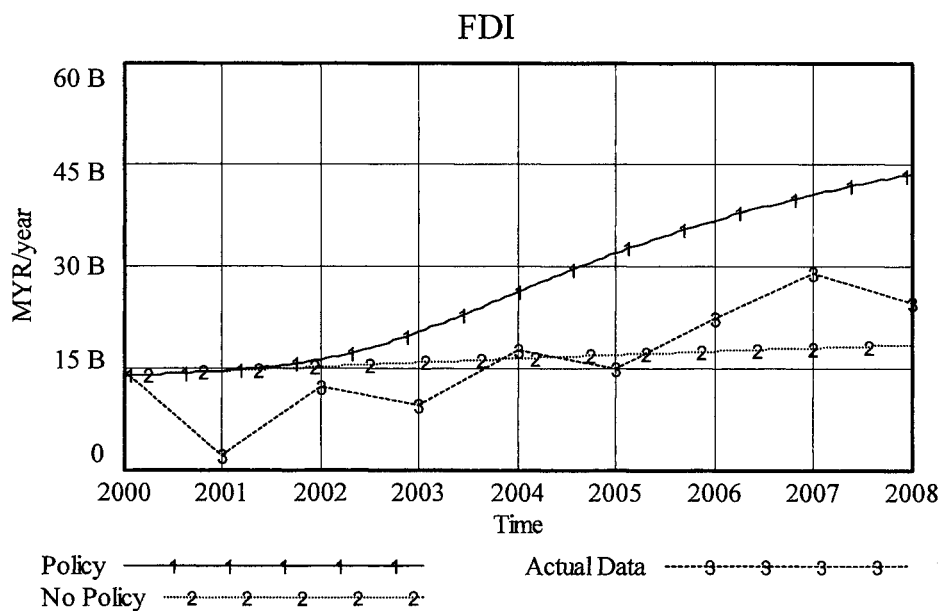


Figure 35: Comparison between the FDI of Malaysia with and without the R&D consortia policy and the actual data

In summary, Malaysia, as well as Thailand, would gain significant benefits from the R&D consortia policy if the policy was implemented. The R&D consortia policy would drive up the Malaysia productivity and GDP per capita, which make Malaysia more attractive for foreign investment.

Vietnam

Vietnam is an interesting case to study the effect of the R&D consortia policy if the policy had been implemented in the past because the foreign investment into Vietnam jumped since 2006 which indicates that foreign investors started to perceive Vietnam as an investment opportunity and the foreign investment barrier in Vietnam was reduced in 2006. Even though foreign investment was limited in 2000, the productivity of Vietnam could have grown significantly from the R&D consortia policy as shown in Figure 36.

Because of the increase in productivity from the R&D consortia policy as discussed before, Vietnam's population on average gained better income which is indicated by the higher GDP per capita in Figure 37.

Even though the actual FDI started to be significant from 2006, the model does not incorporate the business environment that limited the inflow of FDI before 2006. Instead, we assume that the business environment outside the model boundary does not change during the simulation period. Based on the unchanged business environment, FDI in Vietnam would increase significantly if the R&D consortia policy had been implemented in 2000 as shown in Figure 38

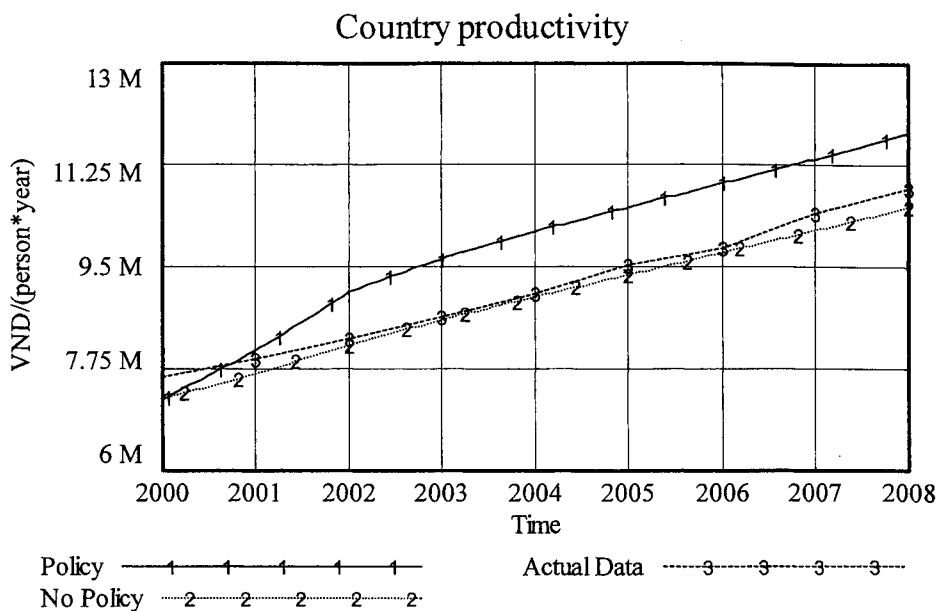


Figure 36: Comparison between the productivity of Vietnam with and without the R&D consortia policy and the actual data

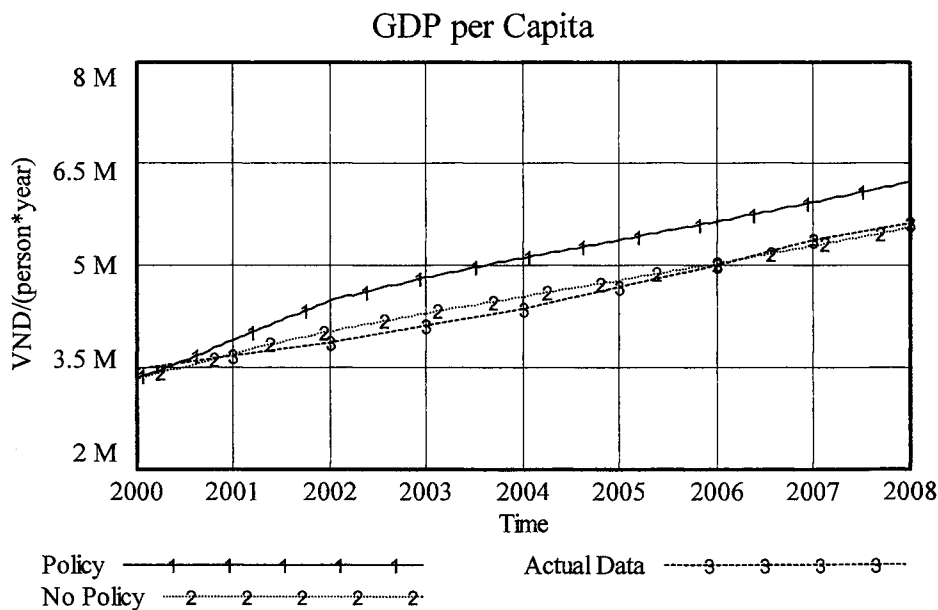


Figure 37: Comparison between the GDP per capita of Vietnam with and without the R&D consortia policy and the actual data

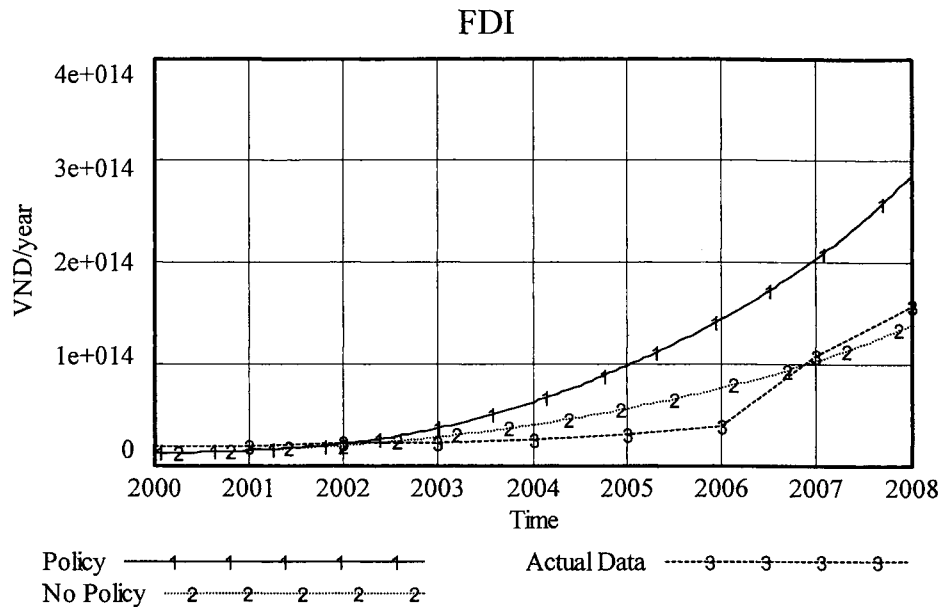


Figure 38: Comparison between the FDI of Vietnam with and without the R&D consortia policy and the actual data

Generalization of the effect of the R&D consortia policy if the policy had been implemented in the past

The study on the effect of the R&D consortia policy on productivity growth from technology spillover through FDI in the Southeast Asia region if the policy had been implemented in the past generally shows the benefits of the policy on the economy and well-being of population in Thailand, Malaysia, and Vietnam. The R&D consortia policy could drive up the productivity of countries in Southeast Asia. An increase in productivity also increases the average income of the population in each country. Even though local companies become direct competitors of foreign firms due to higher

productivity, the higher average income also attracts more FDI because of the market opportunity.

CHAPTER 11: SENSITIVITY ANALYSIS ON THE EFFECT OF THE R&D

CONSORTIA POLICY IMPLEMENTATION PROCESS

Previous chapters demonstrated that the R&D consortia policy would have benefited Thailand, Malaysia, and Vietnam. However, in the previous analysis, the focus is mainly on the effect of the policy without considering the implementation process. The implementation process can affect the result of the policy as well as the policy itself. In this chapter, we focus the analysis on the implementation process of the R&D consortia policy by using sensitivity analysis method.

We focus on two dimensions of the policy implementation; implementation duration and the reaction of the foreign firms toward the R&D consortia policy implementation. It is not clear if the duration to implement the policy affects the result of the policy. Rapid changes can provoke strong resistance and can be costly but it may also instantly push the country into a better competitive position. In this analysis, we focus only on the effect on the policy with different implementation periods without considering the cost of implementation. If the different implementation periods create a significant change in the effect of the policy, it would be worth to further study the cost of implementation and compare the costs and the benefits. If the result is not significantly different, the government should implement the policy in a way that minimizes the implementation cost and resistance.

Another dimension to be studied is the reaction of foreign investors on the implementation of the R&D consortia policy. Sawada (2005) argued that MNEs are discouraged if the host country has higher level of technology leakage. MNEs may conclude that the technology leakage would increase from the R&D consortia policy. Thus, implementing the R&D consortia policy may create a negative effect on the decision making of foreign investors.

We study the effect of the R&D consortia policy implementation process on the Thailand model. The different implementation duration is implemented in the model by varying the policy implementation duration. The negative reaction of the policy implementation on FDI is studied by adjusting the coefficient of the FDI equation when the policy is implemented.

Implementation duration

We study the effect of implementation duration by altering the period to implement the policy in the model. We compare 3 cases of different implementation duration with the case “No Policy” as a base case with no R&D consortia policy implementation. “Policy” case is the scenario that the policy requires 8 iterations to be fully implemented which is the case that we considered in the previous chapters. “Short” and “Long” cases are the situation that the implementation duration lasts for 4 iterations and 12 iterations respectively.

The effects of different R&D consortia policy implementation periods on the result of the policy in Thailand are presented in Figure 39, Figure 40, and Figure 41. The implementation duration affects the country productivity and GDP per capita in the short

term. However, the difference becomes narrower in the long term. To be specific, short implementation duration makes the country productivity and GDP per capita significantly higher than the long implementation duration.

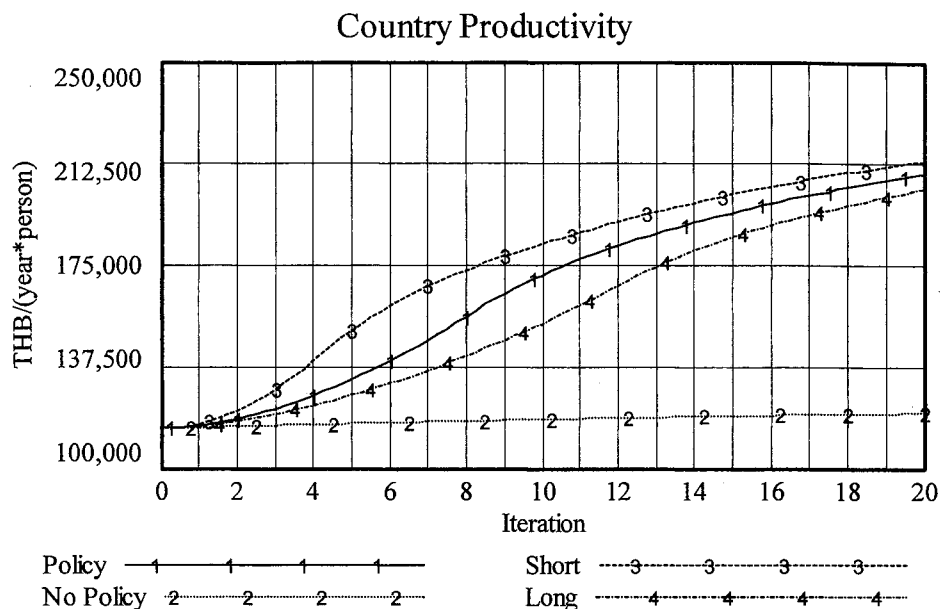


Figure 39: Effect of the implementation duration of the R&D consortia policy on the productivity of the country

The effect of the implementation periods on the FDI is not significant in the short term but in the long term it is significant as shown in Figure 41. The effect of the implementation duration is unclear in the short term because of the delay time between the policy implementation and the effect of the policy on FDI as discussed in previous chapters.

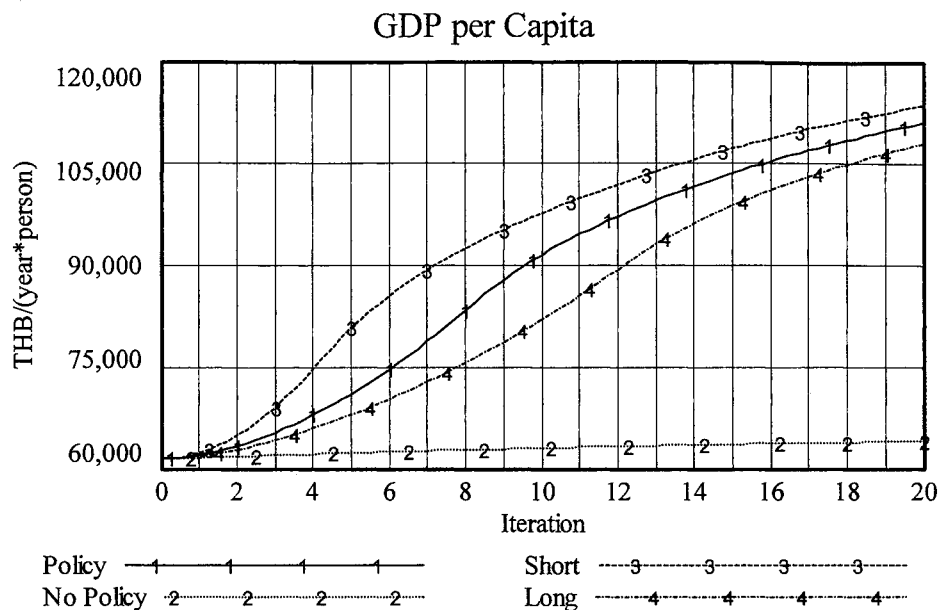


Figure 40: Effect of the implementation duration of the R&D consortia policy on the GDP per capita

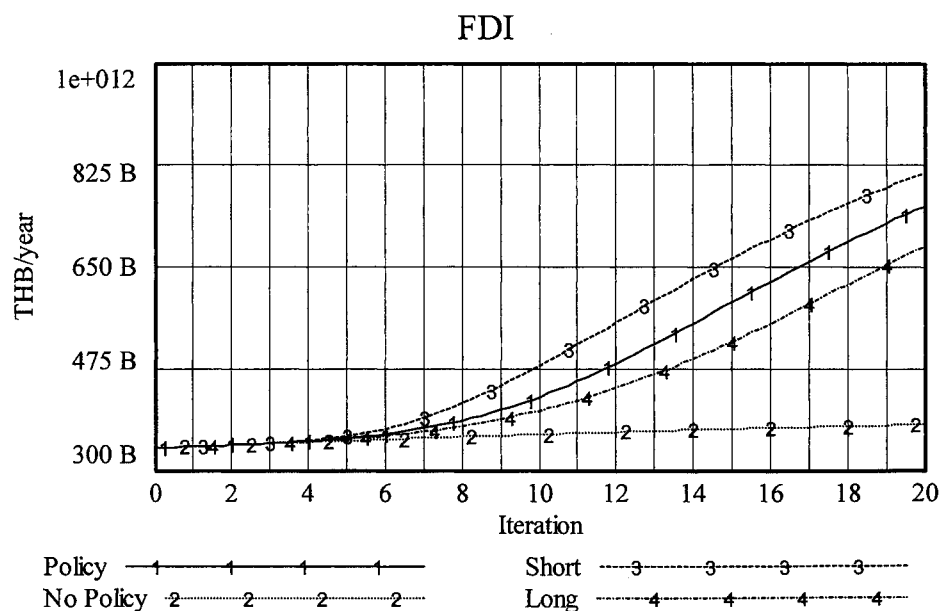


Figure 41: Effect of the implementation duration of the R&D consortia policy on the FDI

The underlining reason of the significant effect of the implementation periods on the country's economy in the short term and insignificant effect in the long term can be examined through the first-order difference of the variable in the system. In this study, we observe the change of the GDP growth as presented in Figure 42. The growth of the variables grows faster if the policy is implemented in a short period. However, the growth rate also drops faster than if the policy is implemented in a long period when it passes the peak growth rate. Therefore, the difference in policy implementation time has less effect in the long term than in the short term.

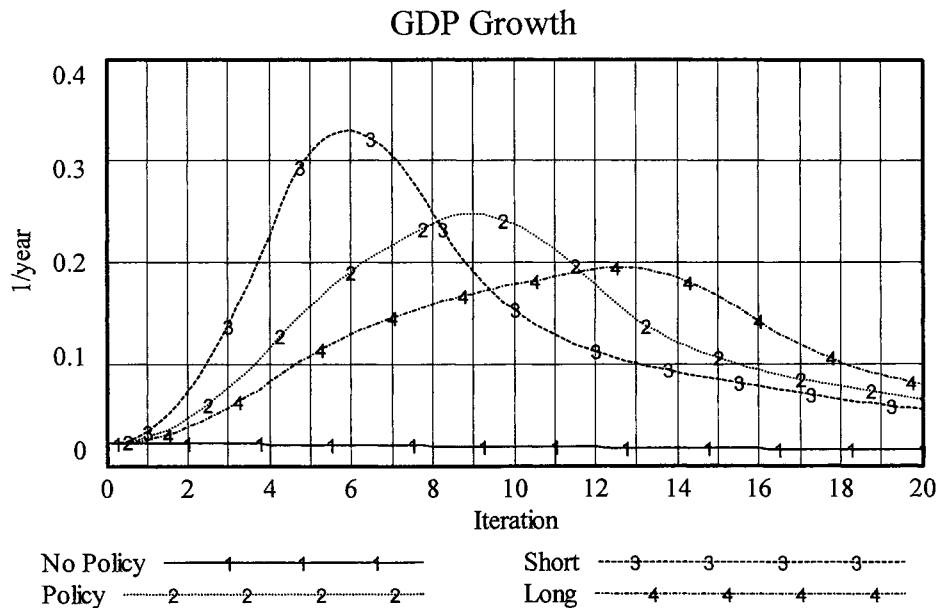


Figure 42: Effect of the implementation duration of the R&D consortia policy on the GDP growth

In summary, implementing the R&D consortia policy using different policy implementation duration creates a different outcome. With faster implementation, the

country can gain more benefits in term of higher country productivity, GDP per capita, and FDI. However, the advantage the country obtains from faster implementation process is obvious only in the short term. In the long term, the level of productivity, GDP per capita, and FDI with different implementation duration converge. Therefore, the duration of implementation should be justified based on the priority of the short-term goal instead of the long-term goal.

Reaction of foreign investors toward R&D consortia implementation

There is an argument that with high technology spillover, FDI is reduced because foreign firms incur additional costs from preventing the technology leakage (Sawada, 2005). The implementation of the R&D consortia policy may results in foreign firms concluding that the level of technology leakage is going to increase. Thus, based on Sawada's argument, FDI may drop if the R&D consortia policy is implemented. In order to demonstrate the reaction of MNEs investment, we compare the effect from implementing the R&D consortia policy with and without any negative reaction and the case in which the R&D consortia policy is not implemented at all. For the simulation with the negative reaction, we examine 2 scenarios – “Weak” and “Strong”. The “Weak” case is the case in which the negative effect reduces the volume of FDI by 5%, and for the “Strong” case the volume of FDI is reduced by 10% when the R&D consortia policy is implemented.

In the case of weak negative reaction, we assume that MNEs have concluded that the Intellectual Property Rights violation and the technology leakage are minimal. However, the strong case is based on the opposite assumption of the MNEs' conclusion.

In this case, the FDI is reduced from a strong expectation of technology leakage due to the lack of the Intellectual Property Rights enforcement.

From the result, the negative reaction of MNEs from implementing the R&D consortia policy does not create a difference in the effect of implementing the R&D consortia policy on country productivity and GDP per capita as shown in Figure 43 and Figure 44 even though the FDI volume is different as presented in Figure 45.

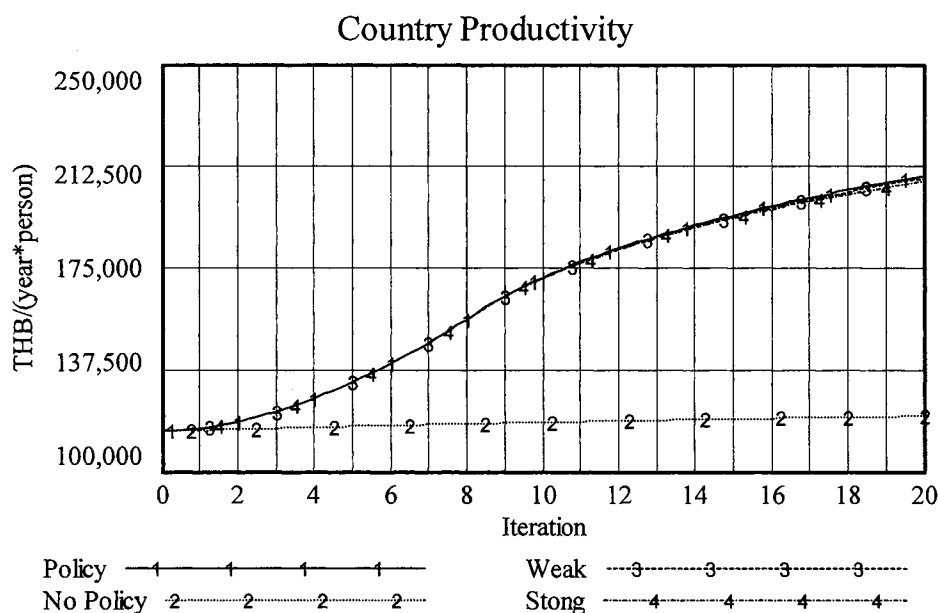


Figure 43: Effect of the negative reaction from MNEs on the country's productivity when implementing the R&D consortia policy

The result of the negative reaction from foreign firms on FDI is not unexpected. The strong negative reaction pulls down the FDI volume and the volume of FDI is highest if the negative reaction is not considered as shown in Figure 45. However, even though the volume of FDI is reduced by 10% ("Strong" case) when implementing the

R&D consortia policy, Thailand still gains significant benefits from having more FDI inflows in the long term.

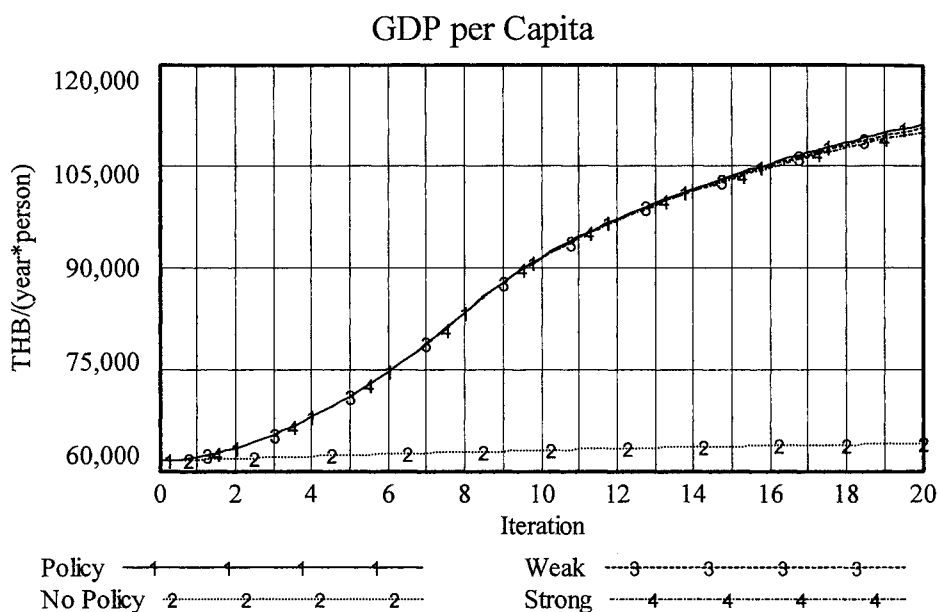


Figure 44: Effect of the negative reaction from MNEs on the GDP per capita when implementing the R&D consortia policy

Even though the negative reaction from foreign firms reduces the inflow of FDI, the productivity and GDP per capita receive no effect from it because of the fixed capital as presented in Figure 46. The amount of fixed capital in Thailand does not change significantly even though a difference in FDI is significant because the new fixed capital investment is small compared to the existing stock of fixed capital.

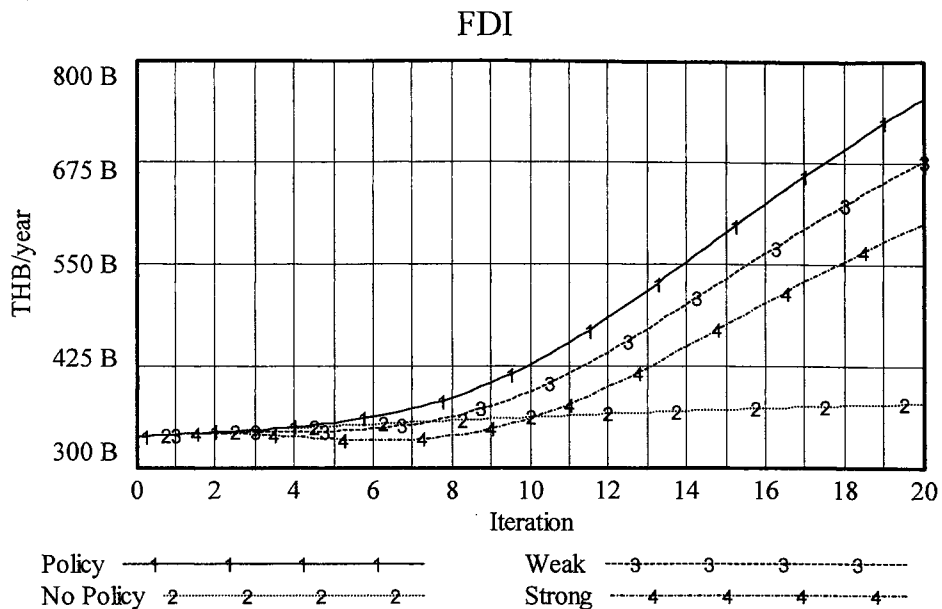


Figure 45: Effect of the negative reaction from MNEs on the FDI when implementing the R&D consortia policy

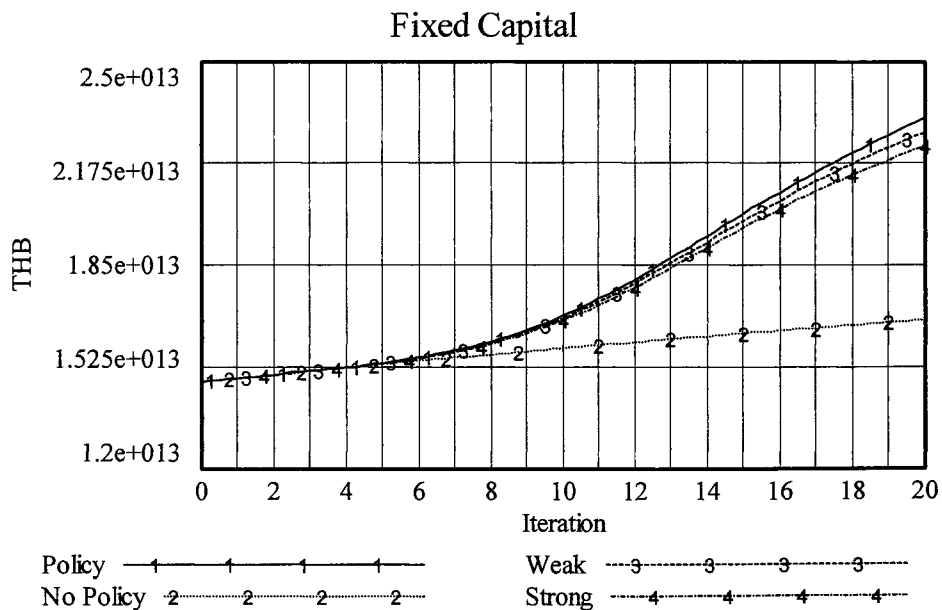


Figure 46: Comparison of the fixed capital of Thailand when implemented the R&D consortia policy with different negative reaction from MNEs

In summary, the negative reaction from foreign firms when implementing the R&D consortia policy reduces the benefits that the country gains from implementing the R&D consortia policy. However, the drop in the FDI value is not significant compared to the total amount of FDI inflow. Even though the FDI slightly dropped, the effect on country productivity and GDP per capita is nearly eliminated because it is absorbed by the fixed capital. Therefore, the consequence of the negative reaction on the benefits that the country obtains from implementing the R&D consortia policy is insignificant.

CHAPTER 12: CONCLUSION

This paper studies the effect of the R&D consortia policy on productivity growth from technology spillover through foreign direct investment in the Southeast Asia region under the dynamic and system approach. This study opens a new perspective in the field of technology spillover from FDI for several reasons. First, the majority of the research on technology spillover focuses on the static view which can only observe the situation as a snap-shot picture. The problem of the snap-shot approach is that it is impossible to understand the development and evolution of the situation over time. In this paper we utilize the dynamics approach which provides the change of the situation at every step within the study period. Second, most of the literature in the field utilizes the linear open-loop approach which studies only the effect of FDI on technology spillover without considering the feedback effect of technology spillover on the FDI. This open-loop approach becomes a major weakness in many papers because the recommendations may provide the opposite results when considering the whole cause and effect loop. Last but not least, this paper analyzes the effect of the R&D consortia policy in the Southeast Asia region which, based on my knowledge, has not been conducted before. One reason behind the lack of research on the R&D consortia policy in the Southeast Asia region is that such a policy has not been implemented in this region before and thus it is impossible to conduct an empirical research on this topic. However, this paper applies the system dynamics method which studies a situation from the simulation developed from the cause

and effect relationship. The system dynamics approach allows us to analyze the possible outcomes from the implementation of the policies that have been utilized in different environment even though they have not been applied in these specific environments.

The study starts from developing a foundation model structure of the productivity growth from technology spillover through FDI using the cause and effect relationship. The developed model has been tested for correctness, accuracy, and robustness by using the dimension consistency method, the behavior reproduction test, the family member method, the surprise behavior method, and the model forecastability method. The foundation structure then is applied to the situation of Thailand, Malaysia, and Vietnam as representative countries in the Southeast Asia region. The coefficients to be input in the model are acquired from the empirical data of Thailand, Malaysia, and Vietnam. The simulation results from the models for Thailand, Malaysia, and Vietnam are also compared to the empirical data to validate the results of the model as well as to check the accuracy of the model. These models are used as the foundation to analyze the effect of the R&D consortia policy on productivity growth from technology spillover through FDI in Thailand, Malaysia, and Vietnam. The model is also applied to the situation in Japan in order to study the behavior of the system of a country in which the R&D consortia policy has already been implemented and also to capture the effect of the R&D consortia policy on each variable in the system. After obtaining the coefficients of the effect of the R&D consortia policy on productivity growth from technology spillover in Japan, these coefficients are implemented into the models for Thailand, Malaysia, and Vietnam to represent what would happen if these three countries utilize the R&D consortia policy. The results are compared to the normal situation in which the R&D consortia policy is

not implemented in order to understand the effect of the R&D consortia policy on productivity growth from technology spillover through FDI in Thailand, Malaysia, and Vietnam. The similarity of the results of these three countries is summarized as the effect of the R&D consortia policy on productivity growth from technology spillover through FDI in the Southeast Asia region.

The simulation results for Thailand, Malaysia, Vietnam, and Japan show that the model can significantly trace the change of the variables that affect the productivity growth from technology spillover through FDI which consists of the productivity of the country, the productivity of foreign country which is selected from the country that has the highest inward FDI share, gross domestic product, GDP per capita, FDI, fixed capital, employment, and population. After implementing the coefficient of the effect of the R&D consortia policy on productivity growth from technology spillover through FDI which is obtained from Japan's model into the models for Thailand, Malaysia, and Vietnam, the results show that all three countries have a significant growth in the productivity of the country. Therefore, it is proved that the R&D consortia policy can improve the productivity growth from technology spillover through FDI in the countries in the Southeast Asia region.

There is a debate that higher technology spillover will block the growth of FDI because foreign investors consider the chance of losing their technology knowledge as an extra cost of operations (Sawada, 2005). This is reasonable if we consider only a one-way relationship which is the effect of technology spillover on FDI. However, the results in this paper show the opposite consequence of higher technology spillover. The technology spillover increases the productivity of the host country which in turn supports the growth

of the people's income. With higher incomes, the host country becomes more attractive for foreign investment as an expanding market opportunity. When compensating the new market opportunity with an increase in cost to prevent the technology spillover, foreign firms still gain benefits from investing in these countries. Therefore, technology spillover increases the FDI through market expansion. As FDI grows, the host countries also get benefits from higher technology spillover as well as more employment and capital investment which create feedbacks to increase the productivity of the country. This works as a closed-loop reinforcing system that drives the economy of host countries up in both the short term and the long term.

The benefits that the country receives from implementing the R&D consortia policy varies based on the economic situation and the risk of the country. The country with mature economy gains higher productivity growth but receive less additional FDI from the R&D consortia policy while the country with rapidly growing economy gains less productivity growth but receive higher inflow FDI. The country with higher risk requires a longer time for the effect of the R&D consortia policy on FDI to happen because foreign investors take longer time to make an investment decision.

The R&D consortia policy implementation process is also affected to the result of the policy. We focus on the effect of policy implementation duration and negative reaction from foreign firms concluding that the technology leakage will increase. Having a fast implementation process provides more benefits to the country than prolonging the process. However, the difference in benefits from shortening the implementation time is significant only in the short term. In the long term, the benefits gap from different implementation time is reduced.

The negative reaction from foreign firms reduces the value of FDI. However, the effect of having low FDI is diminished by the fixed capital because the reduction in additional fixed capital investment is not significant compared to the stock of fixed capital. Therefore, the consequence of the negative reaction on the country productivity and GDP per capita is small.

The policy implication from this research is clear that the governments of the countries in the Southeast Asia region should implement the R&D consortia policy because it will improve the productivity growth of the country as well as the wealth of people in that country and FDI. However, the results do not suggest that the government should implement the policy at all cost. The key factor that drives up all the improvement from the R&D consortia policy is the productivity growth. The R&D consortia policy will increase productivity, average population income, and FDI in both the short term and the long term only if the R&D consortia policy pushes the productivity up from the start. Therefore, if the policy implementation process involves a significant reduction in the productivity of the firms, the R&D consortia policy should be re-analyzed. However, if the implementation process of the R&D consortia policy consists of having lower FDI, the R&D consortia should still be implemented because the higher productivity growth from the R&D consortia policy will drive up the country GDP per capita which then attracts more FDI.

Every research has limitations, including this dissertation. One of the limitations is that there are some country factors that may affect the decision making of foreign investment. These factors include the economic and political situation of the country, exchange rate, interest rate, the degree of government intervention, and corruption and

transparency level. The results may also differ according to the industrial characteristics. Besides, this study is conveyed on the macro level and thus the results are the average results of every firm in every industry. The results on each firm in a different industry may vary and would need the firm-level and industry-level analysis if the detail results are required. Using Japan as the only country to represent a country with the R&D consortia policy is also another limitation of this paper. Some country-specific factors may have an influence on the effect of the R&D consortia policy on technology spillover. By comparing and contrasting several different countries which already implemented the R&D consortia policy would eliminate the effect of these country-specific factors. Another interesting issue to be study is the effect of delay period between policy implementation and the result. Because it takes significant time for FDI to grow from the R&D consortia policy, it may raise a question among the implementers if the policy is effective especially if the negative reaction from foreign firms is strong. The government that concentrates on short-term result may pull out the R&D consortia implementation process which may create an unexpected result. Therefore, the goal and behavior of the government is interesting to be considered.

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