Journal of Economic Cooperation and Development, **36**, 2 (2015), 125-154

Analysis of International R&D Spillover from International Trade and Foreign Direct Investment Channel: Evidence from Asian Newly Industrialized Countries

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This research tries to explain the relation between international R&D spillover from international trade and FDI channel with productivity (TFP) based on endogenous growth theory in Asian Newly Industrialized Countries (ANIC) in period 1990 - 2010. In this research, it is found that R&D spillover is a significant factor in increasing TFP, especially from trade channel. It is also found that the availability of educated workers is another important factor in increasing productivity. From the comparison of the two country groups in ANIC, it is found that in ANIC Tier 2, international R&D spillover from export is not increasing productivity, yet its spillover effect is still significant. Another finding of this research is FDI is not an important channel for technology spillover. However, there is a need to further discuss the FDI spillover measurement.

1. Introduction

The basic of economic growth theory is continuous output per capita growth in the long term. In this case, first theory of economic growth, neoclassical economic growth, created by Solow and Swan (1956) presume that technological innovation is an exogenous factor and capital accumulation does not have diminishing returns in certain technological level. The development of neoclassical economic growth theory, which is endogenous economic growth theorem, tries to explain other factors that cannot be explained by exogenous growth theorem, such as technological advancement and innovation as important variables for economic growth (Romer, 1990) and human capital (Hanushek and Kimko, 2000 and Spiegel and Benhabib, 1994). Similar to technological advancement, other factors, such as international relation and

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globalization, are also significantly affecting economic growth based on endogenous growth model (Coe and Helpman, 1995).

Focusing on the technological advancement, there are two channels that causing an increase in countries' technological advancement. The first channel is research and development from own country (Domestic R&D) and spillover effect that was brought from connecting with other countries (Wei and Liu, 2006). Spillover effect from other countries is caused by the non-rivalry characteristics from technology itself, which means technology can be spread to other regions voluntarily, this is called spillover process. This spillover process occurs when there are international trade and Foreign Direct Investment (FDI) between technology-giver country and technology-receiver country.

However, as the endogenous economic growth theorem said that technological advancement is an important factor for economic growth, there is significant difference in how the countries push their technological advancement, mainly from the R&D expenditure spent from the countries. Based on UNESCO data, it is found that R&D expenditure from the world is concentrated in developed countries, mainly OECD countries, as approximately 92% of R&D expenditure in year 1996 is from OECD countries. This percentage also does not change significantly over year and the proportion is literally the same as year 1996.

Therefore, it can be concluded that innovation and technological advancement concentrate on developed countries. This fact is particularly true because those countries became developed countries and industrialized while spending much on R&D expenditure, thus increasing economic growth, as the endogenous growth theorem stated. However, this fact rises up another question on how other countries can develop themselves to a degree where those countries are on par with developed countries while majority of the technological advancement is dominated by developed countries.

In fact, several countries have catch up effect and make their economies on par with those from developed countries category (Okabe, 2002). This research points out Asian Newly Industrialized Countries (ANIC) classification from UNCTAD, as the example for developing countries that have catch up effect, especially on ANIC tier 1 (Hong Kong, Singapore, and South Korea), which start industrializing earlier than ANIC tier 2 (Indonesia, Malaysia, Philippines, and Thailand). From UNESCO data, it is shown that ANIC have 3 percent share of world R&D expenditure, with tier 1 is dominating while tier 2's share is very small. While this 3% share is significantly large comparing to the share of other countries in the world, which only accounts for 5%, it is still very small comparing to R&D expenditure of OECD countries, especially G7 countries (France, Canada, Germany, Italy, Japan, United Kingdom, and United States of America).

From World Bank data, it is shown that ANIC, both from tier 1 and tier 2 in period 1990 - 2010, have high GDP growth ranging around 4% – 8% per year, which is higher than the average GDP growth from G7 countries, which ranging between 1% and 4%, or below 4%, per year. This high GDP growth is also supported by high export in manufactured goods. From these facts, there is anomaly in Asian Newly Industrialized Countries as ANIC have low R&D expenditure, especially tier 2, the economic growth from those countries are high, and higher than G7 countries, which have far more R&D expenditure and technological advancement. This is also supported by the growth of manufacturing industry, which is described in high export of manufactred goods.

As for the international R&D indicators, this research focuses in R&D spillover from G7 countries as the world technological advancement is dominated by these countries. Because of the large share of world R&D expenditure, there is also probability that indirect spillover can happen to other countries as the technologies from G7 countries spread and used in all over the world (Coe and Helpman, 1995).

There is also strong connection between G7 countries and ANIC, as shown in trade relation. From table 1, it is found that import share from G7 countries is high, especially in ANIC tier 2 (with average of 50% share in year 1996) and South Korea with 72.32% share in year 1996. Even though the share is gradually declining over time, as shown by the table in year 2000 and 2010, the share of import is still high. There is also another fact that is shown in this graph, three dominating countries in R&D expenditure of G7 countries, which are USA, Japan, and Germany, have large import share to Asian Newly Industrialized Economies. In year 1990, import share from Germany is ranging from 2% to 7%, import share from Japan is ranging from 16% to 30%, while import share from USA is ranging from 8% to 27%. Although the share is declining in year 2000 and 2010, these three countries still hold as three largest share in ANIC' share of import. This condition can further induce R&D spillover from technology leader countries and benefitting to the economic growth.

Table 1: Import Share of Total Import from G7 Countries

Share of total import								
Year 1990	**Canada**	**Germany**	**France**	**UK**	**Italy**	**Japan**	**USA**	**Total**
Indonesia	1.86%	6.88%	2.95%	2.01%	1.88%	24.27%	11.54%	51.38%
Malaysia	0.93%	4.51%	1.38%	3.76%	1.45%	25.29%	17.57%	54.89%
Philippines	1.48%	4.30%	1.23%	2.04%	0.72%	18.39%	19.53%	47.69%
Thailand	1.12%	4.87%	2.44%	2.69%	1.26%	30.60%	10.87%	53.85%
Hong Kong	0.42%	2.31%	1.39%	2.20%	1.69%	16.09%	8.07%	32.15%
Singapore	0.51%	3.10%	2.10%	2.69%	1.38%	17.50%	13.98%	41.27%
S. Korea	2.41%	5.40%	2.02%	2.02%	1.93%	30.61%	27.93%	72.32%
Year 2000	**Canada**	**Germany**	**France**	**UK**	**Italy**	**Japan**	**USA**	**Total**
Indonesia	1.92%	3.75%	1.21%	1.68%	1.04%	16.25%	10.21%	36.06%
Malaysia	0.47%	3.03%	1.68%	1.98%	0.68%	21.33%	16.96%	46.15%
Philippines	0.68%	2.18%	1.06%	1.05%	0.54%	18.83%	18.45%	42.80%
Thailand	0.57%	3.14%	1.28%	1.48%	0.92%	25.22%	12.01%	44.61%
Hong Kong	0.66%	1.94%	0.94%	1.86%	1.34%	12.00%	6.81%	25.55%
Singapore	0.30%	2.67%	1.38%	1.73%	1.05%	14.51%	12.81%	34.46%
S. Korea	1.56%	3.43%	1.67%	1.52%	1.22%	23.72%	21.83%	54.96%
Year 2010	**Canada**	**Germany**	**France**	**UK**	**Italy**	**Japan**	**USA**	**Total**
Indonesia	0.82%	2.22%	0.99%	0.69%	0.67%	12.51%	6.95%	24.85%
Malaysia	0.55%	4.09%	1.20%	1.12%	0.87%	12.70%	10.78%	31.31%
Philippines	0.79%	2.04%	1.20%	0.52%	0.39%	12.14%	10.90%	27.98%
Thailand	0.48%	2.66%	0.84%	1.08%	0.84%	21.65%	6.09%	33.63%
Hong Kong	0.36%	1.71%	0.89%	1.18%	1.05%	9.16%	5.38%	19.74%
Singapore	0.34%	2.90%	2.42%	1.82%	0.92%	7.75%	11.60%	27.75%
S. Korea	1.03%	3.31%	1.01%	0.77%	0.88%	15.09%	9.57%	31.67%

Source: Data taken from World Integrated Trade Solution (WITS), World Bank

As in endogenous growth theorem, technological advancement is an important factor for economic growth of a country, as the cases are clearly seen in G7 countries' development. However, there are several developing countries that have catch up effect towards developed countries, namely Asian Newly Industrialized Countries, which have higher growth and export oriented economies while do not have much of domestic R&D expenditure. This case indicates that there are several factors in affecting economic growth beside own technological development. This research will focus on R&D spillover as outer factor that affects economic growth, while there are also several facts that indicates R&D spillover to ANIC.

While there are several facts that are supporting international R&D spillover's role and its importance in ANIC economic growth, as stated in the background, there is still unclear evidence in the interaction between international R&D spillover and economic growth. As the economic growth of ANIC is gradually increasing, there is an importance to observe determinants that cause high economic growth in ANIC. There is also an importance, especially for ANIC tier 2, to know whether high economic growth experienced at this time is also increasing their productivity or not in order to achieve long run economic growth.

From the existing researches, there are lacks of R&D spillover study in developing countries, especially developing countries in Asia. Many literatures are focused on OECD countries and trade channel, with G7 as the center of spillover, such as Coe and Helpman (1994) 22 OECD countries with period of 1971 to 1990, and Xu and Wang (2000) 21 OECD countries with the same period and FDI channel as an addition. Although there are several literatures that focused on developing countries, they are usually aggregates all of the developing countries without focusing on several country groups that may have different aspect towards R&D spillover (Falvey, et al, 2002, and Coe, et al, 1997). The closest research is from Okabe (2002), which observes developing countries in East Asia from year 1976 to 1996.

This research will carry out a difference in the terms of observed countries, time period, and research scope. Asian Newly Industrialized Countries, both from tier 1 and tier 2, are used for countries observation in this research with time period of 1990 – 2010, and also the comparison between ANIC tier 1 and tier 2. Period of 1990 – 2010 is used because this research takes account of high and steady economic growth after 1998 financial crisis and the industrializing and trade openness of ANIC tier 2 after crisis, also for ANIC tier 1 that have start to develop their own technological advancement in that period.

In the end of the observation, there is also partial observation between ANIC tier 1 and tier 2 to compare the effect of international R&D spillover separately because of these countries have different stage of development.

2. Literature Review

The first attempt to endogenize technology is AK model. Assuming that labor grows proportionally to capital, the production function can be written as:

$$Y = F(K, L) = \min\{AK, BL\}$$

Where A and B are the fixed coefficients. Under this technology, producing a unit of output requires $1/A$ units of capital and $1/B$ units of labor; if either inputs fall short of this minimum requirement there is no way to compensate by substituting the other input.

In a fixed coefficient technology, when $AK < BL$, capital is the limitational factor. Firms will produce the amount of $Y = AK$, and hire the amount $(1/B)Y = (1/B)AK < L$ of labor. With a fixed saving rate, the capital stock will grow according to:

$$\dot{K} = sAK - \delta K$$

Thus the growth rate of capital will be:

$$g = \frac{\dot{K}}{K} = sA - \delta$$

In this case, output is strictly proportional to capital and g will also be the rate of growth of output, $g - n$ will be the growth rate of output per person.

From this model, an increase in saving propensity s will raise output growth g. However, if output per person ($g - n$) is rising, the growth will not be permanent because when K is growing faster than L, there is a binding constraint to output from the availability of labor as K grows proportionally with *L*. Beyond that point there will be no more possibility of growth per capita output. However, if output per person is falling, the increase in growth resulting from an increase in saving will be permanent. In this case, diminishing returns will never set because growth of capital is accompanied by faster growth of labor input, which is possible because there is always a surplus of unemployed labor in economy.

Romer (1990) further developed production function model with accounting spillover effect in the formula. With an introduction of imperfect competition because of monopoly rents in intermediate goods sector, it allows firms to be represented as engaging in research activities aimed at creating new knowledge and compensated by monopoly rents. Therefore, Romer extended the model by assuming that in order to enter a new intermediate sector; firms must pay a sunk cost of product development, whose outlay is compensated with monopoly rents. Monopoly rents come from the existence of fixed production costs of increasing returns in intermediate goods sector. Due to the presence of these costs, intermediate goods sector is assumed monopolistically competitive.

Final output is produced using labor and intermediate goods. However, labor is divided into two in this new function as labor used in manufacturing the final good and labor used in research. Furthermore, Romer showed that technological knowledge is **nonrival goods** because all research activities can be used by other intermediate firms, indicating knowledge spillover. However, according to this theory, knowledge is **excludable** because intermediate firms must pay for exclusive use of new designs. In conclusion, there are two major sources of increasing returns in Romer model, which are specialization or product differentiation and research spillovers.

Grossman and Helpman (1990) developed a model for spillover effect based on production function theories that have been stated above. With the assumption that knowledge is public good, the characteristics of knowledge are **non-rivalry** because the same idea can be used in different applications and locations at the same time and **non-excludable** in many cases because the originators of the idea may have difficulty in extracting compensation from all agents that make use of it. There are three outcomes from this theory: First, the relative importance of international trade spillovers as the source for accumulation of domestic knowledge capital declines over time. In the long run, cumulative trade experience makes negligible contribution compared to contribution by cumulative local research. Second, the knowledge gained from trade continues to drive growth in the long run. Third, both volume of trade and number of varieties grow at the rate of g in the long run equilibrium.

Flying Geese Model (Kojima, 2000) describes the relation in dynamic comparative advantage between countries and the industrialization phase in countries. Basic fundamental pattern for Flying Geese Model is the sequence of import (M), domestic production (P), and export (E) occurred in a certain industry.

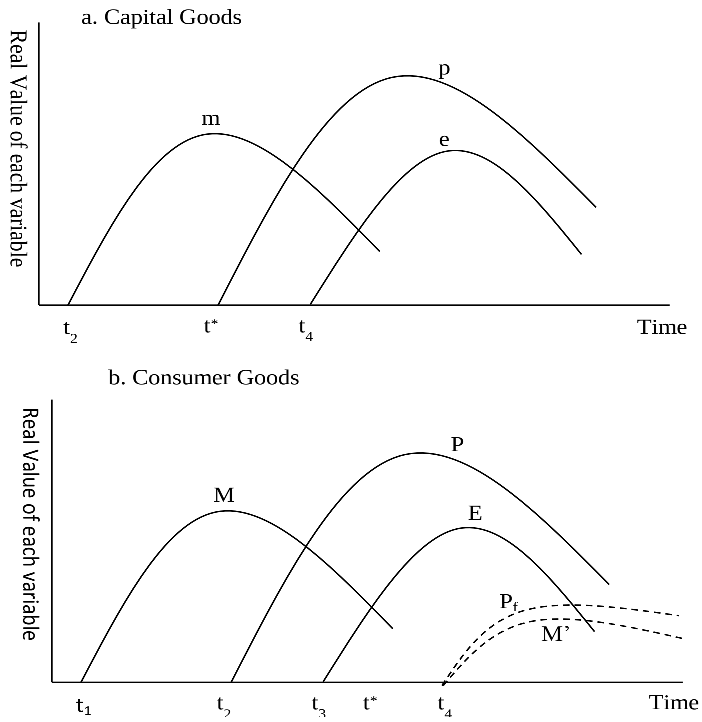
Flying Geese Model is divided into four stages of growth, Stage I is when an underdeveloped nation first enters the international economy, the primary products, which are its specialties, are exported and industrial products for consumption are imported from advanced nations. In figure 1, it described in t_1 period when the consumer goods import curve (M) starts.

Stage II started at period t_2, when domestic production of imported goods is initiated, with the domestic market as the target because of increasing purchasing power makes domestic production is profitable. There is also imported capital drawn into the activity. In figure 1, domestic production is showed by P curve initiates at t_2 in 1b and imported capital is showed by m curve which initiates at the same period in 1a.

In Stage III, domestic consumer goods industry develops into export industry. By this time most of the domestic markets have turned for domestic industrial goods. As production is put on larger scale for mass production and exported in increasing numbers to overseas markets. As for foreign capital goods, is slowly substituted to domestic capital goods and foreign capital goods begin to decline. In figure 1, period t_3 is when the Stage III started. At this period, consumer goods produced begin to be exported as the E curve starts. Around period t*, domestic demand is fully covered by domestic production as D = P – E + M, and M curve intersects with E curve, creating trade in balance. Also in this period, capital goods are started to be produced domestically, substituting foreign capital goods.

In the last Stage IV, the country is started to become a developed country at period t_4. This can be seen from figure 1 that the country started to make offshore production in P_f curve and importing the consumer goods from less developed countries where the country offshores its industry, this is called reverse import. Meanwhile, this country now exporting capital goods at t_4 period as showed in e curve. Kojima called this whole stage IV process as “Pro-trade oriented FDI” because host country gives technology and capital to less developed countries, thus enhancing the comparative advantage from less developed countries, while for the host country, capital used in manufacturing former consumer goods can be reallocated to other consumer goods which enhancing new comparative advantage of host country. In conclusion, this FDI process augments comparative advantages in both countries.

Figure 1: Flying Geese Model of Industrial Development



Source: Kojima (2000), graph is redrawn

While flying geese model is not indirectly observe spillover effect between countries, it is clearly stated in the description that more developed countries tend to share their knowledge and technology through investment and trade, making catch-up effect from less developed countries, and those less developed countries started to industrialize and share the knowledge even further to other less developed countries.

First empirical test for the spillover effect is done by Coe and Helpman (1994) by observing only trade channel from the spillover. Countries observed in this research are from 21 OECD countries plus Israel with period of 1971 – 1990. By using domestic R&D Capital Stock and Foreign R&D Capital Stock, this research also compares the effect between domestic knowledge and international R&D spillover. It turns out that both of the domestic R&D stock and foreign R&D stock is significantly positive against productivity, which measures by TFP. However, it is found that domestic R&D has larger effect in G7 countries than in other OECD countries.

Coe, Helpman, and Hoffmaister (1997) observe the effect international R&D spillover in 77 developing countries using the same period as the research above. It is important to notice that this research does not use domestic R&D stock as the independent variable because of the lack of data and the portion is too small, thus they assume that domestic R&D stock is negligible in developing countries. In addition, they also use bilateral import of machinery (SITC7) instead of overall import because R&D spillover is more clearly generated from those goods, and they also add secondary enrolment ratio as a proxy to educated-workers. The weighting they used is from 22 OECD countries instead of only G7 countries. Similar to the other results, international R&D spillover is important to developing countries. In addition, educated workers have also become an important factor in affecting productivity.

Okabe (2002) observes international R&D spillovers from Newly Industrialized Asian Countries from year 1976 – 1996. Variables used in this research are spillovers from trade, royalty fee ratio of GDP, education expenditure ratio, and interaction of trade spillovers with import share of GDP, FDI inflows share of GDP, and export of intensive goods share of GDP. This research estimates the model from each countries and overall observation. Education expenditure ratio used in this research is to proxy domestic knowledge and although there is no R&D spillover from FDI channel, this research interacts FDI inflows with trade spillover to observe the effect of FDI channel. The result is similar to other researches, that international R&D spillovers increase TFP on observed countries and international R&D spillovers are correlated with international trade, especially manufacture goods. Also, this research also concluded that international R&D spillovers increase economic growth from trade expansion.

de la Potterie and Lichtenberg (2001) observe international R&D spillover solely from FDI channel. The observation for this research uses 13 OECD countries and period from 1971 – 1990. The independent variables used are domestic R&D and foreign R&D with FDI as the indicators and interaction with inflow and outflow FDI. It is found that outward FDI flow and import flow is important spillover channels, even for industrialized countries, inward FDI is not significant because inward FDI tends to capture the technology of host country than share the technology from home country. USA is an important spillover generator, and Japan gets large benefit from foreign R&D but gives little spillover effect.

3. Method

Assuming that Cobb Douglas Production Function can represent the production process, this function is used in calculating Total Factor Productivity. Output in Cobb-Douglas Production Function is calculated from two factors, which are Physical Capital Stock (K) and Labor Force (L), the latter function is written as:

$$Y = A_t K_t^{\alpha} L_t^{1-\alpha}, \quad 0 < \alpha < 1$$

Y_t is Real Gross Domestic Product, K_t is physical capital stock, L_t is labor force, and A_t signifies Total Factor Productivity (TFP), which can be explained as other factors that is not embodied in the physical capital stock and labor force, which can be defined as technological progress in this research. Therefore, the Cobb-Douglas Production Function can be rewritten to calculate the TFP as:

$$TFP_t = \frac{Y_t}{K_t^{\alpha} L_t^{1-\alpha}}$$

Assuming the producer decides the quantity of inputs order the cost minimization problem, the marginal productivity of capital equals the real rental price of capital, and the marginal productivity of labor equals the real wage rate. Therefore,

$$\frac{\partial F(A,K,L)}{\partial K} = r\,, \frac{\partial F(A,K,L)}{\partial L} = w$$

With the latter derivation, income share of capital can be concluded as $\frac{K}{Y} \times r$, where r is real rental price of capital and w is real wage rate. In order to calculate α for TFP, it is assumed that real rental price of capital is equal to sum of real interest rate and depreciation rate. Therefore, α can be described as $\frac{K}{Y} \times (r_i + \delta)$, where r_i is the real interest rate and δ is depreciation rate. According to Okabe (2002), δ is assumed to be 0.1 for calculation. A base year from the data is used to make TFP growth into indices with base year of 2000 as 1. TFP for other years is calculated from the change of TFP in other years toward year 2000. However, TFP will be calculated from its growth, thus TFP variable will be transformed into logarithm form. TFP growth will be denoted as TFPG in the model.

While TFP can be calculated using earlier formula, physical capital stock, marked as K in the formula, must be calculated from capital formation in order to construct TFP. Physical capital stock can be calculated from Real Fixed Capital Formation data from World Bank's World Development Indicators according to the perpetual inventory method. Physical capital stock, expressed in K_t, is described as:

$$K_t = I_t + (1 - \delta) \times K_{t-1}$$

The initial value of physical capital stock, expressed in K_o, is computed as:

$$K_o = \frac{I_o}{(g + \delta)}$$

Where I is the real fixed capital formation at the initial period, g is the average growth rate of the real fixed capital formation during 1990 – 2010, and δ is depreciation rate of capital stock, which is assumed to be 0.1 in this calculation.

International R&D Spillover, expressed as FRD, can be constructed from the weighted average of foreign R&D capital stocks, which are the foreign R&D stocks from G7 countries as the developed countries. The weights used in FRD calculation are the share of import amount to the G7 countries and the share of Foreign Direct Investment (FDI) inflows to sample countries[2] from G7 countries. Based on Coe et. al, 1997, the weighting measure is described as:

$$FRD_i = \sum_{k=1}^{7} \theta_{ik} RDS_k \quad , \qquad \sum_{k=1}^{7} \theta_{ik} = 1$$

From the formula, it is described that the sum of θ_{ik} as the weight equals to 1. θ_{ik} can be defined in two ways, first is derived from the trade channel. θ_{ik} is defined by bilateral import of sample countries *i* from G7 countries *k* divided by total of bilateral import of sample countries *i* from G7 countries. Thus, the share of bilateral import can be summed to one. Bilateral import data used in this research from World Integrated Trade Solution (WITS) by World Bank.

The second definition of θ_{ik} is derived from the foreign direct investment channel (*FRDI*). The share of foreign direct investment is calculated similar to trade channel, as θ_{ik} is defined by foreign direct investment inflows from G7 countries *k* to sample countries *i* divided by total foreign direct investment inflows of sample countries *i* from G7 countries. The share of bilateral FDI inflows can also be summed to one. Data used for foreign direct investment share is obtained from OECD Analytical Database.

Because of the lack of data for bilateral FDI, especially for non-OECD countries, FDI inflows data is obtained from the FDI outflows from each of G7 countries to sample countries *i*. However, there is a slight difference between the calculation of share via trade channel and foreign direct investment channel caused by the lack of data. There are missing observations in some countries, especially in Canada, where the FDI outflows observations to Newly Industrialized Asian Countries are absolutely missing. In order to overcome this problem, the share of FDI inflows of sample countries *i* are no longer using G7 countries as the

[2] Newly Industrialized Asian Countries (Hong Kong, South Korea, Singapore, Indonesia, Philippines, Malaysia, and Thailand).

partners. FDI inflows share is calculated from FDI inflows from G6 countries instead, with Canada excluded from the calculation.

Following the calculation from Coe, et.al (1997), RDS is constructed similarly to physical capital stock calculation, which denoted as:

$$RDS_t = RDE_{t-1} + (1 - \delta) \times RDS_{t-1}$$

From the equation, t is period, especially for the current year, while RDE_{t-1} is R&D expenditure at $t - 1$ period. RDE data used in this research is obtained from OECD analytical database, which gives total R&D expenditure data by industry for G7 countries. In order to use this equation, there is a need to calculate a benchmark for R&D Capital Stock, which is defined similarly to physical capital stock as:

$$RDS_0 = \frac{RDE_0}{(g + \delta)}$$

Similar to the physical capital stock calculation, base RDS_0 is calculated by dividing R&D Expenditure at the base period (RDE_0) with the sum of average growth of *RDE* in observation period, which means 1990 to 2010, and depreciation rate. Again, the depreciation rate used here is the same as physical capital stock, which is 0.1 depreciation rate.

Other indicators used in this research are import share of GDP (*IMPY*), SITC 7 export share of GDP (*EXPY*), FDI inflows share of GDP (*IFDY*), education expenditure ratio (*EDUR*), and secondary enrolment ratio (*SECR*). *IMPY*, *EXPY*, and *IFDY* are all calculated by dividing with nominal GDP, *EDUR* is ratio of education expenditure to government total expenditure from sample countries, and *SECR* is ratio of total secondary enrolment to secondary school age population from sample countries.

Model used in this research is loosely based from Coe and Helpman (1994). Generally, Coe and Helpman used International R&D Spillover from trade channel and Domestic R&D Stock as independent variables towards Total Factor Productivity as dependent variable. However, this research does not use domestic R&D stock in the regression because of the lack of data, instead, international R&D spillover from FDI channel used in this research. The basic Coe and Helpman model is modified based on several literatures (especially from Okabe (2002), Coe, et.al (1997), and Xu and Wang (2000)). Thus, the basic model for this research is constructed as:

$$TFPG = \alpha_0 + \alpha_1 lnFRDT + \alpha_2 lnFRDI + \varepsilon, \qquad (1)$$

The basic model (1) explains the role of international R&D spillover, both from trade (FRDT) and foreign direct (*FRDI*) investment channel, in defining TFP growth (TFPG). Although this model may capture the effect of international R&D spillover, this basic model does not properly capture the role of international R&D spillover from international trade and FDI channel simply because there is no interaction to international trade and FDI indicators, while FRDT and *FRDI* only include spillover from G7 countries.

In order to capture the effect of domestic knowledge, model (1) will be modified by inserting domestic knowledge variable, represented by education expenditure ratio (*EDUR*), as an independent variable. By doing this, the modified model is specified as the following model (2):

$$TFPG = \alpha_0 + \alpha_1 lnFRDT + \alpha_2 lnFRDI + \alpha_3 lnEDUR + \varepsilon, \qquad (2)$$

However, by inserting *EDUR* as independent variable, this model still does not adequately reflect the effect of R&D spillover from international trade and foreign direct investment because it only controls the interaction from R&D spillover towards TFP growth. Import share of GDP (*IMPY*), export share of GDP (*IMPY*), and FDI inflows share of GDP (*IFDY*) are multiplied with R&D spillover variables, thus creating interaction variables between R&D spillover and international trade and investment respectively. The modified model based on model (2) is specified as the following model (3) as:

$$TFPG = \alpha_0 + \alpha_1 IMPY(lnFRDT) + \alpha_2 EXPY(lnFRDT) + \alpha_3 IFDY(lnFRDI) + \alpha_4 lnEDUR + \varepsilon, \qquad (3)$$

Model (3) accounts the interaction between international trade and investment into the specification, making this model is adequately represent international R&D spillover as the defining variables.

However, it is also important to account the interaction between educated workers and R&D spillover from FDI channel, as more workers that are educated in a country will induce more FDI into the country and increasing its R&D spillover, especially from FDI channel. Educated workers level is defined as secondary enrolment ratio in the country (*SECR*) and is multiplied with *FRDI* to reflect the interaction between R&D spillover through investment channel and educated workers. The specification, denoted as model (4), is described by the following function:

$$TFPG = \alpha_0 + \alpha_1 IMPY(lnFRDT) + \alpha_2 EXPY(lnFRDT) + \alpha_3 IFDY(lnFRDI) + \alpha_4 SECR(lnFRDI) + \alpha_5 lnEDUR + \varepsilon, \quad ($$

All of these models are also estimated again by breaking the country observation into two groups, which are ANIC Tier 1 (Hong Kong, Singapore, and South Korea) and ANIC Tier 2 (Indonesia, Malaysia, Philippines, Thailand). By doing so, it is expected that the difference between two groups can be found, as these two country groups have difference in the economic conditions. All the regression will be done using panel regression method.

4. Result and Analysis

The first part of this chapter will discuss the regression using all observation. As can be seen in Table 2, the first regression has *lnFRDT* and *lnFRDI* as the independent variables. This regression using fixed effect after Hausman Specification Test and use Generalized Least Square (GLS) because there is violation to BLUE assumption.

Table 2: Summary of Estimation Results using All Observations

Dependent Variable: TFPG

Independent	**(1)**	**(2)**	**(3)**	**(4)**
lnFRDT	0.8246 *** (0.0631)	0.9168 *** (0.0604)		
lnFRDI	0.0141 (0.0107)	0.0170 * (0.0097)		
IMPY(lnFRDT)			0.0295 *** (0.0045)	0.0214 *** (0.0053)
EXPY(lnFRDT)			0.0157 * (0.0081)	0.0117 * (0.0069)
SECR(lnFRDI)				0.0682 *** (0.0069)
IFDY(lnFRDI)			0.0163 (0.0136)	0.0031 (0.0124)
EDUR		-0.0064 *** (0.0013)	0.0002 (0.0017)	
Constant	-11.324 *** (0.8343)	-12.392 *** (0.7895)	-0.1801 ** (0.0818)	-0.8255 *** (0.0778)
Prob-F	0.000	0.000	0.000	0.000

Significance level: *)α = 0.1; **)α = 0.05; ***)α = 0.01

The result for the first regression are *lnFRDT* as the proxy of R&D channel from trade is positive significant in affecting Total Factor Productivity growth (*TFPG*) while *lnFRDI* as the proxy of R&D channel from FDI is not significant. This can be concluded that from direct R&D spillover from G7 countries, only trade channel is significant in affecting TFP. As the trade channel (*FRDT*) can be interpreted as every 1 percent increase of R&D spillover from trade channel, there is an increase in Total Factor Productivity by 0.82 percent. This can be concluded that direct R&D spillover is an important factor in productivity.

This result is similar to de la Potterie and Lichtenberg (2001) where inward FDI is not significant because FDI inflows tend to capture technology from host country than spill the technology from home country. This fact also can be reinforced by flying geese model, when developed countries invest to less developed countries for offshore production, developed countries tend to use the comparative advantage from less developed countries, such as cheap labor, and export their capital goods, so it may be that the spillover is embodied in trade channel. Xu and Wang (2000) also get the same results by stating that FDI data itself is a poor proxy for activities of multinational enterprises, not to mention technology related activities of multinational enterprises. Moreover, Xu and Wang (2000) also stated that inward FDI transmits technology in ways related to international trade. Keller (2009) also added that the size of positive technological externalities associated with FDI is difficult to obtain because of its relation with many conditions, such as increased competition by FDI inflows can cause either efficiencies or inefficiencies. Lack of measurement and control variables for FDI makes FDI variable may be spurious in technology spillovers.

The second regression tries to explain the relation between knowledge accumulation to productivity. This regression also used fixed effect and Generalized Least Square (GLS) estimation. Knowledge accumulation comes from two aspects, international spillover and domestic R&D. However, it is found that education ratio (*EDUR*) as the proxy of domestic knowledge has significant negative effect to Total Factor Productivity. This is inconsistent to the theory that domestic knowledge is an important factor to TFP. This indicates that while domestic knowledge affects GDP, education expenditure is not optimal as productive expenditures, when used in excess, could become unproductive (Devarajan, et al., 1996). However, education ratio itself has several problems and cannot be fully interpreted as domestic knowledge. This variable is also has several inconsistencies in other estimations, especially in fourth regression where it is detected to have high multicollinearity with education enrolment ratio, as both of them can be interpreted as human capital. Based on this fact, the second regression cannot explain the comparison between domestic knowledge and R&D spillover.

In the first and second regression, the focus of estimation is the direct spillover relation from G7 countries as there is no interaction between the R&D spillover and international trade. Third regression now tries to focus on the international R&D spillover by interacting the R&D spillover with international trade (*EXPY* and *IMPY*) and FDI (*IFDY*), as international trade can also increase country's productivity through indirect spillover (Falve, et. al, 2002). The third regression also use fixed effect regression and Generalized Least Square (GLS).

From the result of the third regression, it is found that international R&D spillover from trade channel, especially from import channel (*IMPY(lnFRDT)*) is positive significant in affecting productivity (TFP). However, while international R&D spillover from export channel is significant in affecting countries' productivity, its effect is lower than import channel, as it is significant only for 0.1 standard error. These facts can become evidence that R&D spillover from trade channel mainly come through importing goods, especially capital goods, with other countries. Moreover, flying geese model also explains that developed countries share their own knowledge through importing capital goods to less developed countries. While the other channel, which is export (*EXPY(lnFRDT)*), does not have direct relation with R&D spillover.

Interaction with international trade through export channel presents unclear evidence because firms benefit from interacting with foreign customer, as firms will try to achieve higher product quality standards based on world's demand (Keller, 2009). In this case, third regression shows that there is significant relation, albeit weak, from high technology goods export channel with productivity, therefore R&D spillover happens through export channel. Every 1 point increase in export and spillover interaction variable will increase TFP by 0.015 percent. The coefficient from *IMPY(lnFRDT)* is approximately large, which can be interpreted as the increase of 1 point of interaction of international trade with R&D spillover gives approximately 0.029 percent increase to TFP index. It is found that education ratio variable (*EDUR*) is not significant; therefore, the coefficient of variable from second regression may be overestimated in its effect to TFP. In the third regression, *EDUR* is positive but insignificant.

Other noticeable case from the third regression is interaction between FDI inflows share and R&D spillover from FDI channel with R&D spillover is insignificant. Similar to the previous explanation, interaction of international FDI inflows with R&D spillover is considered to have several lacks in measurement, which makes the FDI inflows variable is a poor proxy for describing FDI activities.

The fourth regression tries to explain the relation between secondary enrolment ratio (*SECR*) as the proxy of educated-workers and human capital. As already stated in chapter 3 that educated-workers are important in increasing countries' productivity directly from increasing workers' productivity and indirectly by attracting foreign direct investment (Coe, et. al, 1997), *SECR* also represents human capital in the countries as human capital directly increases productivity through the worker knowledge (Benhabib and Spiegel, 1994). Thus, secondary enrolment ratio is interacted with foreign R&D spillover from FDI channel as it enhances FDI inflows. Fourth regression also uses fixed effect regression and generalized least squares (GLS).

The result from fourth regression are positive and significant international R&D spillover from import channel (*IMPY(lnFRDT)*) and secondary enrolment ratio interaction with R&D spillover from FDI channel (*SECR(lnFRDI)*). For *IMPY(lnFRDT)*, it is consistent with the other regressions before. This result further reinforces the fact that international R&D spillover from trade channel is an important factor for countries' productivity. Variable *EXPY(lnFRDT)* is also consistent with the third regression, with weak significances. This fact further reinforces that R&D spillover from export channel is affecting productivity (TFP) from interaction with other firms and consumers. The variables can be interpreted as each increase of *IMPY(lnFRDT)* by 1 point will increase TFP by 0.02 percent and each increase of *EXPY(lnFRDT)* by 1 point will increase TFP by 0.01 percent. Variable *SECR(lnFRDI)* is significant and can be used to reinforce the statement that educated-workers as human capital are important factor in increasing productivity. this variable can be interpreted as 1 point of increase in this interaction variable will increase TFP by 0.068 percent.

Consistent with previous regression, *IFDY(lnFRDI)* variable is not significant when regressed by using fourth model. This indicates that the variable has omitted variable bias in third regression. This further improves the fact that FDI inflows cannot properly explain the spillover from FDI activities as FDI activities may be captured in other independent variables.

The fourth regression is supposed to have education expenditure ratio (*lnEDUR*) as independent variable. However, it is found that *EDUR* variable has high multicollinearity with *SECR(lnFRDI)*. This is to be expected because both of the variables use education as the proxy, thus creating multicollinearity between them. Because of insignificant results from *lnEDUR* variable, this variable is omitted. This can be concluded that education expenditure ratio is not a good proxy in estimating domestic knowledge.

There are two estimation results for this part; Table 3 is the summary of estimation results from Asian Newly Industrialized Countries (ANIC) Tier 1, which are Hong Kong, Singapore, and South Korea, and Table 4 is from ANIC Tier 2, which are Indonesia, Malaysia, Philippines, and Thailand. The regression specification is the same as the latter regression, with four types of regression. The estimation results are as follows:

Table 3: Summary of Estimation Results from ANIC Tier 1

Dependent Variable: TFPG

Independent (Tier 1)	**(1)**	**(2)**	**(3)**	**(4)**
lnFRDT	0.9966 *** (0.0993)	1.0021 *** (0.0997)		
lnFRDI	0.0263 (0.0169)	0.0266 (0.0169)		
IMPY(lnFRDT)			0.0318 *** (0.0057)	0.0827 *** (0.0435)
EXPY(lnFRDT)			0.0289 *** (0.0057)	0.0182 *** (0.0049)
SECR(lnFRDI)				0.0844 *** (0.0163)
IFDY(lnFRDI)			*omitted*	*omitted*
EDUR		0.0018 (0.0037)	-0.0036 (0.0040)	*omitted*
Constant	-13.830 *** (1.3061)	-13.974 *** (1.3343)	-0.1286 (0.1563)	-1.2097 *** (0.1500)
Prob-F	0.000	0.000	0.000	0.000

Significance level: *)α = 0.1; **)α = 0.05; ***)α = 0.01

From the first regression, it can be found that both of the country groups have positive significant *lnFRDT* variable and insignificant *lnFRDI* variable. This can be concluded that both of the country groups gain an increase in TFP through R&D spillover from trade channel and R&D

spillover from FDI channel is not significant in affecting TFP. From the comparison of *lnFRDT* coefficients, it can be found that ANIC Tier 1 have higher effect from trade channel R&D spillover as the coefficient is 0.9966, while the coefficient in ANIC Tier 2 is only 0.7245. This means every increase of trade channel R&D spillover by 1 percent will increase TFP by 0.99 percent in ANIC Tier 1 and 0.72 percent in ANIC Tier 2.

Table 4: Summary of Estimation Results from ANIC Tier 2

Dependent Variable: TFPG

Independent (Tier 2)	**(1)**	**(2)**	**(3)**	**(4)**
lnFRDT	0.7245 *** (0.0785)	0.9001 *** (0.0735)		
lnFRDI	0.0065 (0.0132)	0.0127 (0.0111)		
IMPY(lnFRDT)			0.0353 *** (0.0079)	0.0216 *** (0.0048)
EXPY(lnFRDT)			-0.0315 * (0.0175)	-0.0306 *** (0.0105)
SECR(lnFRDI)				0.0643 *** (0.0060)
IFDY(lnFRDI)			0.0696 (0.0614)	0.0040 (0.0370)
EDUR		-0.0072 *** (0.0013)	0.0017 (0.0019)	*omitted*
Constant	-9.8214 *** (1.0415)	-12.135 *** (0.9740)	-0.2625 *** (0.0943)	-0.4992 *** (0.0565)
Prob-F	0.000	0.000	0.0690	0.000

Significance level: *)α = 0.1; **)α = 0.05; ***)α = 0.01

In the second regression, there is *EDUR* as the additional independent variable. The result shown that in ANIC Tier 1, *EDUR* variable against TFP is not significant in the second regression and in the other specifications and significantly negative in ANIC Tier 2. This can be further concluded that education expenditure is not significant in affecting TFP, especially in ANIC Tier 1. Moreover, ANIC Tier 2 has similar result to the overall estimation before that it may be caused by excess and inefficient usage of education expenditure so that it becomes unproductive. However, there may be an indication that the effect of *EDUR* in ANIC Tier 2 is overestimated because it becomes insignificant in third regression. In both cases, education expenditure is not a good proxy for domestic knowledge and cannot explain domestic R&D relation to TFP.

As for *lnFRDI*, both of the country groups do not have significant effect to TFP. This further concludes that R&D spillover from FDI is insignificant, similar as the other regressions before. *lnFRDT* still has significant effect in both of the country groups, as every increase of R&D spillover from trade channel by 1 percent will increase TFP by 1.00 percent in ANIC Tier 1 and 0.90 percent in ANIC Tier 2.

In the third regression, the interaction between import and FDI share with R&D spillover to capture the interaction with international trade and FDI. From the result of estimation, it can be seen that *EDUR* is not significant variable in both of the country groups, which reinforced the fact that *EDUR* is not significant and second regression *EDUR* result from ANIC Tier 2 is overestimated. *IFDY*(ln*FRDI*) insignificant in ANIC Tier 2; however, *IFDY(lnFRDI)* variable contains high multicollinearity with *EXPY(lnFRDT)* and the variable is omitted for the correction. One possible explanation from this fact is trade and FDI is strongly related. Export activity, especially high technology goods, is dominated by multinational firms that explained by FDI inflows. Therefore, there is multicollinearity because FDI inflows can cause export activities. Keller (2009) further reinforces this explanation by stating that multinational firms often account large portion of trade.

The important result in the third specification is variable *IMPY(lnFRDT)* as this variable is positive significant in both country groups. This result reinforces the fact that international R&D spillover from trade channel, especially from import, is important factor for TFP.

EXPY(lnFRDT) has significant result in both of the country groups, although the significances is weak in ANIC Tier 2. However, there is a difference in how the spillover affects the productivity (TFP). There is positive effect from *EXPY(lnFRDT)* in ANIC Tier 1, which reinforces the fact that high technology goods export channel is an important factor to increase productivity. However, there is negative effect from *EXPY(lnFRDT)* in ANIC Tier 2, which contradicts with the hypothesis. This fact implies that even if the high technology goods sector (SITC7) receives spillovers and raises its technology level, the TFP of the whole economy does not increase unless the improved technology diffuses across other sectors (Okabe, 2002).

The fourth regression contains the interaction between educated workers and R&D spillover from FDI channel, while omitting *EDUR* variable because of multicollinearity. The result of this regression reinforces the previous facts even further. It is found that in both of country groups, *IMPY(lnFRDT)* and *EXPY(lnFRDT)* is constantly significant, with *EXPY(lnFRDT)* is negative in ANIC Tier 2. This means that international R&D spillover from import channel is an important factor for productivity and R&D spillover has different effect in both country groups with the previous explanation.

It is also found that variable *SECR(lnFRDI)* is consistently significant, which is the same result as overall estimation. This result further explains that human capital is an important variable for both of country groups. *IFDY(lnFRDI)* is also insignificant in affecting TFP for both of the country groups. This fact is also consistent to the result from overall estimation, which means that FDI inflows interaction with R&D spillover does not have any significant effect to TFP.

In conclusion, this research cannot capture the domestic knowledge because of inappropriate proxy, as domestic expenditure ratio has multicollinearity with secondary enrolment ratio. However, the findings of this research are international R&D spillover is generally important in increasing TFP, especially in trade channel. International R&D spillover from FDI channel has no significances to TFP in both of country groups, mainly because FDI cannot appropriately describes multinational firms activities. ANIC Tier 1 have different characteristics from Tier 2, especially from *EXPY(lnFRDT)* and *IFDY(lnFRDI)*. ANIC Tier 1 has negative and significant *EXPY(lnFRDT)*, contrast to ANIC Tier 2. This may be caused by the unequal spillover between the industries as high technology goods sector gained spillover from export, it is not diffused into other sectors, making total productivity does not increase. *IFDY(lnFRDI)* is omitted in ANIC Tier 1 group, as the variable contains high multicollinearity with *EXPY(lnFRDT)*. The possible explanation for this case is multinational firms, which are described by FDI, is the main source of high technology goods (SITC 7) exporter in ANIC Tier 1. This condition makes *IFDY(lnFRDI)* is related to *EXPY(lnFRDT)*. In partial observation of country groups, education expenditure ratio (*EDUR*) has consistent insignificant result in the regression.

5. Conclusion

As the endogenous growth theory has stated that economic growth is induced by technological progress, less developed countries can catch up to developed countries by the means of increasing their technological advancement. However, there is an anomaly in the structure of world's technological advancement as R&D expenditure is dominated by developed countries, especially OECD. This fact raises a question about how the less developed countries can catch up to developed countries if they have little R&D expenditure to contribute in their technological advancement.

Endogenous growth theory is developed even further. Romer model indicates that knowledge is non-rivalry and excludable, which indicates that researches and knowledge from home countries can be used by other countries, at a cost. This also indicates that there is a possibility of knowledge spillover from other technological advancement to other countries in the world. The fact is there are several developing countries that have catch up effect to developed countries. This research focused on Asian Newly Industrialized Countries as catch up effect is clearly shown in ANIC Tier 1 and there is indication of catch up effect in ANIC Tier 2. These countries have high economic growth this later decade and start industrializing. Based on the theory, there is a strong indication that these countries received technology spillover from developed countries as ANIC have small domestic R&D expenditure to increase their technological advancement.

By calculating R&D spillover from G7 countries, as the technology leader countries, this research tries to explain the effect of international R&D spillover to productivity. R&D spillover itself can be achieved by two channels, which are trade and FDI, and productivity is represented by Total Factor Productivity (TFP). This research also compares the ANIC tier 1 and tier 2 as they have different economic condition.

This research found that R&D spillover from trade channel generally has positive significant effect to productivity, both directly and indirectly. However, this is not applicable to FDI channel as the effect is not significant. However, this fact cannot conclude that FDI is not an important factor for productivity because FDI measurement itself is not enough to represent enterprises activities and there is a high probability that spillover activities from FDI is embodied in trade activities, such as importing capital goods. In addition, although high technology goods export interaction with R&D spillover is significant in affecting productivity, it has weaker significances than import interaction R&D spillover. This is mainly caused by various effects caused by high technology export interaction with R&D spillover in Asian Newly Industrialized Countries, and more indirect spillover from export than from import.

There is also a significant positive relation between interaction of secondary enrolment ratio and R&D spillover from trade channel to productivity. As secondary enrolment ratio represents human capital, it is to be expected that these variables have significant positive effect as educated workers enhance FDI indirectly and productivity directly. However, this research cannot find the relation from domestic R&D stock to productivity. As domestic R&D is represented by education expenditure ratio, it seems that education expenditure ratio is not an appropriate measure for domestic R&D as it has multicollinearity with secondary enrolment. Therefore, this research cannot answer the relation between domestic R&D and productivity.

From the comparison of the two country groups, it is found that ANIC tier 1 have positive significant effects from R&D spillover through trade channel both from export and import interaction. However, ANIC Tier 2 have different results concerning the R&D spillover. Although Tier 2 have significant positive effect from import interaction with R&D spillover, export interaction with R&D spillover shows significant negative effect. This fact can explain that while the spillover from export is significant in affecting the high technology goods sector, technology spillover in ANIC Tier 2 is not dispersed into other sectors. This makes total productivity in the countries does not increase by R&D spillover from export.

In ANIC Tier 1, it is found that FDI inflows interaction with R&D spillover is omitted because of high multicollinearity with high technology goods export interaction with R&D spillover variable.

Possible explanation from this result is high technology goods export is dominated by multinational firms, which is accounted in FDI inflows in ANIC Tier 1. Therefore, there is relation between FDI inflows and high technology goods export as FDI inflows will affect high technology goods export directly.

There are several constraints in this research. First is the lack of data concerning domestic R&D that makes this research uses education expenditure ratio to represent it. However, this ratio is not a good proxy for domestic R&D and make this research does not capture the effect of domestic R&D, which is important in affecting productivity.

Second, there is also a debatable issue concerning the calculation of TFP and R&D spillover, such as over-simplified TFP calculation and issues regarding weighting method of R&D spillover (Keller, 1997). This makes the indicator used for TFP and R&D spillover is still cannot completely capture the relation between these two variables. Although there is evidence from this research that these variables have significant effect, the result must be treated carefully.

Third, lack of control variables applied in this research which makes there are other indicators that affects productivity and not included in the estimation. TFP itself is not a proxy for technological change alone, but also other factors that is not accounted in exogenous growth theory. This fact means there are other indicators that affect TFP. The period used in this research contains much volatility, especially in the financial crises period. There is a need to control the variable and account the effect of crisis on this period. There is also an indication of non stationarity for larger time period.

Fourth, in R&D spillover from FDI channel, there is a bias in estimation as FDI inflows itself does not fully represent the FDI activities. Several literatures also stated that its effect is embodied through trade channel. However, there is still no appropriate calculation to divide the embodied effects. FDI outflow also an important factor for FDI channel, which is not included in this research because of the lack of data.

Finally, there is a great probability that the variables used, especially R&D spillover variables, in this research are non-stationary as the R&D indicators contain time trend (Edmond, 2001). In addition, the large range of time period further enhance the probability of non-stationarity. The effect of R&D spillover is also happens in the long run, which means this effect cannot be obtained by merely simple regression. The non-stationarity of the variables are not treated in this research because of the limitations.

Based on the results of this research, there are several policy recommendations that can be suggested: As the results clearly stated that international trade is important factors in increasing productivity through R&D spillover, there is a need to increase the degree of openness to trade, especially from import and high technology goods export as the main source for R&D spillover. In addition, human capital is an important factor in productivity and R&D spillover as human capital is the main factor in capturing the effect of R&D spillover. With adequate education of human capital, R&D spillover can be fully absorbed and used to increase country's productivity.

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