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RESEARCH AND DEVELOPMENT SPILLOVERS IN ASEAN COUNTRIES: THE ROLE OF ECONOMIC FREEDOM

Nurnaddia Nordin
Faculty of Management and Muamalah
Selangor International Islamic University College, MALAYSIA
nurnaddia@yahoo.com

Nurhaiza Nordin
Faculty of Entrepreneurship and Business
Universiti Malaysia Kelantan, MALAYSIA
haiza@umk.edu.my

Norzalina Zainudin
Faculty of Human Ecology
Universiti Putra Malaysia, MALAYSIA
norzalina@upm.edu.my

ABSTRACT

The aim of this study is to examine the role economic freedom plays in R&D spillovers for the ASEAN-4 countries. The dynamic ordinary least square panel estimator (D-OLS) is employed using data from 1996 to 2015. There are three important conclusions that can be drawn from the reported results. First, foreign R&D is more important for productivity improvements than domestic R&D. Second, import is the main channel for foreign R&D spillovers. Third, economic freedom plays an important role in moderating both domestic and foreign R&D spillovers. Therefore, policymakers and governments should play an important role in promoting trade liberalization and other policies that enhance freedom of economic activities as both are expected to boost domestic productivity.

Keywords: Domestic R&D, foreign R&D, Economic freedom, panel dynamic ordinary least square and ASEAN countries

1.0 Introduction

Over the years**,** economists have attempted to unveil the causes of growth and inquired on the right policies that countries can implement in order to maintain and promote it. However, explaining why some countries can grow faster than the others is not an easy task, and the literature on this subject is filled with a lot of controversies. Nevertheless several recent studies identify more than sixty different variables that contribute to our understanding of long-term growth performance (Durlauf, Johnson and Temple, 2005, Sala-i-Martin, 1997). Innovation effort such as investment in research and development (R&D) is highlighted as a major source of productivity improvement. However, only a few countries engage actively in R&D activities and they are responsible for the most of the world's investment in R&D. The variations in R&D investment across countries explain a large part of cross-country differences in productivity and countries are found to benefit enormously from international spillovers (Klenow and

Rodriguez-Clare, 2005). In fact, the major source of productivity growth for many countries came from abroad (Keller, 2004).

Although the new growth models predicts that innovation activity is a major source of productivity improvements, only a handful of rich countries involve actively in R&D activity. In fact, the main source of global R&D investment is the high income countries, where they contribute around 48 percent to 60 percent of global R&D investment. According to UNESCO Science Report (2015), there are only seven major developed countries (United States, United Kingdom, Japan, Germany, France, Canada and Italy) that are actively involved in R&D investment. In 2014, this group contributed \$870 billion which represent 48.25 percent of the world R&D expenditure.

This suggests that less developed countries which hardly invest in R&D activity and lags behind the technology frontier must boost their productivity by interacting with R&D leaders. In this way, other countries may benefit from R&D activity done by R&D leaders via R&D spillovers. According to literatures, there are several channels of R&D to have an impact on domestic productivity which can be grouped into domestic and foreign R&D channels. In the case of foreign R&D, the channels include inward FDI, outward FDI, import, export, geographical proximity, international students' flows and general channel. The findings, however, reveal mixed evidence but generally many found that import is the most effective channels for foreign R&D spillovers. However, the importances of other channels are different across different studies. Investment in R&D activity is widely accepted as one of the important factors for productivity improvements (Coe and Helpman, 1995 and Jugsoo, 2002), besides other factors such as trade openness, financial development, human capital, education and infrastructure. Since R&D is important for productivity growth, issues related to R&D spillovers has been widely discussed among the researchers in recent literature (Agovino *et al.,* 2016; Ikeuchi, Kim and Kwon 2016; Jiang, Qian and Yao, 2016).

Recently, some studies reveal that knowledge spillovers like R&D are not an automatic process. It requires some intervention by the host countries. In other words, the process requires that host country poses some quality in order to benefit from foreign knowledge. It require domestic firm to be able to absorb and internalize international knowledge. Therefore, R&D spillovers may be sub-optimal if domestic firms are not able to absorb and internalize new knowledge created others. Recently, several studies suggested that only countries with better quality of institutions (i.e. higher level of economic freedom) benefits from knowledge spillovers because in such an environment firms are more willing to engage in risky activities like the adoption of a new technology. Although the importance of absorptive capacity in FDI spillovers was tested in recent literature, there is however lack of evidence on the role of absorptive capacity in the context of R&D spillovers. Therefore, the next logical step is to test the role of institutions (i.e. economic freedom) in moderating R&D spillovers. The finding is expected to help policymakers in devising specific policies related to R&D activity and also the quality of institutions.

2.0 Review of Literatures

R&D is conventionally defined by OECD (2003) as a creative work undertaken basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new application. The R&D process can be characterized as a process of transforming R&D inputs into R&D outputs. R&D inputs are the existing stocks of knowledge, the expertise and creativity of researcher, supporting labour, capital services (from assets such as buildings, structures and equipment), materials and purchased services. R&D outputs are increments to the stock of knowledge and new technologies (applications of existing knowledge). R&D also serves the purpose of enhancing absorptive capacity that is the ability of identify, assimilate and apply relevant knowledge.

Conceptually, R&D finished where commercialization starts. Further investment in pre-production or commercialization activities is normally required to take inventories to the stage where they can be introduced into commercially-viable production and use. R&D activity is not the only form of knowledge accumulation. Various economic theories have also highlighted the roles of education, acquisition through technology license or capital equipment and learning by doing. R&D has long been seen as an important source of knowledge generation and productivity improvement (Shell, 1966). Recently, endogenous growth theory has emphasized the importance of commercially oriented innovation efforts and R&D knowledge spillovers in explaining countries' productivity. R&D increases productivity by providing new product and process that enhance profits or reduce costs. R&D not only directs affects the productivity of the firm that conducts R&D, but may also produce spillover effects that increase other firms' productivity. R&D spillover occurs not only domestically but also internationally.

Theory by Solow's (1956) neoclassical growth model, which treats productivity, capital accumulation and population growth as the main sources of economic growth, has been modified by later authors to add R&D as a central determinant of growth. Griliches (1979) introduced the idea that productivity growth is the consequence of expenditures on R&D. In the endogenous growth model developed by Romer (1986), firms' expenditure on R&D results in greater aggregate output because private R&D leads to spillovers through its contribution to the public stocks of knowledge. R&D expenditures are central to economic growth because technological change is the result of conscious economic investment, and sustained growth would not be possible without the R&D spillovers (Griliches, 1992).

Besides that, Grossman and Helpman (1994), in their review of growth theory and endogenous innovation, argue forcefully that technological progress has been the main driver of growth in the world, where "most technological progress requires, at least at some stage, an intentional investment of profit-seeking firms or entrepreneurs." According to Grossman and Helpman (1994), a large investment of resources is required in order to reap benefits from the development of scientific ideas. Firms have an incentive to invest in R&D if there is an opportunity for them to increase profits. Therefore, if the profitability of R&D is raised and more investment goes into private-sector R&D, the innovation process accelerates, resulting in higher productivity.

In relation to R&D spillover across region and countries, Coe and Helpman (1995) found that while domestic R&D is associated with greater productivity and economic growth, foreign and knowledge stocks are also critical for explaining TFP. They posit that R&D from abroad could have a direct positive effect on domestic productivity through the development of new technologies and processes and an indirect positive effect through the importation of goods and services. By using data from 21 OECD countries from 1971 to 1990, they provide empirical support to these results. Studied by Frantzen (2000) carried out a cross section analysis of OECD countries. He found that economic growth in those countries was closely related to innovation, which was influenced by domestic and foreign R&D, and that the importance of R&D is higher in G7 countries than in economically smaller countries. Spatial spillovers are also found to be important in the regional work of Bronzini and Piselli (2006).

According to Bayoumi, David and Elhanan (1999), besides the impact that domestic R&D has on a country's productivity in the long run, R&D spillover also can impact from international trade. A country could achieve higher productivity by trading with the other countries that have a large stock of knowledge. Bayoumi et al. (1999) show empirically that the degree to which a country benefit from R&D spillover would be determined by the size of trade between the country benefits from R&D spillover would be determined by the size of trade between the country and its partners.

One way for countries to improve the efficiency of factor inputs is to devote resources towards research and development (R&D). Spending on R&D can lead to the development of new technologies such that existing manufacturing techniques are improved and efficiency gains are realized. As of 1990, OECD countries performed 96 percent of total R&D expenditures in the world (Coe, Helpman and Hoffmeister, 1997). However, world productivity data shows the benefit of R&D spending is distributed relatively evenly throughout the world (Xu and Wang, 2000). This suggests that countries may benefit from their own R&D spending and R&D spending conducted by their trading partners.

Coe and Helpman (1995) present an empirical study showing the extent to which an economy's TFP depends on domestic R&D stock and on the foreign R&D stock of its trading partners. They find that in OECD countries, both domestic and foreign R&D are important channels for international spillovers. Coe, Helpman and Hoffmeister (1997) find both foreign R&D and human capital plays roles for generating international spillovers in a sample of 77 LDCs. Besides that, Engelbrecht (1997) extends Coe and Helpman (1995) by including human capital and a GDP catch up variable in the TFP equation. The catch up variables is defined as real GDP per capita in country i as a percentage of real GDP per capita in the US. They estimate a set of cointegrated regression with pooled annual data. The coefficient of domestic R&D capital stocks is consistent with the Coe and Helpman (1995). In addition, they find human capital to be positive and significant, the catch up variable to be negative and significant, and the interaction term between human capital and the catch up variable to be positive and significant. The coefficients on domestic and foreign R&D capital stocks remain robust for several different specification of the equation.

Other studied by Keller (1998) focuses on the bilateral import shares that were used for weights in the construction of the foreign R&D stock variable. Keller finds spillovers are larger when foreign R&D uses random shares instead of actual shares. Bayoumi et al., (1999) use a multi country macro econometric model to stimulate the effects of domestic R&D, foreign R&D, and trade on output, total factor productivity, consumption and capital. Their data consists of the G-7 countries plus five regions consisting of both industrial and developing countries. The coefficients on domestic R&D, foreign R&D, and international trade are based on the estimation results Coe and Helpman (1995).

Madden and Savage (2000) examines the effect of domestic and foreign R&D, trade and information technology and telecommunications (ITT) on TFP. Their sample includes six Asian countries and fourteen OECD countries from 1980-1995. Their model extends Coe and Helpman (1995) in two ways. First, they include a dummy to represent the size Asian countries. Second, they include two ITT variables that are interacted with foreign R&D capital stock as a means of including another channel through which international spillovers may occur. Their estimation result show domestic and foreign R&D stocks raise productivity in both the Asian and OECD countries. They find a 1 percent increase in foreign R&D stocks raise Asian TFP by an average of 0.03 percent. This result is contradicted with Coe and Helpman (1995), where domestic R&D had minimal effects on Asian productivity.

3.0 Methodology

3.1 Model specification

In order to analyze the role of economic freedom in moderating R&D spillovers, this study uses a model developed by Coe and Helpman (1995) and van Pottelsberghe and Lichtenberg (2001). This model can be used to test R&D spillovers via several channels. Equation (1) provides the basic econometric model which states that total factor productivity is a function different types of foreign R&D capital stocks and domestic R&D capital stock. The model can be expressed as follows:

$$\mathrm{TFP}_{it} = \alpha + \beta_1\,\mathrm{EF}_{it} + \beta_2 \mathrm{S^f}_{it} + \beta_3\,\mathrm{S^d}_{it} + \varepsilon_{it} \qquad (1)$$

where TFP is total factor productivity, S^{f} is various weighted foreign R&D stocks. Specifically, S^{ifdi} is inward FDI-weighted, S^{ofdi} is outward FDI-weighted, S^{im} is import-weighted and control variable used in this model is S^{d} is stock of domestic R&D. In order to test whether economic freedom plays any role in moderating foreign R&D spillovers, the interaction terms constructed as a product of EF index with the S^{f} as (EF x S^{f}) and S^{d} as (EF x S^{d}) are added to equation (1) as an additional explanatory variable, apart from the standard variable used in the productivity equation.

The model for interaction can be expressed as follows:

$$TFP_{it} = \alpha + \beta_1\, EF_{it} + \beta_2\, S^{\mathrm{f}}_{\mathrm{it}} + \beta_3\, S^{\mathrm{f}}_{\mathrm{it}} \text{ x } EF_{it} + \beta_4\, S^{\mathrm{d}}_{\mathrm{it}} + \beta_5\, S^{\mathrm{d}}_{\mathrm{it}} \text{ x } EF_{it} + \varepsilon_{it} \qquad (2)$$

From this estimation, if the coefficient of the interaction term is found to be positive and significance, this would imply that the effect of foreign R&D on productivity depends on the level of EF.

3.2 Dynamic Ordinary Least Square

In order to obtain reliable estimates of long run coefficients for each of the variables, this study uses a dynamic ordinary least squares estimators (D-OLS) proposed by Koa and Chiang (2000). This estimator corrects the standard pooled OLS for serial correlation and endogeneity of regressors that normally present in long run relationship. This approach is an extension of Stock and Watson (1993) procedure. In order to obtain an unbiased estimator, the D-OLS estimator uses a parametric adjustment to the errors by augmenting the static regression with the leads, lags, and contemporaneous values of the regressors in first differences. The D-OLS estimator is obtained from the following equation:

The D-OLS estimator can be applied to equation (1) as follows:

$$TFP_{it} = \alpha + \beta_1 EF_{it} + \beta_2 S^{\mathrm{f}}_{\mathrm{it}} + \beta_3 S^{\mathrm{f}}_{\mathrm{it}}\text{x } EF_{it} + \beta_4 S^{\mathrm{d}}_{\mathrm{it}} + \beta_5 S^{\mathrm{d}}_{\mathrm{it}}\text{x } EF_{it} + \sum_{j=-q}^{q} c_{ij}\, \Delta\, EF_{\mathrm{i,t+j}} + \sum_{j=-q}^{q} c_{ij}\, \Delta\, S^{\mathrm{f}}_{\mathrm{i,t+j}} + \sum_{j=-q}^{q} c_{ij}\, S^{\mathrm{f}}_{\mathrm{i,t+j}}\text{x } EF_{i,t+j} + \sum_{j=-q}^{q} c_{ij}\, \Delta\, S^{\mathrm{d}}_{\mathrm{i,t+j}} + \sum_{j=-q}^{q} c_{ij}\, S^{\mathrm{d}}_{\mathrm{i,t+j}}\text{x } EF_{i,t+j} + \varepsilon_{it} \qquad (3)$$

The number of lead and lags of the model estimation (3) were selected according to Akaike information criterion (AIC).

3.3 Data set

This study focuses on four selected ASEAN countries namely, Malaysia, Indonesia, Thailand and Singapore using data spanning over the 1996–2015 periods. This study uses three different types of weighted foreign R&D stocks.

1. The first measure is an import weighted R&D capital stock (S_{it}^{im}) following Lichtenberg and van Pottelsberghe (1998). The stock can be computed as follows:

$$S_{it}^{im} = \sum_{j=1}^{20} (M_{ijt}/Y_{jt}) DS_{jt}\ , i \neq j \qquad (4)$$

where M_{ijt} is a country i's imports from the exporting country j at time t: Y_{jt} is exporter j's GDP at time t; and DS_{jt} is exporter j's real GDP at time t that is R&D expenditure of 20 OECD countries. List of the 20 OECD countries are listed in the Appendix.

2. The second channel inward FDI flows. Following van Pottelsberghe and Lichtenberg (2001), the inward FDI weighted foreign R&D capital stock S^{ifdi} is constructed as follows:

$$S_{it}^{ifdi} = \sum_{j=1}^{20} (F_{ijt}/K_{jt}) DS_{jt}\ , i \neq j \tag{5}$$

where the F_{ijt} is the flow of FDI from country j towards country i, and K_{jt} is gross fixed capital formation of country j, both expressed in constant value and DS_{jt} is exporter j's real GDP at time t that is R&D expenditure of 20 OECD countries.

3. The outward FDI- weighted foreign R&D capital stock S^{ofdi} is constructed as follows:

$$S_{it}^{ofdi} = \sum_{j=1}^{20} (T_{ijt}/K_{jt}) DS_{jt}\ , i \neq j \tag{6}$$

where the T_{ijt} are outward FDI of a country i towards country j. It states that foreign R&D capital stock of country i correspond to the sum of all its outward FDI embodied in the R&D capital stock of target countries; K_{jt} is gross fixed capital formation of country j, both expressed in constant value and DS_{jt} is exporter j's real GDP at time t, that is R&D expenditure of 20 OECD countries.

The domestic R&D capital stocks were calculated using the perpetual inventory procedure as follows:

$$s_t^d = (1-\delta)s_{t-1}^d + R\&D_{t-1} \tag{7}$$

$$s_t^d = R\&D_t + (1-\delta)s_{t-1}^d + (1-\delta)^2 s_{t-2}^d + (1-\delta)^3 s_{t-3}^d + \cdots \tag{8}$$

of the sample period where the depreciation rate δ is assumed to be 0.05. According to Keller (2004), the values of the depreciation rate range between 0% and 10%, but 5% is commonly used in the literature. To construct the initial stock of capital, we assume a constant annual rate of growth of the past investments,

$$s_t^d = R\&D_t + (1-\delta)gs_t^d + (1-\delta)^2 g^2 s_t^d + (1-\delta)^3 g^3 s_t^d + \cdots \tag{9}$$

The initial capital stock is calculated as follows:

$$s_0^d = \frac{R\&D_0}{(\delta+g)} \tag{10}$$

where g is the annual growth of R&D expenditures over the period for which the R&D data were available, $R\&D_0$ is the R&D expenditure at the beginning of the sample period. R&D capital stocks are computed based on data on research and development expenditure obtained from the *World Development*

Indicators (WDI) database. Since, the data on the R&D expenditure are not available for the whole sample period (1996 - 2015), the extrapolation methods were used following Coe and Helpman (1995) using real GDP and physical capital (gross fixed capital formation).

This study uses economic freedom index from the Fraser Institute. The index is divided into five areas and twenty-four components. The areas are; (1) Size of Government; (2) Legal system and security of property rights; (3) Sound money; (4) Freedom to Trade internationally; (5) Regulation. The first area has four components that indicate the extent to which countries rely on the political process to allocate resources and goods and services. The second area is legal system and property rights which are a central element of economic freedom and a civil society. The key components are rule of law, security of property rights, an independent and unbiased judiciary, and impartial and effective enforcement of the law. The third area measure an access to sound money. There are four components in this area, in which three of them are designed to measure the consistency of monetary policy or institutions with long term price stability and the fourth components in this area is designed to measure the ease with which other currencies can be used via domestic and foreign bank accounts. The fourth area indicates the freedom to trade internationally which contributes substantially to modern living standards. This indicator is key ingredient for economic freedom. Finally, the fifth area focuses on regulatory restraints that limit the freedom of exchange in credit, labour and product market. Each component is measured from 0 (no freedom) to 10 (full freedom).

4.0 Results and Discussion

This section discusses empirical results for testing the role of economic freedom in moderating foreign R&D spillovers using data from four ASEAN countries (Malaysia, Singapore, Thailand and Indonesia). The main methodology procedure used to examine this issue is panel D-OLS proposed by Kao and Chiang (1999). The empirical results are present in tables 1 - 4. As a necessary test for cointegration test, panel unit root test were carried out to evaluate the unit root properties of all variables. The test employed in this study is Levin, Lin and Chu (LLC). The panel unit root tests are based on the null hypothesis that a unit root exists in the autoregressive representation of the data variable. The results of LLC test are presented in table 1. The panel unit roots are tested using model with intercept and intercept plus trend. The results suggest the null hypothesis cannot be rejected at level suggesting that all variables contain unit root. However, the results for testing unit root at first difference generally suggest that all variables are stationary as the nulls can be rejected at the usual level. One exception is the domestic R&D using model with intercept in which the null cannot be rejected at first difference. By and large, the variables are integrated of order 1 or they are *I(1).*

Table 1: Panel unit root tests

Levin, Lin and Chu (LLC) test.				
	Level		**First Difference**	
Variable	**Intercept**	**Intercept +trend**	**Intercept**	**Intercept + trend**
TFP	-0.8871	-1.3537	-6.6722***	-4.8911***
EF	-1.9017	-1.7833	-4.8914***	-3.0922***
S^{ifdi}	0.6722	-3.3479	-8.9857***	-8.5831***
S^{ofdi}	-0.5628	-7.9833	-5.1273***	-5.7354***
S^{im}	0.8825	-3.4537	-6.8933***	-9.7628***
S^{d}	-2.8763	2.7833	-4.5822***	-5.9830***

Test Statistics	Intercept	Intercept + Trend
Z_V	-2.7618 (0.1091)	-2.3323 (0.1687)
Z_ρ	2.6719 (0.0082)	2.0911 (0.0086)
Z_t	-2.7643 (0.0000)	-3.5508 (0.0000)
Z_t^*	-1.8711 (0.0127)	-3.0442 (0.0012)
$\tilde{z}_\rho$	3.2319 (0.0067)	4.1475 (0.008)
$\tilde{z}_t$	-1.7811 (0.0000)	-1.5455 (0.0000)
$\tilde{z}_t^*$	-1.0121 (0.0181)	-1.5107 (0.0654)

Note: TFP= total factor productivity; EF= economic freedom; S^{ifdi} = inward FDI weighted foreign R&D stock; S^{ofdi} = outward FDI weighted foreign R&D stock ; S^{im} = import weighted foreign R&D stock and S^d=domestic R&D.

Having established that each of the variable is integrated of order one *I*(1), the cointegration test suggested by Pedroni (1995, 1999, 2004) are employed for panel cointegration test. Based on seven test statistics of cointegration proposed by Pedroni, four tests examine the cointegration within the dimension and three tests examine group mean panel cointegration between the dimensions. The results of Pedroni panel cointegration test are reported in table 2. The estimation results indicate that, the null hyphothesis of no cointegration can be rejected by panel PP statistics, panel ADF statistics, group PP statistics and group ADF statistics. According to Pedroni (1999), panel ADF test and group-ADF test have better sample property and more reliable. Therefore, it can be safely concluded that there are cointegration among the variables used in this analysis.

Table 2: Results of Cointegration test based on Pedroni (1999, 2004)

Note: Figures in parentheses are p-values. Optimal lag lengths were selected based on AIC. Z_V = panel v-statistic, Z_ρ = panel ρ-statistic, Z_t = panel t-statistic, Z_t^*= group t-statistics (non-parametric), $\tilde{z}_\rho$= group ρ-statistic, $\tilde{z}_t^*$= group t-statistics (parametric).

Having established that the variables are integrated of order one *I*(1) and cointegrated, the next step is to examine the long run relationship between variables using dynamic OLS estimator. Specifically, the main interest of this study is to examine the role economic freedom plays in moderating R&D spillovers. To test this hypothesis, interaction specification is estimated. The reported result in table 3 indicate that the positive impact of foreign R&D can be found in estimated result, suggesting that foreign R&D is more important for the productivity of ASEAN countries. All channels appear to be important in transmitting knowledge across borders. This finding is in line with Boyoumi *et al.* (1999) who also find that foreign R&D is more important than domestic R&D for productivity improvements. They study the impact of domestic and foreign R&D spillovers via import in industrial countries and find that the impact of domestic R&D is smaller than foreign R&D. The result for economic freedom also suggests that freedom of economic activity is expected to boost productivity as the coefficient on economic freedom index appears to be positive and statistically significance in all equations. This finding is consistent with De Vanssay and Spindler (1994), Gwartney, Holcombe and Lawson (1998) and Kneller *et al.* (1999) who also find that economic freedom is important for economic development. The result for testing the role played by economic freedom in moderating R&D spillovers suggest that economic freedom is in fact important in moderating knowledge spillovers across border. The interaction terms appear to be positive and statistically significance almost in all equations. This suggests that countries that promote freedom of economic activity are expected to benefit more from both domestic and foreign R&D. This finding is consistent with Azman-Saini, Baharumshah and Law (2010) who find that economic freedom moderates the impact of FDI on output growth.

Table 3: Estimate of long run coefficients

Variable	**Coefficient**
EF	0.1697
	(0.0086)
S^{ifdi}	0.0017
	(0.4295)
S^{ifdi} $x\ EF$	0.0213
	(0.1035)
S^{ofdi}	0.0027
	(0.0316)
S^{ofdi} $x\ EF$	0.0355
	(0.0178)
S^{im}	0.0259
	(0.0256)
S^{im} $x\ EF$	0.3073
	(0.0136)
S^{d}	0.1415
	(0.0080)
S^{d} $x\ EF$	0.0729
	(0.0075)

Note: TFP= total factor productivity, EF= economic freedom; S^{ifdi} = inward FDI weighted foreign R&D stock; S^{ofdi} = outward FDI weighted foreign R&D stock ; S^{im} = import weighted foreign R&D stock ; S^{d}=domestic R&D and figures in parenthesis is p-value.

In order to identify the most effective channel for spillover, the marginal effects of all R&D stocks were computed. At the margin, the total effect of increasing foreign R&D can be calculated by examining the partial derivative of TFP with respect to the foreign R&D stocks and standard error of the marginal impact are computed following Brambor, Clark and Golder (2005)[33]. The marginal effect of (i) inward FDI weighted foreign R&D stock (S^{ifdi}) is $\frac{\partial TFP}{\partial S^{ifdi}} = \beta_2 + \beta_3 EF$; (ii) outward FDI weighted foreign R&D stock(S^{ofdi}) is $\frac{\partial TFP}{\partial S^{ofdi}} = \beta_4 + \beta_5 EF$; (iii) import weighted foreign R&D stock (S^{im}) is $\frac{\partial TFP}{\partial S^{im}} = \beta_6 + \beta_7 EF$; (iv) domestic R&D stock (S^{d}) is $\frac{\partial TFP}{\partial S^{d}} = \beta_8 + \beta_9 EF$. The results of marginal effect are evaluated at the mean, maximum and minimum values of economic freedom. Table 4 report the estimation results of marginal effect and standard error R&D channels. Based on the estimation marginal effect in table 4, the most important channel of R&D spillovers is import channel. As shown in table 4,

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[33] For example, in the case of model is Y = $\beta_0 + \beta_1 X + \beta_2 Z + \beta_3$XZ + ε, the marginal effect is $\frac{\partial Y}{\partial X} = \beta_1 + \beta_3 Z$ and the standard error is $\hat{\sigma}_{\frac{\partial y}{\partial x}} = \sqrt{var(\hat{\beta}_1 + Z^2 var\ (\hat{\beta}_3) + 2Z cov(\hat{\beta}_1 \hat{\beta}_3)}$

two channels are found to be important namely import and domestic R&D but the marginal effect of import channel is higher than domestic R&D channel. As evaluated at the mean value, the marginal effect of import channel is 0.4577 and significant at 1% significant level and for domestic R&D channel is 0.2369 indicate highly significant at 1%, marginal effect at maximum value indicate the import channel is 0.3617 (1% significant level) and domestic R&D channel is lower value at 0.1104 (5% significant level) and value of marginal effect at minimum value also indicate higher value of import channel (0.1671 at 1% significant level) and marginal effect of domestic R&D channel is 0.0891 significant at 1% significant level. Thus, this finding indicates that import channel is the most important channel of R&D spillovers for ASEAN countries. This finding is consistent with Ang and Madsen (2013) who examine six Asian miracle economies from OECD countries and import channel is the key driver of foreign R&D spillover in Asian miracle economies.

Table 4: Marginal effect of R&D

Channel	Inward FDI (S^{ifdi})	Outward FDI (S^{ofdi})	Import (S^{im})	Domestic R&D (S^{d})
Mean	0.1181	0.0299	0.4577***	0.2369***
	(1.1001)	(2.8172)	(0.1165)	(0.0253)
Maximum	0.0567	0.0864	0.3617***	0.1104**
	(1.8115)	(2.5924)	(0.1289)	(0.0294)
Minimum	0.0281	0.0198	0.1671***	0.0891***
	(0.0850)	(2.0877)	(0.1055)	(0.0154)

Note: S^{ifdi} = inward FDI weighted foreign R&D stock; S^{ofdi} = outward FDI weighted foreign R&D stock; S^{im} = import weighted foreign R&D stock ; S^{d} = domestic R&D stock and figures in parenthesis is standard error. ** and *** indicates the respective 5% and 1% significant level.

5.0 Conclusion and Recommendation

This study investigates the role of economic freedom in moderating the impact of foreign R&D on productivity for four ASEAN countries during the year 1996 - 2015 time period. The results reveal that TFP, foreign R&D stocks, economic freedom and domestic R&D are cointegrated. There are several important conclusions emerge from the analysis. First, the results show that both foreign and domestic R&D activities are critically important for productivity improvements in Asean countries. Second, the elasticity of TFP suggest that the impact of foreign R&D on productivity is larger than domestic R&D after incorporating economic freedom as a moderating variable on productivity growth. Third, based on three channels of foreign R&D spillovers, import appears to be the main channel for foreign R&D spillovers, which is consistent with many studies. Finally, economic freedom appears to be important in enhancing R&D spillovers. This finding underlines the importance of promoting freedom of economic activity. This is also consistent with the growing view on the need for absorptive capacity in order to reap maximum benefits from knowledge flows.

The contribution of this study lies in highlighting the important of absorptive capacity on output growth and R&D spillovers. This study suggests some possible policy implication associated with absorptive capacity, FDI, R&D and growth in developing countries. Hence the policy implication of these issues is interrelated. This study highlights the importance of R&D both developed locally or internationally and import appear to be the most important channel of foreign R&D spillovers. The introduction of trade liberalization for the last two decades by developing countries has encouraged trade flows to developing countries Therefore, developing countries experienced technology spillovers from these trade activities and contribute to the country productivity growth. Due to the important role of trade in knowledge spillovers, necessary trade policies must be put in place. For instant, the implementation of Strategic Plan of Custom Development by ASEAN countries appear to benefited members' country by improving free flows of goods and services. Therefore, policy makers and government should seek other ways to further promote bilateral trade and multilateral trade like elimination of tariff and non-tariff barriers that will provide more inflows from bigger economies like the United States, Japan and China. Besides that, the key finding of this study is that the level of economic freedom is one of the utmost important factors that encourage R&D spillovers. Therefore, to sustain and encourage more R&D spillovers, a set of complementary policies that focus on the freedom of economic activity must be on the top priority among policy makers.

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Appendix

Table A.1. List of OECD countries

Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany
Greece
Ireland
Italy
Netherlands
New Zealand
Norway
Portugal
Spain
Sweden
Switzerland
United Kingdom
United States

Note: Selection of 20 OECD countries is based on study by Ang and Madsen (2013).