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R&D Spillovers and the Role of Economic Freedom

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ABSTRACT

This paper examines the role of economic freedom plays in moderating research and development (R&D) spillovers from developed to developing countries. Two channels are analyzed namely import and international student flows. The empirical results based on generalized method-of-moment system estimation on a panel of 75 developing countries show that spillover effects through import and international student flow are significant, but the latter channel appear to be more important in term of magnitude. This finding is consistent with view that technology diffusion via human capital mobility should not be underestimated. More importantly, the finding reveals that countries with higher level of economic freedom benefit more from R&D spillovers. This provides further support to the idea that successful knowledge acquisition requires absorptive capacity.

Keywords: economic freedom, international student flows, R&D spillovers, total factor productivity, trade

INTRODUCTION

Many economists believe that technological progress is an important determinant for long-run output growth because it is very fundamental to the economy and affects all areas of economic activities (Le, 2012). The new growth models (see

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for example, Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992) suggest that technological progress is not a free gift from heaven but a direct outcome of innovation process. This is in contrast to the neo-classical model which treats technological progress as exogenous. According to the new growth model, investments in innovation activities would allow country to enjoy technological progress and greater productivity which ultimately lead to the expansion of the economy.

Since the pioneering work of Coe and Helpman (1995), many studies have recognized the importance of international research and development (R&D) spillovers. Due to the non-rival characteristics of technology, R&D investment would contribute to the stock of knowledge as it is publicly available to everyone. Hence, R&D of one country does not only affect domestic firms but also foreign firms. This suggests that countries which hardly invest in R&D activities would benefit from new knowledge developed by R&D leaders. The theory suggests that the extent to which local firms can benefit from foreign knowledge depends on many factors such as trade volume (Coe and Helpman, 1995), characteristics of traded products (Coe, Helpman, and Hoffmaister, 1997), flow of foreign direct investment (FDI) (van Pottelsberghe and Lichtenberg, 2001), and human capital mobility (Park, 2004).

Among the factors highlighted above, human capital mobility is a newly established channel for knowledge spillovers across borders. It is argued that some knowledge is difficult to be expressed in words or language (Koskinen, Pihlanto and Vanharanta, 2003) and therefore exchange of goods or investment for spillovers will not help its diffusion across borders (Lee, 2005). Instead, spillovers of this type of knowledge require direct communication. Therefore, international students flow is viewed as conduit for knowledge transmission because students are able to absorb foreign knowledge when they study abroad or through post schooling job experience and transfer it back to domestic country when they return (Park, 2004).

R&D via students flow has been hardly investigated. Two exceptions are Park (2004) and Le (2010). Park (2004) shows that international student flow is an important spillover channel among developed countries while Le (2010) complements the finding for spillovers from developed to developing countries. However, they found that spillover effects through import are relatively stronger than student flow. Recent literatures show that globalization has led to improved communication and mobility across border, and this therefore suggests that disembodied spillovers channel (such as international student flow) today could be at least as important as embodied channel in past decades (Filatotchev, Liu, Lu and Wright, 2011). Hence, a study on recent period could lead to different findings on the relative importance of various spillover channels.

Several recent papers suggest that knowledge spillovers are not automatic consequences of direct or indirect contact with R&D leaders. They argue that host countries must have certain quality which allows them to absorb and internalize the technology generated abroad. For instance, Azman-Saini, *et al*., (2010) show that only countries with sufficient freedom of economic activities are able to absorb and internalize new technologies associated with FDI inflow. In an economically freer environment, firm are more willing to engage in risky investment project, such as trying out news ideas and new technologies, it will motivates domestic firm to absorb foreign technology in local market.

The purpose of this paper is therefore to evaluate the role of economic freedom plays in moderating R&D spillovers from developed to developing countries. Two channels are analyzed namely import and international student flows. In the face of increasing globalization, understanding the effective channels of R&D spillovers across countries is critically important. Evidence on international technology spillover is equally important for both innovation leader and follower. In the case of innovation leader, knowing how knowledge is transmitted across countries is necessary in order to protect the interests of innovators. For the followers, evidence of spillover effects will provide additional incentives for them to further integrate with the rest of the world. Greater openness is expected to provide countries with a better atmosphere for technology acquisition. To achieve this objective, data from 75 developing countries over the 2000-2008 period and a generalized method of moment (GMM) panel estimator are used. This estimator has several advantages over other alternatives.

This paper fills the gap in the literature in several important ways. First, most of the previous studies have mainly focused on embodied channel for spillovers such as import and FDI. On top of embodied channel (i.e. import), this paper also assess the importance of disembodied channel in R&D spillovers. Specifically, it examines the role of international student flows. Secondly, prior researcher on R&D spillovers did not account for the role of absorptive capacity in mediating R&D spillovers. Several recent papers suggest that knowledge acquisition requires the receiving nations to have some level of absorptive capacity. Therefore, we argue that absorptive capacity is able to amplify the effects of R&D spillovers. In this study, we evaluate the role economic freedom plays in enhancing R&D spillovers from industrial countries to a group of developing countries.

The rest of the paper is structured as follows. The next section presents a brief literature review. Then, section on research methodology outlines model specification, methodology and data. Subsequence section discusses empirical results and their interpretation. Conclusion is reported in the final section.

REVIEW OF LITERATURE

Research and development (R&D) is considered as a major source of technological progress. According to OECD (2003), R&D can be defined as a 'creative work undertaken on a systematic 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 applications'. This suggests that R&D is a process of transforming R&D inputs into R&D outputs which materialize in the forms of increments to the stock of knowledge and new technologies (i.e. applications of existing knowledge).

Much of earlier policy debate about technology spillover is based on the presumption that a country's productivity depend on domestic investment in R&D. In line with this emphasis, earlier empirical works on R&D spillover have focused on the impact of domestic R&D activities on growth (e.g. Griliches, 1988, 1992; Nadiri, 1993; Mohnen, 1996). Generally, these studies provide convincing evidence that cumulative domestic R&D is an important determinant of productivity. Indeed, they find that the rate of return on R&D investment is high.

However, with a rapid pace of globalization, productivity growth of a country does not depend only on domestic R&D, but also foreign R&D through interaction with foreign economies. As a result, a more recent stream of empirical literature focuses on international R&D spillover[1]. The pioneering work of Coe and Helpman (1995) (henceforth, CH) assessed R&D spillover across 21 OECD countries plus Israel and demonstrate an empirical relationship between R&D expenditures and total factor productivity (TFP). They find that not only domestic R&D contributes significantly to productivity growth but also foreign R&D incorporated into trade flows. Trade can boost domestic productivity by making available product that embodies technological knowledge of trading partners. By enabling a country to employ larger variety of intermediate product and capital equipment, trade enhances the productivity of resources. Trade also improves domestic productivity by making available useful information that would otherwise be costly to acquire.

A number of papers have made progress by examining international R&D spillover further. Xu and Wang (1999) emphasize that technology diffusion is associated with trade in differentiated capital goods. They decompose total imports into the imports of capital and non-capital goods. They find that about half of the return on R&D investment in a G7 country spilled over to other OECD countries and trade in capital goods was found to be a significant channel for R&D spillovers. Lumenga-Neso *et al*. (2005) argue that `indirect' trade-related R&D spillovers also

[1] Keller (2004) provides an in-depth survey of the existing evaluations of international R&D spillovers.

take place between countries, even if they do not trade with each other. Country A may benefit from country B's technology without importing from country B, if country B exports to country C which in turn exports to country A. Using a specification that captures such indirect effect of R&D spillovers, they provide better empirical results than CH. They find that the `indirect' trade-related R&D spillovers are on average 14 times as large as `direct' spillovers.

The above studies consider international trade as the only channel for international R&D spillover. They are likely to have underestimated the relative magnitude of international spillover effects that pass through other channels. Over the past few decades, foreign direct investment (FDI) by multinational corporations (MNCs) has grown substantially. The growth rate of world FDI has exceeded the growth rates of both world trade and GDP (UNCTAD, 2001). FDI has been an important channel for transferring goods and services across borders (Saggi, 2002). Since MNCs responsible for a large share of global R&D expenditure (Borensztein *et al*., 1998), FDI by MNCs could be a potential channel to access advanced technologies available in the global marketplace. Van Pottelsberghe and Lichtenberg (2001) (henceforth, PL) extend CH's analysis by incorporating both inward and outward FDI flows in addition to the trade flow. Due to limited bilateral FDI data, PL analyze only 13 out of 22 countries covered in CH's study. They find that foreign R&D can affect domestic productivity through both imports and outward FDI (i.e. technology sourcing). Although both inward and outward FDI may facilitate technology acquisition, outward FDI is a more effective channel as it is more likely to involve 'total immersion'. By setting up production and research facilities in countries that have accumulated substantial scientific and technological capabilities, technology follower can have better access to leading technology. The finding of technology sourcing practices is consistent with Dunning (1994) paradigm that companies prefer to invest abroad in order to take advantage of their own technology base instead of diffusing it internationally. The pioneering works on technology sourcing by Kogut and Chang (1991) find that Japanese firms tend to acquire local U.S. firms when they suffer from technological or comparative disadvantage but choose to establish new plants when they poses technological comparative advantages as compared to their U.S. competitors. Evidence on FDI as a spillover channel has inspired several recent studies in this area (e.g. Bitzer and Kerekes (2008); Zhu and Jeon (2007); Savvides and Zachariadis, 2005).

Several recent papers suggest that some knowledge do not require exchange of goods or investment to be transferred (Lee, 2005). They also highlighted that social engagement like face-to-face interactions would reinforces the knowledge sharing (Koskinen, Pihlanto and Vanharanta, 2003). Therefore, the relationship and social connection established between two parties, such as publication, public meeting and conference, information exchange, competitor's products, patent and telecommunication is crucial (Almeida and Kogut, 1999, Cohen, Goto, Nagata, Nelson and Walsh, 2002; Tang and Koveos, 2008). Moreover, Kim and Lee (2004) argue that embodied technology diffusion (via import and FDI) has a larger impact on efficiency while disembodied technology diffusion affects technical change. With regard to this issue, direct communication or "disembodied channel" like human capital is an effective way to transfer knowledge (Song, Almeida and Wu, 2003).

Park (2004) suggests that international student flow is an important mechanism for technology transfer because students who study abroad would acquire external knowledge through education or post schooling job experience, and then bring the knowledge back to home country when they return. International students also learn the foreign country's knowledge of technology, material, production method and organizational structure (Le, 2010). In additional, returnees own the specific human capital and social capital, therefore act as a bridge between source and host countries and accelerate the knowledge transfer (Filatotchev *et al*., 2011). Though not every international student would returns, migrated workers would still benefit their home country. Foreign workers usually maintain a close connection with their home country and able to contribute in home countries' productivity with technology learned from host country (Le, 2008). Empirical evidence on biotechnology industry (Zucker, Darby and Brewer, 1998) and semiconductor industry (Almeida and Kogut, 1999) in the U.S. market show that the mobility of specialists across firms is found to be one of the major determinants for knowledge transfer. Generally, human capital mobility was shown to be an important mechanism for knowledge diffusion and spillovers could be absent without it.

Although research on international R&D spillover has been growing, it remains limited particularly with respect to R&D spillovers from developed to less developed countries. It is well known that much of the R&D activity in the world is concentrated in the industrialized countries. In fact, within the OECD three key players in R&D activity (i.e. United States, Japan and Germany) accounted for 67% of R&D expenditure in 2005. This raise concern of whether less developed countries can benefit from high concentration of R&D activity in a handful of developed countries. The finding of R&D spillovers may have important implications for less developed countries that lag behind technology frontier and hardly invest in R&D activities. Analysis on R&D spillover from developed (North) to developing countries (South) was pioneered by Coe *et al*. (1997). Following similar approach as CH, they estimate the elasticity of TFP in 77 developing countries with respect to R&D stock in developed countries and find that the R&D spillover from North to South is substantial. On average, 1% increase in R&D capital stock in developed countries contributes to 0.06% increase in productivity of developing countries.

Among the developed countries, United States is the largest contributor to the productivity of developing countries owing to its large trade share with developing countries and also because of its huge R&D capital stock compared to other developed countries. Due to data limitation, Coe *et al*. (1997) ignore domestic R&D capital stock in their analysis.[2] Several recent papers that assess North-South R&D spillovers include Madden *et al*. (2001), Kwark and Shin (2006), Le (2010), Tang and Koveos (2008), Le (2012).

In other related development, recent studies show that knowledge diffusion is not an automatic process. Instead, it requires knowledge recipients to have certain level of absorptive capacity.[3] Specifically, the knowledge spillovers may not be strong in countries with poor absorptive capacity. A number of papers have tested the absorptive capacity hypothesis in the FDI-growth context. For instance, Blomstrom *et al*. (1994) reveal that the growth-effect of FDIs is stronger in countries with a higher level of development (i.e., when the country is sufficiently rich in terms of per capita income). Meanwhile, Borensztein *et al*. (1998) found that the positive impact of FDI on output growth certain level of human capital to be available in the host countries. Recently, several authors have assessed the impact of financial sector development on FDI spillovers (Hermes and Lensink, 2003; Alfaro *et al*.,2004, 2010; and Durham, 2004). They find that the success of technology spillovers from MNCs to local firms required well-functioning financial institutions. The development of both banks and stock markets were found to be important pre-conditions for FDI spillovers. Recently, Azman-Saini *et al*. (2010) show that knowledge spillovers via FDI require that host countries to have certain level economic freedom. The authors argue that the lack of economic freedom can limit a firm's (or nation's) ability to absorb and internalize new technology from multinational corporations.

RESEARCH METHODOLOGY

This study uses a generalized version of the model employed by Coe and Helpman (1995), as modified by Lichtenberg and van Pottelsberghe (1998) and van Pottelsberghe and Lichtenberg (2001). Equation (1) provides the basic econometric

[2] Due to underdeveloped financial market or inappropriate policy, developing countries usually have limited R&D investment (Griffith, Redding and Reenen, 2003).

[3] Cohen and Levinthal (1990) define absorptive capacity as a firm's "ability to recognize the value of new information, assimilate it, and apply it to commercial ends." This concept differs from learning-by-doing, which is the automatic process by which firms become more experienced, and hence, more efficient at current practices. In contrast, with absorptive capacity firms may acquire new knowledge developed by others that will enable them to do something in different ways.

model. It states that the domestic total factor productivity of a country is a function of different types of foreign R&D capital stocks: [4]

$$TFP = f(S_M, S_{SF}) \tag{1}$$

where TFP is total factor productivity, S_M and S_{SF} are respectively import-weighted and student flow-weighted foreign R&D capital stocks.

TFP measurement used in this paper is different from those in many of the previous studies. This paper follows a suggestion by Klenow and Rodrigues Clare (1997) and Hall and Jones (1999) who use human capital augmented labor instead of only labor. This approach, therefore, also consider the quality of labor. To highlight the computation of total factor productivity (A), let assume the following production function:

$$Y = AK^{\alpha}H^{1-\alpha} \tag{2}$$

where Y is output, K is capital stock, α is share of capital income in GDP. Capital stocks are computed using gross fixed capital formation following the perpetual inventory method (PIM) and H is augmented labor based on Mincerian's function:

$$H = \exp^{\varphi(E)} L \tag{3}$$

where the labor, L, is assumed to be homogenous and each is trained with E years of schooling.

Equation (3) shows that the labor force is multiplied by efficiency, E, which represents years of schooling and derivative $\varphi'(E)$ is the return to education where labor force with no schooling is $\varphi(0) = 0$. Years of experience and sum of human capital with different education and experience level are found to have only little effect (Klenow and Rodriguez Clare, 1997) and therefore are not used in this paper. Additionally, following Hall and Jones (1999) several adjustments are made. First, output measure is adjusted for natural resource so that the countries would not be ranked as top productivity country due its rich resource. Thus, value added in the mining industry will be subtracted from GDP. Second, α is set to as standard neoclassical approach suggests. Third, $\varphi(E)$ is assumed to be piecewise linear. The rate of return of education is 13.4 percent for the first four years (average of sub Saharan Africa), 10.1 percent for the next four years (average of world), and 6.8 percent for more than eight years (average of OECD). These figures were

[4] Most of the studies which focus on R&D spillovers among developed countries have also included FDI-weighted foreign R&D stock and domestic R&D stocks in their model. This study focuses on North-South spillovers and due to the unavailability of data on domestic R&D and FDI for many developing countries; this study uses a more simplified model as above.

suggested by Psacharopoulos (1994) based on survey on return to schooling from many countries.

Following Le (2010), student flow-embodied capital stocks are computed as follows:

$$Sfs_{it} = \sum \left(\frac{s_{ijt}}{n_{jt}} \right) Sd_{jt} \tag{4}$$

where s_{ij} is the number of tertiary students originating from country *i* and studying at country *j*, n_j is the total number of tertiary students enrolled in country *j*. Sd_j is total domestic R&D stock in country *j*. The weight reflects the concept where country *i* benefits from country *j*'s R&D investments depend on the degree of access by students from country *i* to knowledge available in country *j*.

The import embodied foreign R&D capital stock (Sfm_{it}) is constructed following van Pottelsberghe and Lichtenberg's (2001) method as follows:

$$Sfm_{it} = \sum \left(\frac{m_{ijt}}{y_{jt}} \right) Sd_{jt} \tag{5}$$

where m_{ij} is the value of imported goods and services of country *i* from country *j*. It might be interpreted as embodied with R&D intensity of source country (country *j*), *y* is gross domestic product of country *j*, Sd_j is total domestic R&D stock in country *j*.

This study include as many developing countries as possible but due to data limitation, only annual data series from 75 developing countries over the 2000-2008 periods are used.[5] Data used to compute TFP (i.e. GDP, gross fixed capital formation, labor force) were obtained from the *World Development Indicators* database except for human capital which uses average education year for age above 25 as reported in Barro and Lee (2010). Foreign R&D stocks were constructed based on R&D spending by G7 (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) and the data were collected from the *OECD Main Science and Technology Indicators* database. Bilateral data for import was obtained from the *United Nations Commodity Trade (UN Comtrade)* database. The information on contribution of mining activity to total value added was obtained from the *United Nations Statistics Division National Accounts Main Aggregates Database*. Finally, total number of students enrolled in tertiary level education and number of international students enrolled were collected from the *OECD Education and Training Database*. The economic freedom index was obtained from the *Annual Report of Economic Freedom of the World* published by the Fraser Institute.

[5] This sample period is dictated by the availability of data on student flows.

This paper applies the generalized method-of-moments (GMMs) panel estimator which was first proposed by Holtz-Eakin, Newey and Rosen (1988) and then extended by Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998). One of the reasons for choosing GMM estimator is the need to address country-specific effect. Arellano and Bond (1991) suggest transforming the estimated equation (1) into first-difference to eliminate country specific effects as follows:

$$TFP_{it} - TFP_{it-s} = \alpha\,(TFP_{it-1} - TFP_{it-2}) + \beta_1\,(X_{it} - X_{it-1}) + (\varepsilon_{it-s} - \varepsilon_{it-s}) \qquad (6)$$

where X is a vector of independent variables. Within this framework, lagged levels of the regressors are used as instruments to alleviate bias introduced by possible endogeneity of regressors and also the correlation between ($TFP_{it-1} - TFP_{it-2}$) and ($\varepsilon_{it} - \varepsilon_{it-1}$). This strategy is valid under two assumptions: (i) the error term is not serially correlated, (ii) the lag of explanatory variables are weakly exogenous. Then, following Arellano and Bond (1991) the moment conditions are set as follows:

$$E[TFP_{i,t-s} \cdot (\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0 \qquad \text{for } s \geq 2;\ t = 3, ..., T \qquad (7)$$

$$E[X_{i,t-s} \cdot (\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0 \qquad \text{for } s \geq 2;\ t = 3, ..., T \qquad (8)$$

However, Alonso-Borrego and Arellano (1999) and Blundell and Bond (1998) show that the lagged levels of variables become weak instruments when explanatory variables are persistent. This problem can result in biased parameter estimates and inflated variance. To address this problem, an alternative system estimator was proposed by Arellano and Bover (1995) which combines both difference and level equations in one system of equation. This strategy is known as system GMM and was shown to be able to reduce bias and imprecision associated with different estimator (Blundell and Bond, 1998).

In this approach, lagged first-difference and lagged levels are used as instruments for equations in levels and first difference, respectively. Hence, moment conditions for regression in difference are maintained as in (7) and (8) and additional moment conditions for regression in levels are set as follows:

$$[TFP_{i,t-s} - TFP_{i,t-s-1} \cdot (\eta_i + \varepsilon_{i,t})] = 0 \qquad \text{for } s \geq 2;\ t = 3, ..., T \qquad (9)$$

$$[X_{i,t-s} - X_{i,t-s-1} \cdot (\eta_i + \varepsilon_{i,t})] = 0 \qquad \text{for } s \geq 2;\ t = 3, ..., T \qquad (10)$$

Two specification tests are needed to determine the consistency of GMM estimator. The first is Sargan Test which is used to examine over–identifying restrictions with the null of joint validity of all instruments. The second test examines the hypothesis of no second–order serial correlation in the error term of the regression in difference as assumed in Equation (6) (Arellano and Bond, 1991). If the results fail to reject both null hypotheses, this would indicate that the model is adequately specified and the instruments are valid.

RESULTS AND DISCUSSION

The main objective of this paper is to estimate R&D spillovers through import and international student flow and also to investigate the role of economic freedom in mediating spillover effects. To this end, the GMM estimator outlined in the previous section is used and results are presented in Table 1. Models (1) and (2) include import and international student flow as spillover channels, separately. Model (3) includes both channels simultaneously. As shown in Table 1, TFP elasticities with respect to both foreign capital stocks have plausible magnitudes, lying in absolute value between zero and one.

Import-weighted and student flow-weighted foreign capital stocks are found to be important in all cases. The estimated elasticity for import-weighted capital stock ranges from 0.06-0.08 while the one for student flow is between 0.016 and 0.1. This suggests that increase in import-weighted foreign R&D capital stock will increase domestic productivity by 0.06-0.08 percentage point. In the case of student flows channel, it will increase productivity by 0.016 to 0.1 percentage point. Additionally, the estimated regression passed both specification tests. The

Table 1 R&D spillovers via student flow and import

	(1)	**(2)**	**(3)**
$R\&D_{it-1}$	0.1981***	0.0431***	0.3405***
S_m	0.0833***		0.0658***
S_{sf}		0.0163***	0.1055***
Sargan test (p-value)	0.327	0.684	0.921
AR (2) test (p-value)	0.212	0.725	0.916
Number of observation	600	600	600

Notes: All variables are expressed in logarithmic form. S_m, $S_{sf,}$ are respectively import-weighted foreign R&D, student flow-weighted foreign R&D. *** indicate statistical significance at the 1% level.

null of no second-order serial correlation cannot be rejected at the 5% level. Also, the regression results is not affected by simultaneity bias as the orthogonality conditions cannot be rejected at the 5% level, as indicated by the Sargan test. This suggests that the equation is adequately-specified and the instruments employed in the analysis are valid.

The finding is consistent with Coe and Helpman (1995), Coe *et al*. (1997), Lichtenberg and van Pottelsberghe (1998) and van Pottelsberghe and Lichtenberg (2001) who also find the importance of imports as an important channel. It is also in line with Park (2004), Le (2010) and Le (2012) on the role of student flows in enhancing domestic TFP. However, in term of magnitude of the impact, this finding is not consistent with Park (2004) who finds import as a more important channel than student flow across a group of developed countries for the period 1971-1990. This was further supported by Le (2010) which focuses on spillover effects from developed to developing countries during the 1998-2005 period. One potential reason for the difference between our finding and those of Park (2004) and Le (2010) is because we use recent data during which globalization is prominent. Generally, our finding support the idea that globalization with advancements in communication technology promotes a greater role of human capital mobility in enhancing productivity. As noted by Filatotchev *et al*. (2011), mobility across border nowadays is easier than decades before as globalization taking place.

The next step of the analysis is to assess whether economic freedom plays an important role in mediating R&D spillovers. To this end, we extend Equation (1) to include interaction term constructed as the product of foreign capital stocks and the economic freedom (EF) index (i.e. $S_m \times EF$ and $S_{fs} \times EF$). To ensure that the interaction term does not proxy for S_m, S_{fs}, and EF, the economic freedom were included in the regression independently. Within this framework, we rely on the interaction term to establish the contingency effects. If the term is positive and significant, this would imply that the R&D spillovers increase with economic freedom[6]. The results of this exercise are tabulated in Table 2. The first thing to note is that interaction term $S_{fs} \times EF$ turns out to be positive and statistically significant at the 5% level. This result implies that the effect of foreign R&D via student flows on TFP increases monotonically with EF. However, the same effect could not be established for spillover effects via import. Additionally, all other variables in

[6] It should be noted that the inclusion of interaction term in our model may lead to multicollinearity problem as the term tends to strongly correlated with original variables. This paper follows Azman-Saini et al. (2010) suggestion to adopt the following two-step procedure: First, interaction term is regressed on the foreign capital stock with EF (i.e. Sm×EF and Sfs×EF) and then the residuals from the regressions in the first step are saved and used to represent the interaction term.

level are positive and statistically significant. The p-values of both second-order serial correlation and the Sargan over identification tests suggest that the model is adequately specified.

Table 2 Role of Economic Freedom in R&D Spillovers

	(4)	(5)
$R\&D_{it-1}$	0.4799***	0.5063***
S_m	0.0643***	0.0647***
S_{sf}	0.0987***	0.1088***
EF	0.3451***	0.3989***
$S_m \times EF$		0.0028
$S_{sf} \times EF$	0.5139***	0.3436***
Sargan test (p-value)	0.830	0.925
AR (2) test (p-value)	0.331	0.447
Number of observation	600	600

Notes: All variables are expressed in logarithmic form. S_m, $S_{sf,}$ and EF are respectively import-weighted foreign R&D, student flow-weighted foreign R&D and economic freedom. *** indicate statistical significance at the 1% level.

The finding is consistent with several papers who find that economic freedom is important in influencing economic performance. For instance, Doucouliagos and Ulubasoglu (2006) reveal that economic freedom has an indirect influence on growth through physical capital accumulation. Meanwhile Azman-Saini *et al*. (2010) find that economic freedom moderate the impact of FDI on growth. Recently, Farhadi, Islam and Moslehi (2015) show that improvement in economic freedom is expected to enhance growth through improved rent of natural resources. The overall finding supports the view on the importance of promoting freedom of economic activities to facilitate knowledge spillovers.

Several robustness checks are carried out to ensure that the results we obtain are robust. First, we compute TFP as $Y / (K^{\beta}L^{1-\beta})$. This measurement was used in the pioneering study of Coe and Helpman (1995) and many others (e.g. Coe *et al*., 1997; van Pottelsberghe and Lichtenberg, 2001; Park, 2004; Le, 2010). The result of using alternative TFP is reported in Column (1) in Table 3. Second, we use a different measure of import. Specifically, we use import of machinery and transport equipment and the results are reported in column (2). Third, we use import of manufactured goods and result is presented in column (3). Finally, we expand the source countries for foreign R&D as well as countries of destination for student flows. We include 16 OECD countries for this purpose and the results are reported in column (4) of Table 3[7].

Table 3 Robustness checks

	(1)	(2)	(3)	(4)
Lagged dependent	0.5450***	0.4672***	0.4816***	0.4012***
S_m	0.0938***	0.0781***	0.0798***	5.5480***
S_{sf}	0.0933***	0.0855***	0.0961***	6.7832***
EF	0.2183***	0.3064***	0.2958***	83.0271***
S_{sf}×EF	0.4122***	0.4429***	0.4344***	51.8342***
Sargan test (p-value)	0.989	0.886	0.830	0.936
AR (2) test (p-value)	0.427	0.424	0.426	0.311
Number of observation	600	600	600	600

Notes: All variables are expressed in logarithmic form. S_m, $S_{sf,}$ and EF are respectively import-weighted foreign R&D, student flow-weighted foreign R&D and economic freedom. *** indicate statistical significance at the 1% level.

The results in Table 3 show that all variables are statistically significant at the 1% level and retained their positive signs. Additionally, diagnostic tests for all four regressions suggest the models are adequately specified. Overall, this suggests that the results are consistent and robust.

However, it is worth nothing that when traditional TFP measure is used, the magnitude of coefficients suggest different story about the relative importance of spillover channel. Result in column (1) shows that the size of coefficients on import and international student flow are almost the same which suggest that both channels are equally important for spillover effects. Another observation is that import of machinery and equipment columns and import of manufactured goods performs better than total import (i.e. results presented in Table 3). These findings are similar to those of Coe *et al*. (1997). This is consistent with the view that many consumer goods and services have less technical contents to have any important impact on productivity.

[7] Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherland, Norway, Spain, Sweden, United Kingdom, and United States.

CONCLUSIONS

This study examines R&D spillovers from developed to developing countries via import and student flow channels. It also evaluate whether economic freedom make a difference to the way knowledge are transmitted across borders. The results show that international student flow has a greater influence than import in transmitting knowledge across borders. Thus, this finding supports the view that flexibility in human capital movement across border would enhance the spillover of disembodied knowledge or technology. In addition, economic freedom is found to be able to moderate the spillover effects through international student flow. Thus, countries that actively promote freedom of economic activity could gain more in productivity improvement via this channel. Nevertheless, there is no enough evidence to support its role via import channel. These results cast doubt on the role of economic freedom in assisting the acquisition of new knowledge embodied in imported goods. The results are robust to several sensitivity checks such as different measures of TFP and imports weighted foreign capital stocks. This suggests that government policies that encourage knowledge acquisition in foreign country are expected to enhance domestic productivity. Also, countries that promote freedom of economic activity will provide better environments for domestic firms to internalize foreign technologies.

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APPENDIX

List of Countries

Albania	Fiji	Pakistan
Algeria	Gabon	Panama
Argentina	Ghana	Papua New Guinea
Bahrain	Guatemala	Paraguay
Bangladesh	Guyana	Peru
Barbados	Honduras	Philippines
Belize	Hungary	Poland
Benin	India	Romania
Bolivia	Indonesia	Russian Federation
Botswana	Iran, Islamic Rep.	Rwanda
Brazil	Jordan	Senegal
Bulgaria	Kenya	Sierra Leone
Burundi	Kuwait	South Africa
Cameroon	Latvia	Sri Lanka
Central African Rep.	Lithuania	Syrian Arab Rep.
Chile	Malawi	Thailand
Colombia	Malaysia	Togo
Congo, Rep.	Mali	Tunisia
Costa Rica	Mauritius	Turkey
Cote d'Ivoire	Mexico	Uganda
Croatia	Morocco	Ukraine
Dominican Rep.	Namibia	Uruguay
Ecuador	Nepal	Venezuela, RB
Egypt, Arab Rep.	Nicaragua	Zambia
El Salvador	Niger	Zimbabwe