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Abstract

Using a sample of 15 OECD countries, this paper investigates whether free trade agreements (FTAs) enhance R&D spillovers across national borders and if institutions play some role in affecting this knowledge diffusion process. Dynamic panel regressions employing advanced estimation technique lend strong support to these hypotheses. The paper finds that a country's total factor productivity significantly benefits from trade weighted foreign R&D as trade strengthens the country's access to foreign knowledge pool. By creating more trade with partner countries, FTAs further improve the country's productivity. With regards to institutional factors, countries where the form of government is mainly parliamentary tend to benefit less from their own innovative efforts but more from international R&D spillovers. In addition, countries having both plural and proportional rules of election are generally associated with higher returns to domestic R&D but lower international R&D spillovers as compared to those having a mono rule system.

Keywords: free trade agreements, R&D spillovers, growth, institutions.

JEL classification: F15, O31, O33, O40, O43.

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1. Introduction

Throughout history, the question that attracts most world economists' attention is how to increase long-run output growth. Neoclassical theory, e.g. Solow (1956), Swan (1956), emphasizes factor accumulation as the source of output expansion treating technological progress as exogenous. New growth theory, starting with Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992), suggests that technological progress is the direct outcome of innovation which relies heavily on cumulative R&D experience. These R&D activities account for much of output growth in the last century through the creation of either horizontally brand-new varieties or higher quality versions of existing products.

Technology has a special feature that distinguishes it from other production inputs. This feature lies in its nonrival characteristics. Investment in R&D is not only good for its own investors but also benefits others as technological products contribute to the general knowledge pool which is available for public access. These externalities are referred to as 'technological spillovers'. These spillovers allow a country to benefit from both domestic R&D activities that it conducts and foreign R&D activities conducted overseas. A large amount of research has examined this issue since the pioneering work by Coe and Helpman (1995). It has been generally agreed that trade is a special conduit for technological transfer (Engelbrecht, 1997; Keller, 1998, 1999, 2002; Lee 2006; Zhu and Zeon, 2007; Coe *et al.*, 2009).[2]

This paper contributes to the literature on international R&D spillovers in the following ways. First, it is one of the first studies that attempt to investigate the role of FTAs in enhancing R&D spillovers. It is well known that there has been a dramatic rise in the number of regional trade agreements (RTAs) which has become a phenomenal feature in international trade

[2] Other recognized channels for technological transfer include foreign direct investment (van Pottelsberghe and Lichtenberg, 2001; Lee, 2006; Zhu and Zeon, 2007), high skilled labour mobility (Park, 2004; Le, 2008, 2010; Le and Bodman, 2010) or pure proximity in the technological space (Park, 1995; Frantzen, 2002).

especially in the past two decades. As of February 2010, 462 RTAs were notified at the World Trade Organisation (WTO) with 271 of them currently in force (around 80% of these had been concluded since the late 1990s). Currently, every single WTO member, except for Mongolia, participates in at least one of these RTAs and belongs to six RTAs on average).[3] Unlike non-discriminatory trade liberalization, an FTA requires a member country to eliminate its tariff on imports from its FTA trading partner(s). However, the country can still retain this tariff on imports from other non-FTA countries. This may bring a change in the direction and volume of trade flows among countries, which is not observed in case of global trade liberalisation.[4] The change, in turn, is likely to affect the international transmission of knowledge and economic growth. Despite the remarkable proliferation of FTAs, there are surprisingly very few studies that try to identify the impact of FTAs on growth, especially on the TFP levels of member countries. Sohn and Lee (2006) test the impact of FTAs on income convergence among member countries and find that FTAs accelerate income convergence among member countries. Vamvakidis (1998) examines if growth of member countries is influenced by regional trade agreements (RTAs) and finds no evidence of faster growth from those RTAs.[5] To our knowledge, Schiff and Wang (2003) is the only research work that studies a similar question to the one in this paper: the potential impact of FTAs on TFP. Nevertheless, it is only limited to the impact of a specific FTA, the North American Free Trade Agreement (NAFTA) on the TFP level a particular country, Mexico. By contrast, the analysis in this paper is conducted on all available FTAs and for a number of countries using FTA generated trade weighted foreign R&D computation.

[3] Of these RTAs, FTAs and partial scope agreements account for 90%, while customs unions account for 10 %. Data on RTA information are available on the WTO website: http://rtais.wto.org/UI/PublicMaintainRTAHome.aspx.

[4] There is a rich literature on the effects of FTAs on trade flows. For more about this literature, see, for example, Baier and Bergstrand (2007) and Magee (2008).

[5] The RTAs include Association of South East Asian Nations (ASEAN), Andean Common Market (ANCON), Central American Common Market (CACM), European Union, and Union Douaniere et Economique de l'Afrique Centrale (UDEAC).

Second, this paper considers the impact of institutional factors on the degree of R&D spillovers across national borders and the contribution of domestic R&D to TFP. Given that institutions turn out to be deep determinants of growth and TFP in the literature (e.g. Acemoglu *et al.*, 2001; Rodrik *et al.*, 2004), it is important to examine the roles of institutions within an R&D-based context. So far, Coe *et al.* (2009) is the only paper that examines the impact of institutions on the R&D-TFP growth nexus. However, their measures of institutions are different from those used in this paper. Specifically, they use ease of doing business, quality of tertiary education systems, patent protection, and legal origins as proxies for institutions while this paper is more concerned with possible effects of electoral rules and forms of government on R&D spillovers and TFP growth. These factors may affect the way R&D budget and funding are allocated and the way trade policies are conducted. Moreover, Coe *et al.* (2009) do not consider the role of FTAs in affecting knowledge transmission process as this paper does.[6]

The main findings of this paper are as follows. Both international trade and its arrangements turn out to be important channels for R&D spillovers. FTAs enhance the knowledge transmission process through trade even further by creating more trade with partner countries. Countries where the form of government is mainly parliamentary tend to benefit less from their own innovative efforts but more from international R&D spillovers. Countries having both plural and proportional rules of election are generally associated with higher returns to domestic R&D but lower international R&D spillovers in comparison to countries having a single rule system. This paper obtains all these results by using cointegration and dynamic ordinary least squares (DOLS) estimation method, an advanced econometric technique on panel data.

[6] Guellec and van Pottelsberghe (2004) also tests the role of institutions in an R&D context, however, from a different perspective: how institutional sources of funding (public institutions versus higher education institutions) matter.

The rest of the paper is structured as follows. Section 2 briefly discusses the theoretical and empirical framework based on which econometric estimates of the impact of domestic and alternative foreign R&D on national productivity growth are performed. It also summarizes the construction of some key variables used for the estimation. A brief description on data sources is provided in Section 3. Section 4 presents empirical results and findings following a discussion on the econometric techniques of panel cointegration. Section 5 addresses the importance of institutions on the extent to which domestic R&D and international R&D affect TFP. Section 6 offers concluding remarks.

2. Theoretical framework and empirical consideration

In general, a particular country consists of a large number of final goods producers. However, for simplicity, assume that all final goods producers, on aggregate, produce a homogenous consumption good according to the following production function:

$$Y_t = AK_t^{\beta} D_t^{\alpha} L_t^{1-\alpha-\beta}, \quad A>0, \quad 0<\alpha,\beta,\alpha+\beta<1 \tag{1}$$

where Y_t is the output level at time t, K_t is the existing stock of physical capital, L_t is the labour employment, and D_t is a composite input of differentiated goods which is defined as follows:

$$D_t = \left[\int_0^{N_t} \left(q_{mvt} X_{vt} \right)^{\alpha} dv \right]^{\frac{1}{\alpha}} \tag{2}$$

In this equation, the variable N_t denotes the range of intermediate inputs used for production of final goods in the country (it might be different from the range of intermediate inputs produced in that country given imported intermediate inputs). X_{vt} is the physical amount of capital product v employed, and q_{mvt} is its attached productivity grade. Capital goods are produced by specialised intermediate firms. Each firm produces only one kind of capital good at production cost, which is normalised to 1 for simplicity and rent it out to final goods producers at a rental rate P_{vt}.[7] The optimality condition dictates that the rental rate of a capital good is equal to its marginal product:

$$\frac{\partial Y_t}{\partial X_{vt}} = AK_t^{\beta} L_t^{1-\alpha-\beta} \alpha q_{mvt}^{\alpha} X_{vt}^{\alpha-1} = P_{vt} \tag{3}$$

This gives the demand function for capital good v:

$$X_{vt} = \left(\frac{AK_t^{\beta} L_t^{1-\alpha-\beta} \alpha q_{mvt}^{\alpha}}{P_{vt}} \right)^{\frac{1}{1-\alpha}} \tag{4}$$

With the assumption that each capital good producer facing a fixed set up cost μ, the lifetime profit from producing a capital good is:

$$\Pi_{vt} = -\mu + \int_t^{\infty} (P_{vt} - 1) X_{vt} e^{-r(s-t)} ds \tag{5}$$

In this formula, $(P_{vt} - 1) X_{vt}$ is the instantaneous profit flow at a point of time. The goal of intermediate firms is to set the price P_{vt} at each date to maximise this profit flow:

$$Max_{P_{vt}} \ (P_{vt} - 1). \left(\frac{AK_t^{\beta} L_t^{1-\alpha-\beta} \alpha q_{mvt}^{\alpha}}{P_{vt}} \right)^{\frac{1}{1-\alpha}} \tag{6}$$

This delivers the monopoly price that intermediate firms will charge:

$$P_{vt} = \frac{1}{\alpha}, \quad \forall v,\ t,\ m \tag{7}$$

[7] Each firm may produce more than one differentiated products. However, to make it simple, assume that whenever a new intermediate product is produced, a new firm is established. This simplified assumption does not change the result of the model.

This implies that the monopoly price is a mark-up over the marginal cost. Plugging the result into the demand function determines the total demand for capital variety v in equilibrium:

$$X_{vt} = \left(AK_t^{\beta} L_t^{1-\alpha-\beta} \alpha^2 q_{mvt}^{\alpha}\right)^{\frac{1}{1-\alpha}} \tag{8}$$

Demand is the same for all capital varieties of the same quality. For those of higher quality, the demand is also higher. Substituting the result into the final goods production function yields:

$$Y_t = \tilde{A} Q_t K_t^{\gamma} L_t^{1-\gamma} \tag{9}$$

where $\tilde{A} = A^{\frac{1}{1-\alpha}} \alpha^{\frac{2\alpha}{1-\alpha}}$, $\gamma = \dfrac{\beta}{1-\alpha}$, and $Q_t = \int_0^{N_t} q_{mvt}^{\frac{\alpha}{1-\alpha}} dv$ representing the aggregate technology index. The development of this index includes both the introduction of new capital goods (increases in N_t) and quality enhancement (increases in q_{mt}). If TFP is defined as $F_t = \dfrac{Y_t}{K_t^{\gamma} L_t^{1-\gamma}}$, it means that:

$$\log F_t = \log \tilde{A} + \log Q_t \tag{10}$$

This implies that productivity is positively related to the range and quality of the employed product variety. With international trade, both domestic and foreign intermediate goods can be employed for country i's production. Following Keller (1998), assume that domestic intermediate goods (Q_{it}^d) is weakly separable from their foreign counterparts (Q_{it}^f) then:

$$\log F_{it} = \log \tilde{A}_i + \alpha_1 \log Q_{it}^d + \alpha_2 \log Q_{it}^f \tag{11}$$

Because R&D investment leads to the expansion of product varieties so by an appropriate choice of unit normalisation, Q_{it}^d is identical to the cumulative stock of R&D expenditure

SD_{it}, and Q_{it}^{f} is captured by the foreign knowledge stock variable SF_{it}. This means that TFP in country i may grow either as a result of domestic innovation or international technological spillovers from foreign countries.

To test the above-mentioned hypothesis, two different measures of the foreign R&D capital stock variable, SF, are constructed. The first, the import-embodied foreign R&D capital stock, is generated as follows:

$$SF_{it}^{m} = \sum_{j \neq i} \frac{m_{ijt}}{y_{jt}} . SD_{jt} \tag{12}$$

where m_{ijt} is the value of imports of goods and services of country i from country j, and y_{jt} is country j's GDP at time t. This way of constructing foreign R&D capital stock is similar to that of Lichtenberg and van Pottelsbergher (1998). The variable generated is equivalent to the trade weighted R&D capital stock computed by Coe and Helpman (1995).[8] The key assumption of this method is that whenever an innovation succeeds, innovative knowledge spreads thinly and equally among all goods produced and part of that diffuses to a foreign country though the trade channel.

The second variant on the measure of the variable foreign R&D capital stock, SF, is the foreign R&D capital stock embodied in *trade generated through free trade agreements*. This measure is constructed as follows:

$$SF_{it}^{f} = \sum_{j \neq i} \frac{m_{ijt}}{y_{jt}} . SD_{jt} . FTA_{ijt} \tag{13}$$

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[8] In Coe and Helpman (1995), the stock of foreign R&D capital is computed as $SF_{it} = \sum_{j \neq i} \frac{m_{ijt}}{m_{it}} . SD_{jt}$, where m_{it} is total imports of country i at time t, and measured as an index number (1985=1). However, this has been shown by Lichtenberg and van Pottelsberghe (1998) to lead to a misspecified regression equation. In addition, the Coe and Helpman's method is also challenged by Keller (1998) who claims that regressions using counterfactual (randomly created) international trade patterns produce even more positive R&D spillovers and explain more of the variation in productivity than if actual bilateral trade patterns are used.

where FTA_{ijt} is an index representing the existence of a free trade agreement between country i and country j (which is equal to 1 if there is a free trade agreement and 0 otherwise). While the construction of bilateral import weighted foreign R&D has been familiar in the literature, the weighting scheme used for computing the FTA trade weighted R&D capital stocks is considerably novel. The employment of this particular measure of foreign R&D capital stocks is expected to capture international spillover effects through FTA generated trade.

Allowing different intermediate inputs from different sources to have different productivity effects, a formulation for TFP analogous to the above is:

$$\log F_{it} = \alpha_i + \alpha_d \log SD_{it} + \alpha_f \log SF_{it}^{g} + \varepsilon_{it} \qquad (15)$$

where $i =$ 1, 2, …, N is a country index, $t =$ 1, 2, …., T is a time index, and $g = m, f$ representing the kind of trade weighted foreign R&D (general or through FTAs).[9] This framework is necessary for examining the degree of international R&D spillovers on TFP where trade flows, especially those generated by FTAs, are considered as a significant conduit.

As institutions are regarded as deep determinants of TFP and growth in the current literature, the original framework is then extended to investigate the impact of a change in institutional factors on the degree of R&D spillovers across national borders. To this end, several proxies for institutions are employed. It is important to emphasize that these institutional variables mainly characterize *institutional designs* or forms of institutions. They do not necessarily reflect the quality of institutions or *institutional performance*. The purpose of using

[9] Human capital is another important determinant of TFP. In addition, it can serve as a measure of the absorptive capacity of an economy. Many studies, such as Coe *et al.* (1997) and Engelbrecht (1997), use Barro and Lee (2010)'s data on educational attainment as a proxy for stock of human capital. However, these data are only available in 5-year average format. Given that all other data in the current paper are annual data, this prevents us from considering the role of human capital in this paper.

institutional designs instead of institutional performance is twofold. First, it helps avoid endogeneity problems due to the so-called 'halo effect' between institutions and growth as per Hall and Jones (1999) and Dollar and Kraay (2003). Institutional designs such as the forms of government (e.g. parliamentary versus presidential system) or the electoral rules (e.g. simple majority versus proportional regime) seldom change and are therefore relatively less prone to endogeneity problems as compared to institutional performance measures. Second, the heterogeneity among countries in terms of innovative activities can be reflected based on country-specific institutions rather than on changes in institutional quality which are hard to be captured given limited time span of the sample.

3. Data description

The annual data set on business sector activity for 15 OECD countries during 1973-2005 is taken from OECD STAN Database (2008). This data set includes value added, stock of capital formation, and employment (full-time equivalent) which are useful for constructing TFP variables. R&D expenditure data from OECD STAN databases (2006) are used to generate domestic R&D capital stocks. Bilateral import flows are obtained from OECD International Trade Database. Data on FTAs come from Baier and Bergstrand (2007) and the WTO's Regional Trade Agreement Database. They are employed to construct two different measures of foreign R&D capital stocks as described above in the text. Data on forms of government and electoral rules used as proxies for institutional design variables are extracted from Keefer (2005). More details on data sources, variable definition and construction, as well as list of countries included in the sample can be found in the Appendix.

4. Empirical analysis

Before estimating any equations, this paper examines all the variables against the possibility of spurious regressions. To this end, panel unit roots tests suggested by Hadri (2000) and Im *et al.* (2003) are conducted (at 5% level of significance) to see if the variables are non-stationary or not. The test by Hadri (2000) starts with the null hypothesis of stationarity for the variable under consideration. By contrast, Im *et al.* (2003) tests for the null hypothesis of unit root existence.

(Insert Table 1 about here)

Results in Table 1 indicate that both tests confirm the nonstationarity for almost all variables. The only exception is log(*TFP*) where the Hadri's (2000) test shows that the variable is nonstationary which is in contrast with the result from the Im *et al.*'s (2003) test. However, this paper is more inclined to the result from the Hadri's (2000) test because for the purpose of proving a certain variable to be nonstationary, its hypothesis seems more appropriate.

Given that all variables are nonstationary, the next step is to check if the variables exhibit any cointegrating relationship. This paper conducts two panel cointegration tests proposed by Pedroni (1999) at 5% level of significance. The results are reported in Table 2.

The test results show that there is panel cointegration between variables of interest for all model specifications. This implies that the associated regressions are not spurious. The estimated coefficients can be interpreted as representing the long-term relationship between interested variables. Long-run relationship can be estimated using pooled estimation technique and, to some extent, group mean estimation technique.

(Insert Table 2 about here)

The literature on econometric techniques for estimating panel cointegration has developed significantly over the past few decades. Early models, e.g. Coe and Helpman (1995), Engelbrecht (1997), often use Ordinary Least Squares (OLS) technique to estimate the long-run relationship between TFP and other interested variables within R&D context. However, as criticized by Kao *et al.* (1999), this technique suffers from a second-order asymptotic bias that leads to invalid standard errors although its estimator is superconsistent. Other alternative estimation procedures include Fully Modified OLS (FMOLS) suggested by Pedroni (2000) and Dynamic OLS (DOLS) proposed by Kao and Chiang (2000). When comparing these two panel estimators of some particular forms using Monte Carlo experiments, Kao and Chiang (2000) indicate that DOLS estimator has superior small sample properties. Hence, this paper employs the DOLS method for its regression equations to take advantage of this method. This method is still new to the R&D growth literature since few papers have applied this method for their estimation except for Lee (2006) and Coe *et al.* (2009). This method requires the selection of lead and lag terms of the first differenced independent variables. Checking over a range of lead and lag terms, it is found that the signs, the significance levels, as well as the relative magnitudes of the estimated coefficients do not change substantially. Thus, this paper chooses two leads and two lags to perform the estimation given the short time horizon of the sample used.

Table 3 presents panel DOLS estimates of all possible specifications for 15 OECD countries over the period 1973-2005. To examine whether domestic R&D and foreign R&D (through technological diffusion) activities may be able to contribute to domestic TFP, this paper concentrates on equations that relate the log of TFP to the logs of domestic and alternative trade weighted foreign R&D capital stocks. All equations include unreported constants to take account for missing country-specific fixed factors. It can be seen that all regressions have quite substantial fits. In terms of comparison across models of a same dependent variable, adjusted R^2 is an appropriate criterion. Equation (3.5) is, hence, the most preferable due to its highest value of adjusted R^2.

In each cointegrating regression, the estimated elasticity of the domestic R&D capital stock is positive and significant. This confirms the essential role of domestic innovative activities in enhancing home TFP level as projected in R&D-based growth models such as Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992).

(Insert Table 3 about here)

Regressions (3.1) and (3.2) show the estimated productivity elasticities of domestic R&D and each of the trade weighted foreign R&D capital stocks. With regard to the impact of outside R&D embodied in import flows, it is shown that there exist significant international R&D spillovers where imports are the important conduit. In equation (3.1), the elasticity of foreign R&D capital stock embodied in general trade is positive and highly significant. This result is consistent with that of the current literature on the field (e.g. Coe and Helpman, 1995; Lee, 2006; Coe *et al.*, 2009). In equation (3.2), a positive and significant estimate for the elasticity of foreign R&D capital stock embodied in trade generated through FTAs is obtained. This is a novel finding to the literature since it confirms that FTAs can make contributions to the enhancement of productivity back home through accelerating knowledge transfer by increasing trade. Having FTAs with OECD partner countries increases a country's access to foreign knowledge pool which is necessary for generating more growth for that country.

Equations (3.1) and (3.2) are then modified to become equation (3.3) and (3.4). Although each foreign knowledge stock in these equations consists of import weighted foreign R&D capital stocks, the weights may not fully capture the level of trade, either general or through FTAs. It might be expected that when two countries have the same composition of trade and face the same composition of R&D capital stocks among economic trading partners, the country that has more imports relative to its GDP may benefit more from foreign R&D. For these reasons, equations (3.3) and (3.4) are modified versions of equations (3.1) and (3.2) in the sense that they account for the interaction between each type of trade weighted foreign R&D capital stock and its corresponding intensity, that is, the general import-GDP ratio (for the general trade case) or the FTA generated import-GDP ratio (for the FTA generated trade case). It follows that the elasticity of TFP with respect to these foreign R&D capital stocks varies across countries in proportion to each type of import intensity. In equation (3.3), the estimated coefficient for the interaction between import ratio and import-weighted R&D capital stock is positive but insignificant. By contrast, the estimated coefficient for the interaction between FTA generated import ratio and its corresponding foreign R&D capital stock is found positive and significant in equation (3.4). This is an interesting finding as it confirms that the combination of FTA generated trade and R&D strongly drives TFP growth while there is less evidence for the general trade case. In other words, FTAs facilitate the diffusion process far stronger.

While equation (3.5) incorporates equation (3.1) into equation (3.2), equation (3.6) is a combined version of equations (3.2) and (3.4). It mainly reflects multicolinearity as the coefficient on the interaction term between FTA import weighted foreign R&D capital stock and its corresponding intensity is found negative (not the expected sign) although significant. Equation (3.5) offers more interesting result as it demonstrates that the coefficients associated with both kinds of trade weighted foreign R&D capital stocks are positive and significant while their magnitudes are not very much affected. This reinforces the robustness of the obtained results. It also highlights that countries having FTAs with other trading partners are likely to benefit more from foreign technological base than their counterparts. This can be explained on the ground of trade creating and trade diverting effect of FTAs below.

When a country enters an FTA with its trading partners, there are often two different effects involved. As the country lowers or eliminates tariffs on imports from an FTA partner, it is expected that there will be an increase in imports from that FTA partner if other things equal.[10] It is called 'trade creating effect'.[11] Under this trade creating effect, the productivity of the

[10] For example, Baier and Bergstrand (2007) find that trade volume between member countries increases approximately two times with an FTA. Similarly, while examining the Canada-US Free Trade Agreement (CUSFTA) and FTAs in Europe respectively, Clausing (2001) and Eicher *et al.* (2007) find strong empirical evidence of trade creation effect.

[11] According to Viner (1950) who first introduces this concept, trade creation refers to the situation in which a country imports more from another country where the cost of production is lower.

economy may be improved in two different dimensions as indicated in the theoretical model in Section 2. In particular, newly created trade under the FTA allows a larger set of product varieties to be employed for domestic production, as suggested by Krugman (1980), so more R&D spillovers are expected. According to Chaney (2008), this effect is amplified by the extensive margin of trade due to FTA. He shows that in case of heterogeneous firms with different levels of productivity, firms which were not profitable to export may now be profitable to do so due to lower trade barriers. There will be more varieties to be imported from a partner country and domestic firms will be expected to produce more of varieties which are used as intermediate goods.

In addition, the reduction of trade barriers against the partner country causes more competition in the domestic market making domestic firms work towards increasing productivity by innovating more rapidly and applying more cost-efficient production methods (the quality self-improvement process). Melitz (2003) and Unel (2010) argue that opening up to trade will increase aggregate productivity with heterogeneous firms. Lowering trade barriers increases the productivity cut-off for survival, which forces the least productive firms to exit the market and the most productive firms take larger market share. Their arguments are empirically supported by Bernard *et al.* (2003) in U.S. manufacturing. After all, trade creation is likely to produce a positive effect on TFP and growth.

However, a problem may arise. Under the FTA, as preference is given to member countries, the country under consideration is expected to switch part or all of its imports from a non-member to an FTA partner. If the non-member country is more efficient than the member country in terms of productivity, this creates a ‘trade diverting effect’. Just like a reversed situation of trade creation, the decreased imports from the non-member country reduce the range of the intermediate goods available for domestic production, which may lower the productivity of the economy. In addition, as the member country now imports more from the less efficient partner country while importing less from the more productive non-member country, productivity embodied in imports will be down-graded compared to that in status quo. Consequently, trade diversion may generate a negative effect on TFP and growth of the member country. Here, in equation (3.5), the positive sign of the estimated coefficient on $\log(SF^f)$ implies that the trade creating effect dominates the trade diverting effect in our analysis. As a result, countries will be able to benefit more from foreign knowledge pool.[12]

5. Institutions and R&D

As institutions are gradually regarded as an essential factor affecting economic growth and TFP (see, for example, Hall and Jones, 1999; Acemoglu *et al.*, 2001; Rodrik *et al.*, 2004), this paper extends its analysis to consider if institutional factors affect the technological diffusion among OECD countries. To this extent, this paper is similar to Coe *et al.* (2009) in introducing institutional variables into the R&D-based growth context, however, uses completely different institutional measures that reflect the characteristics of the government: the forms of the government and the electoral rules.[13] These institutional variables could potentially affect the extent to which domestic and foreign R&D affects TFP in different ways. Forms of government may affect the way R&D budget and funding are allocated. They also affect the way a country trades with its partners, hence, its access to foreign technological base. Different electoral rules are expected to influence on government officers' responsibility and accountability in making their policies. As a result, this may also influence R&D expenditure and productivity of foreign R&D to some extent. An advantage of using these institutional variables is that they are institutional design measures which help to avoid potential endogenity problems.

[12] Kowalczyk (2000), Freund (2000), and Eicher *et al.* (2007) indicate that trade volume between a member country and a non-member country does not necessarily decrease after an FTA. For example, if a good imported from the non-member country is complementary to a good exported from the member country, the member country may end up importing more from this non-member country after an FTA. In this case, a larger number of the varieties will be employed for production in the member country which results in a positive effect on TFP.

[13] Coe *et al.* (2009)'s institutional variables include: ease of doing business, quality of education systems, patent protection, and legal origins.

One aspect of institutions is the maintenance of political power. A regime can either be *presidential* or *parliamentary.* In the former, the president can hold onto power without gaining support from the assembly whereas in the latter, the government's existence depends on the continuous backing of the majority of congress. In order to examine the idea about how the forms of government may affect the R&D - growth nexus, this study divides countries in the existing sample into presidential and parliamentary sub-groups. Accordingly, a dummy variable is generated: the dummy *Par* is equal to 1 if a country is under the parliamentary regime and 0 otherwise. Countries with a presidential regime represent the control group.

(Insert Table 4 about here)

Estimation results for the forms of the government are provided in Table 4. Regression (4.1) in this table is identical to regression (3.1), and regression (4.3) is identical to regression (3.2) in Table 3. In regression (4.2), the estimated coefficient on the interaction between parliamentary system and domestic R&D is negative and significant while that on the interaction between parliamentary system and general import weighted foreign R&D is positive and significant. This implies that there is evidence to support the claim that countries where a parliamentary government is in place benefit less from domestic R&D but more from international R&D spillovers. Similarly, in regression (4.4), the estimated coefficient on the interaction between parliamentary system and domestic R&D is negative and significant. The coefficient on the interaction between this dummy variable and FTA import weighted foreign R&D has a positive sign and high level of significance. All of these confirm that country differences in the forms of government lead to differences in the way R&D, both domestic and foreign, affects TFP.

Besides the forms of government, countries can differ vastly in their voting systems. This paper stratifies the OECD countries in the sample according to their electoral rules: *proportional rule*, *majority rule,* or both. Under proportional rule, seats for each party are given in proportion to the vote share (each party then elects politicians from the party's list), whereas under the majority rule, seats are allocated according to politicians with the highest vote. In comparison, the latter system is more likely to make politicians individually accountable to the voters. To capture those features of institutions, this paper constructs two dummy variables named *Plu* and $\Pr o$ respectively. The dummy *Plu* is equal to 1 for a democratic majority system and 0 otherwise. The dummy $\Pr o$ is set to 1 for a democratic proportional system and 0 otherwise. In this way, economies with both democratic proportional and majority rules represent the control group.

(Insert Table 5 about here)

Countries having different electoral rules also seem to benefit differently from domestic R&D activities and foreign knowledge transmission. This result is presented in Table 5. Regressions (5.1) and (5.3) are identical to regressions (3.1) and (3.2) respectively in Table 3. From regressions (5.2) and (5.4), the coefficients on interaction terms between electoral rule dummies for majoritatian system and proportional system and domestic R&D capital stocks are negative and mostly significant. The coefficients on interaction terms between electoral rule dummies and alternative sort of foreign R&D are positive and mostly significant. This implies that electoral rules also have significant impact on the way domestic and foreign R&D affects TFP of OECD countries. Relatively to countries that maintain both electoral rules, those having a single rule system significantly benefit less from their own R&D efforts and significantly more from international R&D.

6. Conclusions

This paper has been concerned with the enquiry into international technological diffusion through international trade with special attention to trade flows generated by free trade agreements using the panel data of 15 OECD countries over 33 years. Using newly constructed panel data and appropriate estimation technique, the paper attempts to differentiate the FTA generated trade from the general trade in promoting international knowledge spillovers. Since there has been a rapid increase in the number of FTAs over the past few decades, it is worth examining the effect that FTAs might have on economic growth of participating countries, especially from knowledge diffusion aspect.

The results obtained confirm that knowledge capital embodied in FTA generated imports play a significant role in transferring knowledge across national borders. Specifically, FTA generated imports could help to improve the productivity of importing countries in various ways. FTAs increase the imports from member countries by lowering or eliminating import tariffs. This in turn raises the availability of intermediate products necessary for production. In addition, the increased competition due to the tariff elimination could induce the rapid improvement of productivity in the domestic market. These results would help to justify that FTAs, which are intended to encourage trade by abolishing tariffs or reducing other trade barriers, would contribute to the economic development process through facilitating knowledge spillovers across countries.

The paper then extends its analysis to the role of institutional factors in affecting international R&D spillovers. It finds evidence that countries where the form of government is mainly parliamentary tend to benefit less from their own innovative efforts but more from international R&D spillovers. In addition, it finds that countries having both plural and proportional rule of election are generally associated with higher returns to domestic R&D but lower international R&D spillovers.

This paper provides a first step in addressing a complicated issue. The role of individual industries in knowledge spillovers across countries could be investigated if secured R&D data at industry level were obtained. Moreover, other measures of institutions should also be examined to give a richer picture on the matter. It is also interesting to investigate the issue of

R&D spillovers and institutions in a North-South trade context. All of these suggest a promising active research agenda in the future.

Appendix - Data sources and definitions

Countries included in the study are: Australia, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, United Kingdom, and United States (15 OECD countries). For each country, the total factor productivity F is defined as

$$F = \frac{Y}{K^{\gamma} L^{1-\gamma}}$$

where Y is value added in the business sector, K is the stock of business sector capital, and L is employment (full-time equivalent) in the business sector for the period 1973-2005. The coefficient γ is the average share of capital income and is set to 0.3 in this paper. Y, K, and L are from OECD STAN Database (2008). The TFP variable for each country after being calculated is converted to index format (with 1990 = 1).

We used the method described by Coe and Helpman (1995, p.878) to estimate domestic business sector R&D capital stocks (lagged by one year) based on R&D expenditures data for total business enterprises from OECD STAN Databases (2006). First, we computed real R&D expenditure by deflating nominal expenditures by an R&D price index, PR, which is defined as:

$$PR = 0.5P + 0.5W$$

where P is the implicit deflator for business sector output, and W is an index of average business sector wages (both of them come from OECD Economic Outlook Database, 2006). According to Coe and Helpman (1995), this definition of PR reflects that half of R&D expenditures are labour costs, which is consistent with available data on the composition of

R&D expenditures. We then calculated domestic R&D capital stocks, SD, the beginning of period stocks, based on the above obtained data on real R&D expenditures, R, and the perpetual inventory model:

$$SD_t = (1-\delta)SD_{t-1} + R_{t-1}$$

where δ is the depreciation rate, which was assumed to be 5 percent.[14] The benchmark for SD was calculated as follows:

$$SD_0 = \frac{R_0}{g+\delta}$$

where R_0 is the R&D expenditure of the first year for which the data were available, SD_0 is the benchmark for the beginning of that year, and g is the average annual logarithmic growth of R&D expenditures over the period for which R&D data were available. The domestic R&D capital stocks were expressed in 1985 PPP million US dollars.

Import ratios were generated by dividing total value of imports of goods and services by the value of GDP. Data used for computation of these series are bilateral import flows obtained from OECD International Trade Database.

Two measures of the foreign R&D capital stocks were computed for each country. The first is the sum of the domestic R&D capital stocks of 15 trading partners weighted by bilateral imports as share of GDP deflated by bilateral distance. The second estimate of the foreign R&D capital stocks is those embodied in trade conducted through free trade agreements. It is constructed to proxy for R&D spillover effects occurred between countries that establish special trading relation by signing FTAs. Data on FTAs come from Baier and Bergstrand

[14] This paper also computes the data series assuming the depreciation rate of 10%. However, the results qualitatively stay the same.

(2007) and the World Trade Organization's Regional Trade Agreement Database. The formulas for computing the foreign R&D capital stocks are presented in the text.

Finally, data on institutional variables are extracted from Keefer (2005). They are used to construct a dummy variable for the forms of government. By the same token, two dummy variables were generated to characterize the electoral rules.

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Table 1- *Panel unit root tests (at 5% level of significance, 15 countries, 1973-2005)*

Variable	*Hadri (2000) test*		*Im et al. (2003) test*		*Decision*
	Statistics	*Implication*	*Statistics*	*Implication*	
$\log(TFP)$	13.724 (0.000)	$I(1)$	-7.264 (0.000)	$I(0)$	$I(1)$
$\log(SD)$	12.817 (0.000)	$I(1)$	1.332 (0.909)	$I(1)$	$I(1)$
$\log(SF^m)$	13.258 (0.000)	$I(1)$	4.907 (1.000)	$I(1)$	$I(1)$
$\log(SF^f)$	10.444 (0.000)	$I(1)$	2.639 (0.996)	$I(1)$	$I(1)$
$m.\log(SF^m)$	9.646 (0.000)	$I(1)$	-0.509 (0.305)	$I(1)$	$I(1)$
$f.\log(SF^f)$	9.421 (0.000)	$I(1)$	0.900 (0.816)	$I(1)$	$I(1)$

Note: $\log X$ is log of X. TFP, SF^m, SF^f, m, and f are total factor productivity, foreign R&D capital stock based on imports, foreign R&D capital stock based on imports from FTA partner countries, imports as share of GDP (import intensity), and imports from FTA partner countries as share of GDP (FTA import intensity) respectively. p-values are in parentheses.

Table 2 – *Panel cointegration tests (based on Pedroni (1999) at 5% level of significance, 15 countries, 1973-2005)*

	Panel t-statistics	*Group t-statistics*	*Decision*
$\log(TFP)$, $\log(SD)$, $\log(SF^m)$	10.072 (0.000)	17.794 (0.000)	*CI*
$\log(TFP)$, $\log(SD)$, $\log(SF^f)$	10.686 (0.000)	15.643 (0.000)	*CI*
$\log(TFP)$, $\log(SD)$, $m.\log(SF^m)$	9.805 (0.000)	20.804 (0.000)	*CI*
$\log(TFP)$, $\log(SD)$, $f.\log(SF^f)$	15.085 (0.000)	23.371 (0.000)	*CI*
$\log(TFP)$, $\log(SD)$, $\log(SF^m)$, $\log(SF^f)$	6.270 (0.000)	8.922 (0.000)	*CI*
$\log(TFP)$, $\log(SD)$, $m.\log(SF^m)$, $f.\log(SF^f)$	8.270 (0.000)	14.257 (0.000)	*CI*

Note: $\log X$ is log of X. TFP, SF^m, SF^f, m, and f are total factor productivity, foreign R&D capital stock based on imports, foreign R&D capital stock based on imports from FTA partner countries, imports as share of GDP (import intensity), and imports from FTA partner countries as share of GDP (FTA import intensity) respectively. p-values are in parentheses.

Table 3 – *DOLS estimation results (fixed effects, 15 countries, 1973-2005)*

Dependent variable: log(*TFP*)	*(3.1)*	*(3.2)*	*(3.3)*	*(3.4)*	*(3.5)*	*(3.6)*
$\log(SD)$	0.425***	0.670***	0.740***	0.755***	0.279***	0.659***
	(0.029)	(0.041)	(0.033)	(0.043)	(0.043)	(0.038)
$\log(SF^m)$	0.475***				0.595***	
	(0.045)				(0.073)	
$\log(SF^f)$		0.093***			0.079***	0.155***
		(0.021)			(0.014)	(0.034)
$m.\log(SF^m)$			0.711			
			(0.663)			
$f.\log(SF^f)$				1.776**		-3.136***
				(0.697)		(0.790)
R^2	0.854	0.805	0.815	0.797	0.871	0.809
$Adj-R^2$	0.845	0.787	0.803	0.779	0.857	0.788

Note: $\log X$ is log of X. TFP, SF^m, SF^f, m, and f are total factor productivity, foreign R&D capital stock based on imports, foreign R&D capital stock based on imports from FTA partner countries, imports as share of GDP (import intensity), and imports from FTA partner countries as share of GDP (FTA import intensity) respectively. White heteroskedasticity consistent standard errors are in parentheses. *, **, *** indicate parameters that are significant at 10%, 5%, and 1% levels of significance respectively. All regressions include unreported country specific constants. Here, the DOLS regressions include two leads and two lags of the first differenced independent variables.

Table 4 – *Forms of the government (DOLS, fixed effects, 15 countries, 1973-2005)*

Dependent variable: log(*TFP*)	*(4.1)*	*(4.2)*	*(4.3)*	*(4.4)*
$\log(SD)$	0.425***	1.265***	0.670***	2.623***
	(0.029)	(0.101)	(0.041)	(0.364)
$\log(SF^m)$	0.475***	-0.120**		
	(0.045)	(0.052)		
$\log(SF^f)$			0.093***	-0.483***
			(0.021)	(0.085)
$Par.\log(SD)$		-0.895***		-1.954***
		(0.101)		(0.366)
$Par.\log(SF^m)$		0.688***		
		(0.093)		
$Par.\log(SF^f)$				0.577***
				(0.102)
R^2	0.854	0.859	0.805	0.805
$Adj-R^2$	0.845	0.845	0.787	0.778

Note: $\log X$ is log of X. TFP, SF^m, SF^f, m, and f are total factor productivity, foreign R&D capital stock based on imports, foreign R&D capital stock based on imports from FTA partner countries, imports as share of GDP (import intensity), and imports from FTA partner countries as share of GDP (FTA import intensity) respectively. *Par* is a dummy variable for the form of government (=1 if it is a parliamentary system and 0 otherwise). White heteroskedasticity consistent standard errors are in parentheses. *, **, *** indicate parameters that are significant at 10%, 5%, and 1% levels of significance respectively. All regressions include unreported country specific constants. Here, the DOLS regressions include two leads and two lags of the first differenced independent variables.

Table 5 – *Electoral rules (DOLS, fixed effects, 15 countries, 1973-2005)*

Dependent variable: log(*TFP*)	*(5.1)*	*(5.2)*	*(5.3)*	*(5.4)*
$\log(SD)$	0.425***	0.786***	0.670***	0.660***
	(0.029)	(0.082)	(0.041)	(0.095)
$\log(SF^m)$	0.475***	-0.081		
	(0.045)	(0.070)		
$\log(SF^f)$			0.093***	0.025
			(0.021)	(0.116)
$Plu.\log(SD)$		-0.589***		-0.297***
		(0.082)		(0.099)
$\mathrm{Pr}\,o.\log(SD)$		-0.216**		-0.084
		(0.094)		(0.068)
$Plu.\log(SF^m)$		0.762***		
		(0.092)		
$\mathrm{Pr}\,o.\log(SF^m)$		0.275*		
		(0.147)		
$Plu.\log(SF^f)$				0.792***
				(0.108)
$\mathrm{Pr}\,o.\log(SF^f)$				0.046
				(0.114)
R^2	0.854	0.889	0.805	0.902
$Adj-R^2$	0.845	0.873	0.787	0.883

Note: $\log X$ is log of X. TFP, SF^m, SF^f, m, and f are total factor productivity, foreign R&D capital stock based on imports, foreign R&D capital stock based on imports from FTA partner countries, imports as share of GDP (import intensity), and imports from FTA partner countries as share of GDP (FTA import intensity) respectively. Plu is a dummy variable for electoral rule (=1 if it is a majority regime and 0 otherwise). $\mathrm{Pr}\,o$ is another dummy variable for electoral rule (=1 if it is a proportional regime and 0 otherwise). White heteroskedasticity consistent standard errors are in parentheses. *, **, *** indicate parameters that are significant at 10%, 5%, and 1% levels of significance respectively. All regressions include unreported country specific constants. Here, the DOLS regressions include two leads and two lags of the first differenced independent variables.