Globalization and Knowledge Spillover:
International Direct Investment, Exports and Patents

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Abstract

This paper examines the impact of the three main channels of international trade on domestic innovation, namely outward direct investment (ODI), inward direct investment (IDI), and exports. The number of Triadic patents serves as a proxy for innovation. The data set contains 37 countries that are considered to be highly competitive in the world market, covering the period 1994 to 2005. The empirical results show that increased exports and outward direct investment are able to stimulate an increase in patent output. In contrast, IDI exhibits a negative relationship with domestic patents. The paper shows that the impact of IDI on domestic innovation is characterized by two forces, and the positive effects of cross-border mergers and acquisitions by foreigners is less than the negative effect of the remaining IDI.

Keywords: International direct investment, Exports, Imports, Triadic Patent, Outward direct investment, Inward direct investment, R&D, negative binomial model.

JEL: F14, F21, O30, O57.

1. Introduction

“Globalization” means different things in different contexts. From an economic perspective, it refers to the cross-border movements of goods, funds, personnel and information. The more easily do such movements take place, the higher is the degree of globalization. In this context, the movement of goods refers to trade, while movements of funds refer to international direct investment (Liu et al., 2005). Furthermore, based on the direction of the flow of capital, foreign direct investment can be broken down into outward direct investment (hereafter ODI) and inward direct investment (hereafter IDI).

According to the World Investment Report by the United Nations and the World Development Indicators by the World Bank, in 2008 ODI and exports for the world as a whole over the years have generally exhibited an upward trend. Both have accounted for an important share of GDP (as shown in Figures 1, 2 and 3), have played an essential role in the process of globalization, and have been regarded as the main channels for technology spillover. However, international technology spillovers can occur through a number of channels: (i) embodied technology can be transmitted through international trade (exports and imports) of goods and services, capital flows, and mobility of scientists; and (ii) disembodied technology is diffused via international trade of technology (Cohen and Levinthal, 1989; Geroski et al., 1993, Coe and Helpman, 1995; Coe et al., 1997, 2009; Keller, 1998, 2004; Kneller, 2005; Madsen, 2007; Branstetter, 2006; Liu & Zou, 2008; Mancusi, 2008).

Furthermore, according to endogenous growth theory, technological innovation is important for the “sustained” growth of an economy (Romer, 1986; Lucas, 1988). The main reasons for the economic growth of the late-industrializing economies have been the acquisition of knowledge and intelligence, technological innovation and human capital accumulation (Bassanini and Scarpetta, 2002; Hu & Mathews, 2005; Mueller, 2006).

From the above, it can be seen that countries that frequently engage in ODI also attract IDI and promote export activities. Such behavior raises the issue as to why countries wish to engage in such activities. For this reason, we seek to answer the following question: Are ODI, IDI and exports capable of enhancing a country's innovation and technological depth? Conversely, it needs to be asked whether these activities can lower a country's willingness to engage in innovation activities and, over the long term, cause the country to lose competitiveness in international markets, thereby leading to unsustainable economic growth and eventual recession.

This paper examines, within the context of globalization, the impact of the three main channels of international trade, namely ODI, IDI and exports, on domestic innovation, where the number of patents serves as a proxy for innovation. By examining the impact between countries of ODI, IDI and exports on patents, the results of this paper should serve as a reference for public and private policy. Consequently, appropriate international trade policies may be formulated to increase a country's innovation activities, upgrade its industrial technology, and ultimately promote economic sustainability and stable growth.

The remainder of the paper is organized as follows. Section II provides a review of the literature on exports and innovation, and international direct investment and innovation. Section III presents the variables, data and sample statistics for the empirical analysis. Section IV discusses the research methods. Section V introduces the empirical model and analyzes the results. Section VI provides the conclusion and some suggestions for further research.

2. Exports, Imports, International Direct Investment, and Innovation

Traditional economic theory on the relationship between innovation and exports largely focuses on the topic of whether innovation influences exports. For example, the technological gap theory (Posner, 1961) and the life-cycle theory (Vernon, 1966) both argue that innovation will give manufacturers a greater comparative advantage, so that they will become net exporters. Moreover, in early studies, the focus was on whether a country that is engaged in innovation activities can provide a boost to exports (Roper & Love, 2002; Gourlay & Seaton, 2004; Yang et al., 2004; Gourlay et al., 2005; Roper et al., 2006; Tomiura, 2007). In contrast, the impact of exports on innovation has not yet led to consistent results (Keller, 2009).

In recent years, studies on these two issues have focused mainly on discussing the impact of exports on innovation. For example, Lin & Yeh (2005) found that the exports of Taiwan's electronics industry exhibited a significantly positive relationship with that industry's R&D, but that such a relationship only existed in the case of manufacturers engaged in foreign direct investment. For South Korean manufacturers as an example, Han & Lee (2007) used the number of patents approved by the U.S. Patent Office and the South Korean Intellectual Property Office (KIPO) as the explained variables to examine the impact of the export ratio on innovation. Their results indicated that the proportion of exports only exhibited a significant and positive relationship in regard to those patents approved by the U.S.. It was argued that this difference arose because the different strategies adopted by manufacturers in applying for patents either at home or abroad.

The discussion to date has not taken into consideration the possibility that the impact of exports on innovation was subject to a time lag. In fact, the impact of exports on innovation is likely to have a deferred effect. For example, Salomon & Shaver (2005) discovered that for Spanish manufacturers there existed a significant and positive relationship between the export behavior of Spanish manufacturers, with a time lag of one or two periods, and the number of products innovated in the domestic economy, as well as the number of approved patent applications. Through exports, it was possible to acquire knowledge that was lacking in the domestic market, and thereby to promote innovation. In other words, the effect of learning by exporting was found to exist. In order to verify this learning effect, Girma et al. (2008) analyzed manufacturers in the U.K. and Ireland. Their results showed that Irish exports were able to increase innovation activities with a time lag of one period, whereas in the U.K. there was no compelling evidence to show that exports could increase innovation activities. The authors concluded that this difference was due to the domestic markets, the sizes of these two countries, and the different destinations of their exports.

Existing empirical evidence also suggests that imports are an important channel of international knowledge spillovers (see, for example, Coe and Helpman, 1995; Coe et al., 1997, 2009; Keller, 1998; Madsen, 2007).

Coe and Helpman (1995) extended the theories of economic growth that treat commercially-oriented innovation efforts as a major engine of technological progress depends not only on domestic R&D capital but also on foreign R&D capital. The foreign R&D capital was constructed as a weighted sum of the cumulative R&D expenditures of the country's trading partners, where the weights are given by the bilateral import shares. Their estimates indicate that foreign R&D has beneficial effects on domestic productivity, and that these are stronger the more open is an economy to foreign trade.

Keller (1998) used a Monte Carlo-based robustness test to compare the elasticity of domestic productivity with respect to foreign R&D, as estimated by Coe and Helpman (1995), with an elasticity based on counterfactual international trade patterns. His results show that randomly created trade patterns give rise to positive international R&D spillover estimates, which are often larger, and explain more of the variation in productivity across countries, than if "true" bilateral trade patterns were employed. Keller’s finding casts doubt on the claim that patterns of international trade are important in driving R&D spillovers.

Madsen (2007) tested whether knowledge has been transmitted internationally through imports, and used a dataset on imports of technology and total factor productivity (TFP) over 135 years for the OECD countries. The empirical estimates show that there is a robust relationship between TFP and imports of knowledge, and that 93% of the increase in TFP over the past century has been due solely to imports of knowledge.

Based on Salvatore’s (2007) definition, international direct investment refers to real investment engaged in overseas, and includes the acquisition and control of factories, capital goods, land, inventory and management. It frequently involves either the setting up of overseas subsidiaries or purchasing large quantities of shares in order to obtain the right to operate. According to the direction in which the funds for investment flow, a distinction may be made between ODI and IDI. Two main types of result may be inferred from past empirical studies: in terms of its impact on innovation, international direct investment has (1) positive spillover effects, and (2) negative or uncertain spillover effects.

The positive spillover effects refer to the discovery of knowledge spillovers, such as technology or management, when engaging in IDI or ODI. This leads to an increase in innovation activities in the host country and/or home country. For example, Lin & Yeh (2005) interpret IDI and R&D as being mutually dependent, so that if the quantity of input of one increases, the amount of expenditure on the other is also increased. Blind & Jungmittag (2004) argued that externally-induced competition has a training effect on the host country’s domestic market which, in turn, has a positive effect on the host country’s innovation activities. However, Lin et al. (2009) adopted a quite different approach to analyzing ODI. They argued that ODI benefits the home country’s innovation. Branstetter (2006) also advanced a similar view, and considered that international direct investment embodied a feedback effect, so that ODI not only caused the innovative behavior of the host country to increase, but also led to a positive effect on innovation activities in the home country.

The negative spillover effect refers to inflows of foreign capital which result in the host country becoming excessively dependent on technology, thereby leading to a reduction in innovation activities (Kumar, 1987). However, the uncertain spillover effect refers to foreign capital impacting the host country’s innovation activities both positively and negatively. First, different measurement indicators of IDI are used simultaneously, as in Girma et al. (2009), who used the proportion of foreign investment and the amount of foreign investment sold domestically as the IDI indicator. The empirical evidence showed that the proportion of foreign investment has a positive and significant effect on product innovation, while the amount of foreign investment is characterized by a significant and negative relationship with product innovation.

Second, different studies have focused on different industries. For instance, Deolalikar & Evenson (1989) estimated the patent demand function for India. Their empirical results indicated that the higher is the proportion of foreign investment in the chemical industry, the lower is the number of patents. In contrast, in light engineering and other engineering industries, IDI was found to be positively related to patents.

Finally, various results have also been obtained when international direct investment is decomposed into ODI and IDI. For instance, Pottelsberghe & Lichtenberg (2001) used a sample of 13 OECD countries to examine whether FDI led to a technology transfer effect, and concluded that transfers of technology across borders as part of FDI should not be considered in one direction only. Thus, they decomposed FDI into ODI and IDI in order to view capital flows as moving in two directions. Their empirical evidence showed that ODI is a technology spillover channel that has both a significant and positive effect on the domestic country's total factor productivity. In contrast, IDI did not help to improve the technology of the host country, and even adversely affected it. The reason for this was that IDI had a tendency to acquire technology from the host country, and then to give this technology, which it did not disseminate in its own country (home country), to another country (host country).

Using panel data from 16 Organization for Economic Cooperation and Development (OECD) countries for the period 1981–2000, Lee (2006) examines the relative effectiveness of several channels including inward and outward foreign direct investment, imports of intermediate goods, and a disembodied direct channel, as measured by technological proximity and patent citations between countries. His results indicate international knowledge spillovers through inward FDI and the disembodied direct channel are significant and robust. In contrast, outward FDI and imports of intermediate goods are not conducive to international knowledge spillovers.

In addition, as the proportion of cross-border mergers and acquisitions (hereafter cross-border M&A,) in international direct investment has been increasing annually (UNCTAD, 2007), in empirical research the topic of IDI has also been examined together with that of cross-border M&A. For example, Liu & Zou (2008) found that the significant and positive relationship between cross-border M&A activities in China's high-technology industry and innovation only existed among different industries, and that within a particular industry the relationship was positive but not significant. The reason for this was that mergers and acquisitions activities may increase the degree of industrial concentration and monopoly power, so that industries within the same domestic sector will be characterized by relatively little innovative behavior.

Using a sample of 14 OECD member states, Bertrand & Zuniga (2006) examined the relationship between cross-border M&A by foreigners and R&D, and their empirical results showed that the overall relationship was positive but not significant. By focusing on the industries' technology intensity, the relationships between these mergers and acquisitions activities and R&D for high, medium and low levels of technology were found to be negative and not significant, significant and positive, and positive and not significant, respectively. Thus, it can be seen that the significant and positive relationship between cross-border M&A by foreigners and innovation exists only in the local context.

3. Data

This paper uses panel data for 37 countries covering the period 1994 to 2005. There are three criteria for selecting the sample, as follows: (1) globalization, (2) OECD member states, and (3) upper-middle or high income countries. The reason for using these three criteria is that the emphasis in this paper is on globalization, so that the most important economies on the five continents, namely Europe, Asia, America, Oceania and Africa, are included in the sample. Second, the motivation for including the OECD countries in the sample is that more than 90% of the world's foreign direct investment originates in OECD countries (Ou Yang & Hwang, 2006), so that the vast majority of OECD countries are engaged in cross-border direct investment activities. Finally, the reason for selecting upper-middle or high income countries is that when relatively high income countries are compared with low income countries, the higher income countries will tend to engage in R&D activities, and will attach greater importance to patents, which are the embodiment of intellectual property rights.

As shown in Table 1, the sample is subdivided into continents, with 22 countries in Europe, eight countries in Asia, four countries in the Americas, two countries in Oceania, and one country in Africa. Second, as shown in Table 2, there are 28 OECD member countries and nine countries that are not members of the OECD. Finally, when countries are categorized according to the World Bank's income classification, 28 countries are high income countries, eight are upper-middle income countries, and one country is a low-middle income country[1]. The only low-income country is China. As China has a significant influence on the world economy, and as one of the main countries into which foreign capital flows, in discussing the topic of globalization the Chinese economy should be incorporated into the sample. Overall, the sample comprises advanced countries, that is, a highly competitive group of countries in the world market that encompasses the world's major economies on all five continents. Although we do not examine each country in the world in detail, the sample serves as a basis for discussing the topic of globalization in the broader sense.

In addition, the data for all the variables are obtained primarily from three sources: OECD's Main Science and Technology Indicators (MSTI) for 2007, the United Nations' World Investment Report (hereafter WIR) published in 2008, and the World Bank's World Development Indicators (hereafter WDI), also published in 2008. Due to the omission of data on Singapore's exports (for which the data were not available from 1994 to 2000), the data for Singapore's exports were obtained from the Singapore Trade Development Board. In addition, as Taiwan is not included in the above publications, the data for Taiwan were obtained from the Directorate-General

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[1] According to the World Bank's income classification, income can be subdivided into the following four levels: high, upper-middle, lower-middle, and low.

of Budget, Accounting and Statistics, Taiwan.

This paper uses patents as a proxy for innovation, as shown in Table 3. In selecting the number of patents, previous studies have frequently used the number of approved patent applications submitted to a specific patent office as the innovation index (Branstetter, 2006; Deolalikar & Evenson, 1989). Alternatively, they have used the “corresponding” numbers of patents applied for to the patent offices of two countries to represent this number, and thereby facilitate a comparison (Han & Lee, 2007).

In this paper, it is argued that comparing the differences in innovation output between countries will lead to bias, due to the host country’s home advantage, if only the applications for approved patents by a single patent office are used. When an inventor applies for a patent, as compared with applying to a patent office in another country, they are more likely to prefer applying to their own country’s patent office for a patent. For this reason, we use a triadic patent that is based on approved “simultaneous” applications by patent offices in Europe, USA and Japan as an appropriate indicator. In this way, we can reduce the bias that is generated due to the host country’s home advantage.

In addition, as a patent is the outcome of innovation, if we can presume that a higher economic value of an innovation is implied by a triadic patent, the greater will the patent be able to reflect economic growth. In addition, this paper uses patents applied for in one direction to the European patent office, that is, unilateral patents, so that we can further compare whether differences in the numbers of patents are significant in relation to the coefficients of the explanatory variables.

Patents are used as a proxy for domestic innovation. However, it is well known that patents are not an ideal proxy for innovation output as: (i) not all innovation outputs are patented or patentable; and (ii) patents may be filed for the purpose of deterring entry other than protecting invention. The use of the more restrictive triadic patents may further reduce the ability of patents to proxy innovation.

Exports and international direct investment constitute the main channel of technology spillover among countries (Branstetter, 2006; Liu & Zou, 2008). Of these, international direct investment is bidirectional, and can be divided into ODI and IDI (Pottelsberghe & Lichtenberg, 2001). Meanwhile, based on the definition provided in the WIR for 2008, Foreign Direct Investment comprises three parts, namely, equity capital,[2] reinvested earnings,[3] and intra-company loans.[4] Thus, we further decompose IDI into two parts, namely cross-border M&A by foreigners, and other direct investment.

In addition, R&D activities require inputs over a long period of time to produce results, the inputs in the current period will be separated from the benefits not yet seen by a time lag extending to future periods (Tsou & Liu, 1997). For this reason, the lag of R&D is taken into consideration (Han & Lee, 2007). The above explanatory variables are shown in Table 3. As the sample includes data for 37 countries, to remove differences in the amounts expended on R&D varying from country to country, all of the explanatory variables are divided by their own-country GDP.

From Table 4, which gives the descriptive statistics for the empirical variables, three phenomena may be observed. First, regardless of whether the triadic patent (TRI_PATENT) or the unilateral patent (EPO_PATENT) is used, the respective standard deviations are both twice as large as their means. From this, we see that the patent information is characterized by over-dispersion. Second, by adding the means

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[2] This refers to shares of companies bought by foreign direct investors outside the countries in which they reside.

[3] This refers to the portion of the surplus on the direct investors' investments that is retained and used for reinvestment.

[4] This refers to the loans in the form of short-term or long-term funds between direct investors and affiliated companies.

of total exports (EXP) and ODI, their combined share of GDP exceeds 40 percent (0.3896 + 0.0254 = 0.415). In other words, exports and ODI together account for a high proportion of international trade. Third, with cross-border M&A by foreigners (M & A_SALE) accounting for more than one-half of IDI (0.0176 / 0.0325 = 0.54), it is clear that cross-border M&A are the main component of international direct investment.

4. Models

4.1 Negative binomial model

As a patent is a non-negative discrete variable, this paper uses the count data model. The two types of count data model commonly used are the Poisson model and the Negative binomial model. The Poisson model's probability density function is given in equation (1), where y_{it} is the number of patents in country i in year t, and λ_{it} is the average number of patents in country i in year t, namely the unit frequency of approved patent applications. In this model, the mean and variance are equal, as shown in equation (2). However, in empirical research, patent data are often characterized by over dispersion (Aggarwal, 2004), that is, the variance is greater than the mean. Thus, the Poisson model may be inappropriate, so that the negative binomial model is commonly used to resolve the shortcomings of the Poisson model:

$$Prob(y_{it}) = \frac{e^{-\lambda_{it}} \lambda_{it}^{\ y_{it}}}{y_{it}\,!} \qquad y_{it} = 0,1,2,\ldots,n \tag{1}$$

$$E(y_{it}) = \lambda_{it}\text{, } Var(y_{it}) = \lambda_{it} \tag{2}$$

According to Hausman et al. (1984), the negative binomial model, which has individual and unobserved effects, generalizes the Poisson model. It assumes that the Poisson model parameter, λ_{it}, conforms to a Gamma$\left(\gamma_{it}, \delta\right)$ distribution, where δ does not change across countries or over time. The basic negative binomial model is given in equation (3) (for a detailed derivation, see Hausman et al. (1984)):

$$
\begin{aligned}
Prob\left(y_{it}\right) &= \int_{0}^{\infty} \frac{1}{y_{it}!} e^{-\lambda_{it}} \lambda_{it}^{y_{it}} f\left(\lambda_{it}\right) d\lambda_{it} \\
&= \frac{\Gamma\left(\gamma_{it}+y_{it}\right)}{\Gamma\left(\gamma_{it}\right)\Gamma\left(y_{it}+1\right)} \cdot \left(\frac{\delta}{1+\delta}\right)^{\gamma_{it}} \cdot \left(1+\delta\right)^{-y_{it}}
\end{aligned}
\qquad (3)
$$

The negative binomial model relaxes the assumption in the Poisson model that the mean and variance are equal, so that it allows the number of patents to be characterized by over dispersion, as in (4):

$$
\begin{aligned}
&Var\left(y_{it}\right) = \frac{\gamma_{it} \cdot \left(1+\delta\right)}{\delta^{2}} \\
&E\left(y_{it}\right) = \frac{\gamma_{it}}{\delta} \\
&\frac{Var\left(y_{it}\right)}{E\left(y_{it}\right)} = \frac{\left(1+\delta\right)}{\delta} > 1
\end{aligned}
\qquad (4)
$$

As this paper uses panel data, we can use the fixed effects and random effects models, each of which is explained below.

4.2 Fixed effects negative binomial model

First, we configure the model parameters, γ_{it} and δ_{i}, as shown in equations (5)-(8) below:

$$\lambda_{it} = \gamma_{it} \cdot \alpha_i = e^{\beta \cdot X_{it}} \cdot e^{\mu_i} \tag{5}$$

$$\delta_i = \frac{\phi_i}{e^{\mu_i}} \tag{6}$$

$$\gamma_{it} = E(y_{it}) = e^{\beta \cdot X_{it}} \tag{7}$$

$$\alpha_i = e^{\mu_i} \tag{8}$$

where y_{it} is the number of patents in country i in year t, γ_{it} is the expected value of y_{it}, X_{it} denotes the explanatory variables, β is a parameter to be estimated, and α_i is the fixed effect of an individual country i that does not change over time.

Under the conditions of the sum of the patents, $\sum_t y_{it}$, the conditional probability density function of $y_i \equiv (y_{i1}, \ldots, y_{it})$ is given in equation (9). From equation (10), it can be seen that the variance is greater than the mean, so that this model allows the explained variable to be characterized by over dispersion:

$$Pr\left(y_i \mid \sum_t y_{it}\right) = \frac{\Gamma\left(\sum_t \gamma_{it}\right) \Gamma\left(\sum_t y_{it} + 1\right)}{\Gamma\left(\sum_t \gamma_{it} + \sum_t y_{it}\right)} \cdot \left[\prod_t \frac{\Gamma(\gamma_{it} + y_{it})}{\Gamma(\gamma_{it}) \Gamma(y_{it} + 1)}\right] \tag{9}$$

$$Var(y_{it}) = \left(\frac{e^{\beta \cdot X_{it} + \mu_i}}{\phi_i}\right) \cdot \left(1 + \frac{e^{\mu_i}}{\phi_i}\right)$$

$$E(y_{it}) = \frac{e^{\beta \cdot X_{it} + \mu_i}}{\phi_i}$$

$$\frac{Var(y_{it})}{E(y_{it})} = \frac{e^{\mu_i} + \phi_i}{\phi_i} > 1 \quad \Rightarrow \qquad Var(y_{it}) > E(y_{it}) \tag{10}$$

Finally, we can derive the likelihood function, as shown in equation (11). After $\gamma_{it} = e^{\beta \cdot X_{it}}$ is substituted, maximum likelihood estimation can be used to obtain estimates of the parameters:

$$\ln L = \sum_{i} \left[\begin{array}{l} \ln \Gamma\left(\sum_{t} \gamma_{it} \right) + \ln \Gamma\left(\sum_{t} y_{it} + 1 \right) - \Gamma\left(\sum_{t} \gamma_{it} + \sum_{t} y_{it} \right) \\ + \sum_{t} \ln \Gamma\left(\gamma_{it} + y_{it}\right) - \ln \Gamma\left(\gamma_{it}\right) - \ln \Gamma\left(y_{it} + 1\right) \end{array} \right] \tag{11}$$

4.3 Random effects negative binomial model

The steps for inferring the random effects model are essentially the same as those for the fixed effects model discussed above. It is necessary to configure the parameters, γ_{it} and δ_i, as shown in equations (12)-(15). The difference from the fixed effects model is that the random effects model assumes that δ_i is randomly distributed, in which case the joint probability density function for $y_i \equiv \left(y_{i1}, \ldots, y_{it}\right)$ and δ_i is given in equation (16) below:

$$\lambda_{it} = \gamma_{it} \cdot \alpha_i = e^{\beta \cdot X_{it}} \cdot e^{\mu_i} \tag{12}$$

$$\delta_i = \frac{\phi_i}{e^{\mu_i}} \tag{13}$$

$$\gamma_{it} = E(y_{it}) = e^{\beta \cdot X_{it}} \tag{14}$$

$$\alpha_i = e^{\mu_i} \tag{15}$$

$$\Pr(y_i, \delta_i) = \Pr(y_i) \cdot g\ (\delta_i) \tag{16}$$

In order to obtain the probability density function of y_i, it is necessary to use integration to remove δ_i from the joint probability density function. For this reason, it is necessary to select an appropriate distribution for δ_i, as shown in equation (17), where z_i conforms to a Beta (a, b) distribution. The probability density function is given in equation (18):

$$z_i = \frac{\delta_i}{1+\delta_i} = \frac{1}{1+\frac{e^{\mu_i}}{\phi_i}} \tag{17}$$

$$f(z_i) = \left[B(a,b)\right]^{-1} z^{a-1}(1-z)^{b-1} \tag{18}$$

Through substitution of the above conditions and using integration, we can obtain the probability density function of y_i, as shown in equation (19), and obtain its likelihood function, as in equation (20). After $\gamma_{it} = e^{\beta \cdot X_{it}}$ is substituted, by using maximum likelihood estimation, we can obtain the estimates of the parameters:

$$\begin{aligned} Pr(y_i) &= \int_0^1 \prod_{t=1}^{T} \left[\frac{\Gamma(\gamma_{it}+y_{it})}{\Gamma(\gamma_{it})\Gamma(y_{it}+1)} z_i^{\gamma_{it}} (1-z_i)^{y_{it}} \right] f(z_i)\, dz_i \\ &= \frac{\Gamma(a+b)\cdot\Gamma\left(a+\sum\gamma_{it}\right)\cdot\Gamma\left(b+\sum y_{it}\right)}{\Gamma(a)\cdot\Gamma(b)\cdot\Gamma\left(a+b+\sum\gamma_{it}+\sum y_{it}\right)} \cdot \left[\prod_t \frac{\Gamma(\gamma_{it}+y_{it})}{\Gamma(\gamma_{it})\Gamma(y_{it}+1)}\right] \end{aligned} \tag{19}$$

$$\ln L = \sum_i \left\{ \begin{aligned} &\ln\Gamma(a+b) + \ln\Gamma\left(a+\sum\gamma_{it}\right) + \ln\Gamma\left(b+\sum y_{it}\right) - \ln\Gamma(a) - \ln\Gamma(b) \\ &-\ln\Gamma\left(a+b+\sum\gamma_{it}+\sum y_{it}\right) + \sum_t\left[\ln\Gamma(\gamma_{it}+y_{it}) - \ln\Gamma(\gamma_{it}) - \ln\Gamma(y_{it}+1)\right] \end{aligned} \right\} \tag{20}$$

Model 1 in this paper examines the impact of exports, imports, ODI, IDI and R&D expenditure, using a time lag of one period on triadic patents, with the empirical model given in equation (21). In (21), γ_{it} represents the expected value of the triadic patent, EXP_{it} denotes exports, EXP_{it} IM_{it} denotes imports, ODI_{it} is outward direct investment, IDI_{it} is inward direct investment, $L1\_GERD_{it}$ is domestic R&D expenditure, with a time lag of one period, ε_{it} is the error term, and β_1, β_2, β_3 β_4 and β_7 are the unknown parameters associated with the explanatory variables:

Model 1

$$\gamma_{it} = exp\,(\beta_1 \cdot EXP_{it} + \beta_2 \cdot IM_{it} + \beta_3 \cdot ODI_{it} + \beta_4 \cdot IDI_{it} + \beta_7 \cdot L1\_GERD_{it} + \varepsilon_{it}) \tag{21}$$

As the proportion of cross-border M&A in international direct investment increases annually (see UNCTAD, 2007), we decompose inward direct investment (IDI) into cross-border M&A by foreigners and other direct investment, with a view to examining the impact of these two forces on triadic patents. The empirical model is given in Model 2, equation (22), where MA_{it} denotes cross-border M&A by foreigners, $PRIVATE_{it}$ is other direct investment, γ_{it}, EXP_{it}, IM_{it}, ODI_{it}, $L1\_GERD_{it}$ and ε_{it} are as defined above, and β_1, β_2, β_5, β_6 and β_7 are the unknown parameters:

Model 2

$$\gamma_{it} = exp\,(\beta_1 \cdot EXP_{it} + \beta_2 \cdot IM_{it} + \beta_3 \cdot ODI_{it} + \beta_5 \cdot MA_{it} + \beta_6 \cdot PRIVATE_{it} + \beta_7 \cdot L1\_GERD_{it} + \varepsilon_{it}) \tag{22}$$

In order to make the empirical results reflect more accurately the source of most R&D expenditure, we change the data on R&D expenditure from total domestic R&D expenditure (GERD) to R&D expenditure for the domestic business sector (BERD). The empirical model is given in Model 3, equation (23), where $L1\_BERD_{it}$ represents R&D expenditure in the domestic business sector, with a time lag of one period. The definitions of the rest of the variables are as described above, and β_1, β_2, β_5, β_6 and β_7 are the unknown parameters:

<u>Model 3</u>

$$\gamma_{it} = exp\,(\beta_1 \cdot EXP_{it} + \beta_2 \cdot IM_{it} + \beta_3 \cdot ODI_{it} + \beta_5 \cdot MA_{it} + \beta_6 \cdot PRIVATE_{it} + \beta_7 \cdot L1\_BERD_{it} + \varepsilon_{it}) \tag{23}$$

Finally, the patent data are changed from triadic patents to unilateral patents, and the empirical model is given in Model 4, equation (24), where θ_{it} represents the expected values of the unilateral patents, the definitions of the remaining variables are as described above, and β_1, β_2, β_4, β_5 and β_6 are the parameters:

<u>Model 4</u>

$$\theta_{it} = exp\,(\beta_1 \cdot EXP_{it} + \beta_2 \cdot IM + \beta_3 \cdot ODI_{it} + \beta_5 \cdot MA_{it} + \beta_6 \cdot PRIVATE_{it} + \beta_7 \cdot L1\_GERD_{it} + \varepsilon_{it}) \tag{24}$$

In Models (1)-(4), *ODI* and *IDI* (or its decomposition) may be endogenous because they may be correlated with a country's productivity level and technological development. In order to eliminate the endogeneity issue, we use lagged EXP, lagged IM, lagged ODI and lagged IDI as the lagged R&D expenditures in Models 1-4. However, in order to include the country-level characteristics, all explanatory variables in Models 1-4 have been divided by GDP.

5. Empirical Results

As mentioned in the previous section, to eliminate the endogeneity problem, the empirical version of Model 1 examines the impact of five variables, namely lagged exports, lagged imports, lagged ODI, lagged IDI and lagged R&D expenditure on patents. In order to maintain consistency, it is necessary to determine the number of periods for which R&D expenditure is deferred in order to establish Model 1. In order to enhance efficiency in estimation, we use bootstrapping methods to estimate the variances. Tables 5-10 report the t-values both with and without bootstrapping.

Table 5 reports the results of determining the number of periods by which the R&D expenditure should be deferred using the negative binomial model based on both fixed and random effects. The empirical results indicate that the influence of R&D expenditure deferred one period improves explanatory power. The finding that the impact of the R&D input on patents has a one-period lag effect is consistent with that of Tsou & Liu (1997). For this reason, in the subsequent discussion, R&D expenditure deferred one period (L1_GERD) will serve as the R&D expenditure variable, such that columns (2) and (6) in Table 5 will be Model 1.

In Table 6, we test the model using the Hausman test, with the null hypothesis as the random effects model, and the alternative hypothesis as the fixed effects model. As the test does not reject the null hypothesis, the subsequent analysis is explained using the random effects model.[5] From Model 1, we can draw the following conclusions:

(i) Exports deferred one period (L1_EXP) exhibit a significant positive relationship with patents at the 1% level. This result explains the strong competition facing world markets. For a country's exporters to gain a foothold in international markets, it is necessary to improve the quality of their exports. For this reason, they have an incentive to engage in R&D, and to apply for patents to protect their innovations, thereby enhancing their export competitiveness.

(ii) Outward direct investment deferred one period (L1_ODI) also exhibits a significant and positive relationship with patents at the 1% level. This

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[5] Although this paper discusses the random effects model, each of the tables also lists the results for the fixed effects model.

suggests that a country that is engaged in ODI is able to access knowledge, technology and other additional products from the host country, import this to the home country, to engage in innovative R&D to enhance the level of technology, and in turn apply for a patent. In contrast, inward direct investment by foreigners deferred one period (L1_IDI) exhibits a negative, though insignificant, relationship with the home country's patents. This indicates that inflows of foreign investment not only do not positively benefit the innovation in the home country, but negatively impacts it instead. The results of the impact of the two-way direct investment (ODI and IDI) effect on innovation are consistent with the conclusion reached by Pottelsberghe & Lichtenberg (2001).

(iii) Domestic R&D expenditure with a lag of one period (L1_GERD) exhibits a positive relationship with the patent at the 9% level. The results suggest that further discussion on this issue is required, as R&D expenditure and patents are innovative inputs and outputs, and hence should be characterized by a highly significant relationship. For this reason, we discuss this issue at greater length below.

(iv) By comparing three behavioural coefficients, namely exports, ODI and R&D expenditure, that can be determined in the home country, it is found that the impacts of all three coefficients on patents, from the largest to the smallest, are as follows: R&D expenditure (9.362), exports (1.628), and ODI (1.521).

Table 7 presents the empirical results for Model 2, wherein IDI is decomposed into cross-border M&A (M&A), and other direct investment by foreigners (PRIVATE), and the impact of each on patents is then tested. The empirical results are presented in Table 7, with the following conclusions:

(i) the relationships and significance between L1_exports, L1_ODI, L1_GERD and patents are all consistent with the results of Model 1;

(ii) cross-border M&A by foreigners deferred one period (L1_M&A) exhibit a negative but insignificant relationship with the patents.

This result is similar to that of Bertrand & Zuniga (2006), who use 14 OECD member countries in their sample. Other direct investment (L1_PRIVATE) has a negative but insignificant relationship with patents. From these two impacts on patents, one negative and one positive, we can indirectly explain why IDI exhibits a negative but insignificant relationship on patents. The reason is that the negative effect of other direct investment on patents is stronger than the positive effect on patents of cross-border M&A by foreigners. In other words, inflows of foreign capital, in general, are of little or no benefit to domestic innovation. However, if these inflows are decomposed into two parts, namely cross-border M&A by foreigners and other direct investment, then there is only a limited positive effect on innovation.

The results of Model 1 show that R&D expenditure does not have a significant impact on patents, so we now examine the innovation inputs and outputs, as represented by R&D expenditure and patent data. First, we change the R&D expenditure data from the overall domestic R&D expenditure (GERD) used in Model 1 into the domestic business sector R&D expenditure (BERD), and examine whether this replacement is able to change the significance of R&D expenditure on patents. By comparing columns (2) and (4) in Table 8, it can be seen that, in the random effects model, R&D expenditure with a lag of one period is still not significant for patents, but the estimated coefficients are significantly different from each other.[6] Second, the patent data based on triadic patents (TRI_PATENT) are replaced with data based on

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[6] Based on the random effects model, the L1_GERD coefficient has a value of 10.244, and the L1_BERD coefficient a value of 15.235.

unilateral patents (EPO_PATENT). From columns (6) and (8) in Table 9, it can be seen from the random effects model that the significance of the three explanatory variables, namely R&D expenditure lagged one period, other direct deferred one period (L1_PRIVATE) investment, and cross-border M&A by foreigners deferred one period (L1_M&A), markedly increases for unilateral patents when compared with that for triadic patents. For the first two variables, this significance increases from the 5% to the 1% level. In the case of cross-border M&A by foreigners, this significance increases less markedly to the 5% level.

Thus, it can be seen that the differences in the patent data differ markedly in relation to the significance of the coefficients of the explanatory variables. In other words, when comparing the results of innovation across countries, the selection of patents is important. Taking the present paper as an example, because the sample encompasses five continents, if unilateral patents are used as the innovation indicator, such a choice is clearly not objective and can lead to bias. Thus, it is suggested that using the triadic patent as a proxy for innovation is more appropriate.

The empirical results above have shown that inflows of foreign capital are of little or no benefit to domestic innovation, but instead lead to a negative impact. In contrast, by engaging in autonomous behaviour through exports, ODI and R&D, it is possible to promote innovation activities domestically. In order that excessive reliance and expectations are not placed on inflows of foreign capital, the best policy for the promotion of innovation is to maintain a firm grasp on the domestic country’s affairs. It is only in this way that the level of technology can be enhanced, technical standards upgraded, and ultimately the promotion of economic growth sustained.

The reason why inventors apply for patents is to protect their innovations. However, behind the results of innovation, there is usually a perceived economic value. The higher is this economic value, the greater is the incentive for these inventors to apply simultaneously for patents in different countries. From the definitions of the variables described above, triadic patents represent approved simultaneous applications for patents in Europe, USA and Japan, while unilateral patents refer to approved applications for patents made to the European patent office. For this reason, it can be assumed that triadic patents are superior to unilateral patents in terms of representing economic benefits.

Columns (5) and (7) in Table 9 present the regression results in relation to triadic and unilateral patents, and these lead to the following results. The first phenomenon is that the contribution of ODI to products of low economic value in the home country is greater than that of products of high economic value. We propose two possible reasons. First, although the ODI results that obtaining factors, such as technology and knowledge, are helpful to the home country's innovation, individuals are nevertheless rational, as are countries. For this reason, the host country will retain a number of key innovation factors (products with relatively high economic value), so that it will not be easy to obtain technology in relation to ODI that has a correspondingly high economic value. Second, the samples used in this paper are primarily for developed countries, with upper-middle levels of income or higher, and the bids for ODI for the countries sampled are mostly directed towards countries with levels of technology that are lower than their own. Thus, the level of technology that can be obtained is limited, so that it is not easy to obtain technology with a high economic value.

The second phenomenon is that the impact of IDI on the absolute value of the coefficient of the triadic patent coefficient is greater than the absolute value of the coefficient of the unilateral patent.[7] That is, the harm done to the host country's products of high economic value is greater than that to its products of low economic

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[7] As IDI has a negative relationship with patents, our goal is to compare which of the two impacts of IDI on triadic and unilateral patents has the greater influence. The existence of a negative value will influence the results, and so it is necessary to use absolute values.

value. This paper proposes two possible reasons for this phenomenon. In relation to foreign investment, the inflows of such investment into the domestic country will not only generate substantial economic profits, but will also result in some factors being obtained that can help domestic innovation. The more important are these innovation factors, the better, that is, the greater is the economic value of the products, the better. For this reason, the harm done to the domestic country's products of high economic value will be greater.

Finally, in order to verify the two observed phenomena discussed above, we change the R&D expenditure variable from total domestic R&D expenditure (GERD) to domestic business sector R&D expenditure (BERD). We test the differences between these R&D expenditure variables in order to examine whether we can obtain the same phenomena. The empirical results presented in columns (5) and (7) in Table 10 suggest that the above two phenomena still exist, so that, regardless of whether GERD or BERD is used for R&D expenditure:

(1) the contribution of ODI to the domestic country's products of low economic value is greater than to products of high economic value; and

(2) the harm caused by IDI to the domestic country's products of high economic value is greater than to products of low economic value.

6. Conclusions and Recommendations

In this paper, we used panel data for 37 countries for the period 1994 to 2005, and performed an empirical analysis using a negative binomial model. The main purpose was to examine the impact of the two main technology spillover channels, namely international direct investment (IDI) and exports on innovation. IDI was decomposed into outward direct investment (ODI) and inward direct investment (IDI) based on the direction of capital flows, and because of the increasing importance over the years of cross-border mergers and acquisitions (cross-border M&A) by foreigners. For these reasons, we decomposed inward direct investment into cross-border M&A by foreigners and other direct investment. In addition, as R&D expenditure and patents are innovation inputs and outputs, we also included R&D expenditure in the model as an explanatory variable. Moreover, among the dependent variables, we used the number of patents as a proxy for innovation, and also used data on both triadic and unilateral patents.

In summary, within the context of globalization, this paper investigated the impact of exports, imports, ODI, IDI, cross-border M&A by foreigners and R&D expenditure on the number of patents for 37 countries that are considered to be highly competitive in world markets. Based on the empirical results, we can draw the following conclusions:

1. Among the main channels of international trade, exports and ODI exhibited a positive relationship with the domestic country’s patents, that is, increased exports and ODI are able to stimulate an increase in patent output. In contrast, IDI exhibits a negative relationship with domestic patents.
2. R&D expenditure deferred one period has a significant and positive impact on the number of patents, which explains the deferred nature of the impact of the R&D input on the patents. The input in the current period will only exhibit a significant outcome in the following period.
3. Imports are found not to have a significant effect on technology spillovers.
4. Differences in patent data can lead to substantial differences in the estimated results.

Finally, when comparing the results of innovation among countries within the framework of globalization, if unilateral patents are used as the dependent variable, the results obtained are likely to be much improved. However, it is also likely that, because of the presence of a host country’s advantage, the empirical estimates are likely to be biased. Thus, it is necessary to use triadic patents as a proxy for innovation as they are the more appropriate variable, and also closer to the actual innovation results for each country.

In an era of globalization, although countries are frequently engaged in exchange with each other, each government has sought to attract foreign investment, and has been wary of outflows of capital from the domestic economy. However, the empirical results indicate that the competitive behaviour between countries is similarly rational and individualistic, so that inflows of foreign capital are of little or no benefit to domestic innovation, and instead can lead to a negative impact.

In contrast, countries that engage in autonomous behaviour related to exports, ODI and R&D input are then able to encourage innovation activities. In other words, there are not excessive expectations of, or reliance on, inflows of foreign funds from abroad, so that inflows of foreign capital may contribute to a country’s GDP in the short term. However, when viewed from a long-term perspective, the key to sustained and stable economic growth is still innovation, and the promotion of such innovation must still be grasped. Only in this way can the level of technology be raised and the sustained growth of the economy ultimately enhanced.

References

Aggarwal, A. (2004) “Macro Economic Determinants of Antidumping: A Comparative Analysis of Developed and Developing Countries”, *World Development*, 32, pp. 1043-1057.

Bassanini, A. and S. Scarpetta (2002) “Does human capital matter for growth in OECD countries? A pooled mean-group approach”, *Economics Letters*, 74, pp.399-405.

Bertrand, O. and P. Zuniga (2006) “R&D and M&A: Are Cross-border M&A Different? An Investigation on OECD Countries, *International Journal of Industrial Organization*, 24, pp. 401-423.

Blind, K. and A. Jungmittag (2004) “Foreign Direct Investment, Imports and Innovations in the Service Industry”, *Review of Industrial Organization*, 25, pp. 205-227.

Branstetter, L. (2006) “Is Foreign Direct Investment a Channel of Knowledge Spillovers? Evidence from Japan’s FDI in the United States”, *Journal of International Economics*, 68, pp. 325-344.

Coe, D.T., and E. Helpman (1995) “International R&D Spillovers”, *European Economic Review* 39, 859-887.

Coe, D.T., E. Helpman, and A.W. Hoffmaister (1997) “North-South R&D Spillovers”, *The Economic Journal* 107, 35-150.

Coe, D.T., E. Helpman, and A.W. Hoffmaister (2009) “International R&D Spillovers and Institutions”, *European Economic Review*, 53, 723-741.

Cohen, W.M. and Levinthal, D.A. (1989) “Innovation and Learning: Two Faces of R&D”, *The Economic Journal*, 99, 569-596.

Deolalikar, A.B. and R.E. Evenson (1989) “Technology Production and Technology Purchase in Indian Industry: An Econometric Analysis”, *The Review of Economics and Statistics*, 71, pp. 687-692.

European Patent Organisation (2010), accessed at http://www.epo.org/about-us/epo.html

Geroski, P., S. Machin, J. Van Reenen (1993) “ The Profitability of Innovating Firms“, *Rand Journal of Economics*, 24, 198-211

Girma, S., Y. Gong, and H. Görg (2009) “What Determines Innovation Activity in Chinese State-owned Enterprises? The Role of Foreign Direct Investment”, *World Development*, 37, pp. 866-873.

Girma, S., H. Görg, and A. Hanley (2008) "R&D and Exporting - A Comparison of British and Irish Firms", *Review of World Economics*, 144, pp. 750-771.

Gourlay, A., and J. Seaton (2004) "Explaining the Decision to Export: Evidence from UK Firms", *Applied Economics Letters*, 11, pp. 153-158.

Gourlay, A., J. Seaton, and J. Suppakitjarak (2005) "The Determinants of Export Behaviour in UK Service Firms", *The Service Industries Journal*, 25, pp. 879-889.

Han, Y.J., and W.Y. Lee (2007) "The Effects of the Characteristics of Korean Firms on the Patent Production Function", *Economics of Innovation and New Technology, 16,* pp. 293-301.

Hausman, J.A., B.H. Hall, and Z. Griliches (1984) "Econometric Models for Count Data with an Application to the Patents-R&D Relationship", *Econometrica, 52,* pp. 909-938.

Hu, M. C., and J. A. Mathews (2005) "National Innovative Capacity in East Asia", *Research Policy,* 34, pp. 1322-1349.

Keller, W. (1998) "Are International R&D Spillovers Trade-Related? Analyzing Spillovers Among Randomly Matched Trade Partners", *European Economic Review*, 42, 1469-1481.

Keller, W. (2004) "International Technology Diffusion", *Journal of Economic Literature*, 42(3), 52-782

Keller, W. (2009) "International Trade, Foreign Direct Investment, and Technology Spillovers", NBER Working Paper 15422. Cambridge, MA: National Bureau of Economic Research.

Kneller, R. (2005) "Frontier Technology, Absorptive Capacity and Distance", *Oxford Bulletin of Economics and Statistics*, 67(1), 1-23

Kumar, N. (1987) "Technology Imports and Local Research and Development in Indian Manufacturing", *The Developing Economies,* 25, pp. 220-233.

Lee, G. (2006) "The Effectiveness of International Knowledge Spillovers Channels", *European Economic Review,* 50, 2075-2088.

Lin, H.L., and R.S. Yeh (2005) "The Interdependence between FDI and R&D: An Application of an Endogenous Switching Model to Taiwan's Electronics Industry", *Applied Economics*, 37, pp. 1789-1799.

Lin, H.L., R.S. Yeh, and C.F. Chung (2009) "The Effect of Outward Investment to China on Domestic R&D: A Two-hurdle Model with Endogenous ODI", *Applied Economics,* 41, pp. 1191-1198.

Liu, B.-J., T.-J. Chen and Y.-H. Weng. (2005) *Trade Theory and Policy*, Taiwan: Yeh-Yeh Book Gallery. (in Chinese)

Liu, X. and H. Zou (2008) “The Impact of Greenfield FDI and Mergers and Acquisitions on Innovation in Chinese High-tech Industries”, *Journal of World Business*, 43, pp. 352-364.

Lucas, R.E. (1988) “On the Mechanics of Economic Development”, *Journal of Monetary Economics*, 22, 3-42.

Madsen, J. B. (2007) “Technology spillover through trade and TFP convergence: 135 years of evidence for the OECD countries”, *Journal of international Economics*, 72, 464-480.

Mancusi, M.L. (2008) “International Spillovers and Absorptive Capacity: A Cross-Country Cross-Sector Analysis Based on Patents and Citations”, *Journal of International Economics*, 76, 155-165.

Mueller P. (2006) “Exploring the knowledge filter: How entrepreneurship and university–industry relationships drive economic growth”, *Research Policy*, 35, 1499–1508.

OECD. (2007). Main Science and Technology Indicators. OECD.

Ou Yang, H. and J.-T. Hwang. (2006) “*International Trade Theory and Policy*”. Taiwan: San Min Books. (in Chinese)

Posner, M.V. (1961) “International Trade and Technical Change. *Oxford Economic Papers*”, 13, pp. 323-341.

Pottelsberghe, B.P. and F. Lichtenberg (2001) “Does Foreign Direct Investment Transfer Technology across Borders?”, *Review of Economics and Statistics*, 83, pp. 490-497.

Romer, P.M. (1986) “Increasing Returns and Long-Run Growth”, *Journal of Political Economy*, 94, 1002-1037.

Roper, S. and J.H. Love (2002) “Innovation and Export Performance: Evidence from the UK and German Manufacturing Plants”, *Research Policy*, 31, pp. 1087-1102.

Roper, S., J.H. Love, and D.A. Hígon. (2006) “The Determinants of Export Performance: Evidence for Manufacturing Plants in Ireland and Northern Ireland”, *Scottish Journal of Political Economy*, 53, pp. 586-615.

Salomon, R.M. and J.M. Shaver (2005), “Innovation, Learning by Exporting: New Insights from Examining Firms”, *Journal of Economics & Management Strategy*, 14, pp. 431-460.

Salvatore, D. (2009) *International Economics*, New York: Wiley.

Tomiura, E. (2007) “Effects of R&D and Networking on the Export Decision of Japanese Firms”, *Research Policy*, *36*, pp. 758-767.

Tsou, M.-W. and J.-T. Liu. (1997) “The Spillover Effect from Foreign Direct Investment: Empirical Evidence from Taiwan Manufacturing Industries”, *Taiwan Economic Review*, 25(2), pp.155-181. (in Chinese)

UNCTAD (2007) *World Investment Report: Transnational Corporations, Extractive Industries and Development*, New York and Geneva: United Nations.

Vernon, R. (1966) “International Investment and International Trade in the Product Cycle”, *Quarterly Journal of Economics*, 80, pp. 190-207.

World Bank (2010), Country Classification by Income, accessed at http://data.worldbank.org/about/country-classifications/country-and-lending-groups

Yang, C.H., J.R. Chen, and W.B. Chuang, (2004) “Technology and Export Decisions”, *Small Business Economics*, 22, pp. 349-364.

Table 1. OECD Countries

	Europe	Asia	Americas	Oceania	Africa
Country	United Kingdom, Austria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Sweden, Switzerland, Netherlands, Portugal, Slovak Republic, Spain, Norway, Slovenia, Poland, Romania	Japan, Korea, Singapore, Israel, Turkey, Taiwan, Russian Federation, China	USA, Canada, Mexico, Argentina	Australia, New Zealand,	South Africa
Total	22	8	4	2	1

Table 2. OECD Countries by Income

Income Level	OECD Member	Non-OECD Member	Total
High	25[a]	3[b]	28
Upper-Middle	3[c]	5[d]	8
Lower-Middle	0	1[e]	1
Total	28	9	37

Source: World Bank

Notes: a: United Kingdom, Austria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Sweden, Switzerland, Netherlands, Portugal, Slovak Republic, Spain, Norway, Japan, Korea, United States, Canada, New Zealand, Australia; b: Slovenia, Singapore, Israel; c: Poland, Turkey, Mexico; d: Romania, Taiwan, Russian Federation, Argentina, South Africa; e: China

Table 3. The Variables

Dependent Variable		
TRI_PATENT	Triadic Patent[a]	Number of triadic patent families. (i.e. A patent is filed at the EPO, the JPO and is granted by the USPTO.
EPO_PATENT	European Patent Office Patent[b]	Number of patent applications approved by the EPO[c].
Independent Variable		
EXP	Export	Ratio of Export divided by GDP
IM	Import	Ratio of Import divided by GDP
ODI	Outward Direct Investment	Ratio of ODI divided by GDP
IDI	Inward Direct Investment	Ratio of IDI divided by GDP
M&A_SALE	Inward Cross-Border M&A	Ratio of Inward Cross-Border M&A divided by GDP
PRIVATE	Other Direct Investment	Variable “IDI” minus Variable “M&A_SALE”
GERD	Gross Domestic Expenditure on R&D	Ratio of Gross Domestic Expenditure on R&D by GDP
BERD	Expenditure on R&D in the Business Enterprise Sector	Ratio of Expenditure on R&D in the Business Enterprise Sector by GDP
L0, L1, L2, L3	Three-year time lag: Current, one year, two year and three year time lag in sequence	

Note:

a: It’s the main dependent variable, provided with the intention of improving international comparability (the home advantage is suppressed, the values of the patents are more homogeneous) (OECD, 2007).

b: the minor dependent variable that compared to the triadic patent.

c: The European Patent Office provides a uniform application procedure for individual inventors and companies seeking patent protection in up to 40 European countries, and is the executive arm of the European Patent Organization. The European Patent Organization is an intergovernmental organization that was set up on 1977 on the basis of the European Patent Convention (EPC) signed in Munich in 1973.

Table 4. Summary Statistics

Variables	Mean	Std. Error	Min.	Max.
TRI_PATENT	1184.12	3182.04	0.0000	16368
EPO_PATENT	2644.45	6031.13	3.0000	32064
EXP	0.3896	0.2490	0.0752	1.9006
IM	0.3778	0.2325	0.0707	1.6554
ODI	0.0254	0.0415	-0.0497	0.4351
IDI	0.0325	0.0410	-0.1578	0.2675
M&A_SALE	0.0176	0.0236	0.0000	0.2321
PRIVATE	0.0149	0.0348	-0.1698	0.2130
L1_GERD	0.0202	0.0101	0.0046	0.0662
L1_BERD	0.0122	0.0081	0.0012	0.0498

Note: The only country with a zero value for TRI-Patent is Romania.

Table 5. Lag Structure of R&D

TRI_ PATENT	Fixed Effects				Random Effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EXP	1.636	1.273	0.845	0.086	1.684	1.350	0.959	0.249
	(2.27)**	(1.77)*	(0.69)	(0.11)	(2.28)**	(1.86)*	(0.83)	(0.28)
	[4.30]***	[3.24]***	[2.06]**	[0.19]	[4.38]***	[3.39]***	[2.31]**	[0.54]
IM	-0.045	0.365	0.862	1.747	-0.181	0.180	0.615	1.419
	(-0.04)	(0.30)	(0.54)	(1.95)*	(-0.15)	(0.15)	(0.41)	(1.62)
	[-0.10]	[0.72]	[1.56]	[2.78]***	[-0.39]	[0.36]	[1.11]	[2.26]**
ODI	1.411	1.336	1.088	0.897	1.454	1.389	1.142	0.944
	(2.89)***	(3.13)***	(2.23)**	(1.93)*	(3.10)***	(3.14)***	(2.37)**	(2.03)**
	[2.93]***	[2.91]***	[2.43]**	[2.08]**	[3.01]***	[3.01]***	[2.54]**	[2.18]**
IDI	-0.909	-0.881	-0.776	-0.830	-0.927	-0.893	-0.771	-0.797
	(-1.20)	(-1.61)	(-1.20)	(-1.87)*	(-1.21)	(-1.54)	(-1.27)	(-1.85)*
	[-1.91]*	[-1.95]*	[-1.79]*	[-1.97]**	[-1.93]*	[-1.95]*	[-1.76]*	[-1.86]*
L0_GERD	11.725				12.204			
	(1.33)				(1.34)			
	[3.54]***				[3.71]***			
L1_GERD		10.144				10.640		
		(1.42)				(1.49)		
		[3.26]***				[3.44]***		
L2_GERD			7.171				7.750	
			(1.21)				(1.20)	
			[2.41]**				[2.62]***	
L3_GERD				5.221				5.931
				(0.92)				(1.10)
				[1.77]*				[2.03]**
CONSTANTS	1.614	1.812	2.020	2.237	1.626	1.828	2.040	2.262
	(2.45)**	(2.39)**	(2.13)**	(1.78)*	(2.45)**	(2.38)**	(2.21)**	(1.83)*
	[12.91]***	[14.21]***	[15.46]***	[16.32]***	[13.08]***	[14.41]***	[15.70]***	[16.60]***
Log likelihood	-1967.3	-1769.7	-1577.0	-1383.5	-2316.8	-2117.5	-1922.9	-1727.1
Wald chi2	42.53	33.98	10.74	12.28	41.94	30.53	10.18	12.85
Prob＞chi2	0.000	0.000	0.057	0.031	0.000	0.000	0.070	0.025
Groups	37	37	37	37	37	37	37	37
Observations	440	403	366	329	440	403	366	329

Note: Bootstrapping *t*-statistics are in the parentheses and *t*-statistics without bootstrapping appear in square brackets. The asterisks ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table 6. Model 1

TRI_PATENT	Fixed Effects	Random Effects
L1_EXP	1.596 (1.81)* [3.87]***	1.628 (1.86)* [3.90]***
L1_IM	-0.263 (-0.19) [-0.56]	-0.377 (-0.28) [-0.80]
L1_ODI	1.465 (3.73)*** [2.60]***	1.521 (3.79)*** [2.69]***
L1_IDI	-0.993 (-1.46) [-1.81]*	-1.023 (-1.44) [-1.85]*
L1_GERD	8.898 (0.94) [2.60]***	9.362 (1.05) [2.75]***
CONSTANTS	1.894 (2.51)** [14.44]***	1.905 (2.54)** [14.59]***
Log likelihood	-1778.5	-2125.7
Wald chi2	28.32	26.48
Prob＞chi2	0.000	0.000
Groups	37	37
Observations	403	403
Hausman test (Prob＞chi2)		-3.70

Note: Bootstrapping *t*-statistics are in the parentheses and *t*-statistics without bootstrapping appear in square brackets. The asterisks *** and * denote significance at the 1% and 10% levels, respectively.

Table 7. Model 2 - Decomposition of IDI

TRI_PATENT	Fixed Effects	Random Effects
L1_EXP	1.608 (1.87)* [3.87]***	1.638 (1.87)* [3.89]***
L1_IM	-0.264 (-0.19) [-0.56]	-0.377 (-0.28) [-0.80]
L1_ODI	1.360 (3.38)*** [2.43]**	1.414 (3.51)*** [2.53]**
L1_M&A	-0.141 (-0.22) [-0.19]	-0.153 (-0.22) [-0.20]
L1_PRIVATE	-1.519 (-1.45) [-2.35]**	-1.568 (-1.43) [-2.40]**
L1_GERD	8.283 (0.96) [2.38]**	8.753 (0.95) [2.53]**
CONSTANTS	1.902 (2.55)** [14.42]***	1.913 (2.60)*** [14.57]***
Log likelihood	-1777.3	-2124.4
Wald chi2	27.13	26.34
Prob＞chi2	0.000	0.000
Groups	37	37
Observations	403	403

Note: Bootstrapping *t*-statistics are in parentheses and *t*-statistics without bootstrapping appear in square brackets. The asterisks *** and * denote significance at the 1% and 10% levels, respectively.

Table 8. Model 3 - Effects of Using Different R&D Data

TRI_PATENT	Fixed Effects (1)	Random Effects (2)	Fixed Effects (3)	Random Effects (4)
L1_EXP	1.608 (1.87)* [3.87]***	1.638 (1.87)* [3.89]***	1.444 (1.44) [3.57]***	1.467 (1.43) [3.57]***
L1_IM	-0.264 (-0.19) [-0.56]	-0.377 (-0.28) [-0.80]	-0.183 (-0.12) [-0.41]	-0.291 (-0.20) [-0.64]
L1_ODI	1.360 (3.38)*** [2.43]**	1.414 (3.51)*** [2.53]**	1.224 (3.24)*** [2.20]**	1.273 (3.14)*** [2.29]**
L1_M&A_SALE	-0.141 (-0.22) [-0.19]	-0.153 (-0.22) [-0.20]	-0.206 (-0.33) [-0.28]	-0.217 (-0.36) [-0.29]
L1_PRIVATE	-1.519 (-1.45) [-2.35]**	-1.568 (-1.43) [-2.40]**	-1.422 (-1.43) [-2.20]**	-1.467 (-1.39) [-2.25]**
L1_GERD	8.283 (0.96) [2.38]**	8.753 (0.95) [2.53]**		
L1_BERD			13.720 (1.09) [3.46]***	14.396 (1.16) [3.66]***
CONSTANTS	1.902 (2.55)** [14.42]***	1.913 (2.60)*** [14.57]***	1.986 (2.76)*** [15.89]***	1.999 (2.77)*** [16.05]***
Log likelihood	-1777.3	-2124.4	-1746.5	-2093.1
Wald chi2 Prob > chi2	27.13 0.000	26.34 0.000	25.32 0.000	22.62 0.000
Groups Observations	37 403	37 403	37 399	37 399

Note: Bootstrapping *t*-statistics are in parentheses and *t*-statistics without bootstrapping appear in square brackets. The asterisks *** and * denote significance at the 1% and 10% levels, respectively.

Table 9. Model 4 - Effects of Using Different Patent Data (under GERD)

	Fixed Effects				Random Effects			
	TRI_PATENT		EPO_PATENT		TRI_PATENT		EPO_PATENT	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L1_EXP	1.596	1.608	1.713	1.758	1.628	1.638	1.775	1.818
	(1.81)*	(1.87)*	(2.81)***	(2.88)***	(1.86)*	(1.87)*	(3.06)***	(2.89)***
	[3.87]***	[3.87]***	[4.33]***	[4.44]***	[3.90]***	[3.89]***	[4.42]***	[4.51]***
L1_IM	-0.263	-0.264	-0.348	-0.319	-0.377	-0.377	-0.491	-0.461
	(-0.19)	(-0.19)	(-0.28)	(-0.27)	(-0.28)	(-0.28)	(-0.45)	(-0.42)
	[-0.56]	[-0.56]	[-0.79]	[-0.72]	[-0.80]	[-0.80]	[-1.09]	[-1.02]
L1_ODI	1.465	1.360	1.683	1.503	1.521	1.414	1.780	1.598
	(3.73)***	(3.38)***	(3.35)***	(3.39)***	(3.79)***	(3.51)***	(3.78)***	(3.41)***
	[2.60]***	[2.43]**	[2.81]***	[2.60]***	[2.69]***	[2.53]**	[2.98]***	[2.76]***
L1_IDI	-0.993		-0.247		-1.023		-0.290	
	(-1.46)		(-0.42)		(-1.44)		(-0.49)	
	[-1.81]*		[-0.42]		[-1.85]*		[-0.49]	
L1_M&A_SALE		-0.141		1.485		-0.153		1.454
		(-0.22)		(2.04)**		(-0.22)		(1.91)*
		[-0.19]		[1.97]**		[-0.20]		[1.92]*
L1_PRIVATE		-1.519		-1.387		-1.568		-1.451
		(-1.45)		(-1.79)*		(-1.43)		(-1.76)*
		[-2.35]**		[-2.00]**		[-2.40]**		[-2.07]**
L1_GERD	8.898	8.283	19.215	18.013	9.362	8.753	19.377	18.20
	(0.94)	(0.96)	(2.25)**	(2.12)**	(1.05)	(0.95)	(2.23)**	(2.04)**
	[2.60]***	[2.38]**	[5.72]***	[5.26]***	[2.75]***	[2.53]**	[5.79]***	[5.35]***
CONSTANTS	1.894	1.902	1.171	1.183	1.905	1.913	1.193	1.205
	(2.51)**	(2.55)**	(2.34)**	(2.50)**	(2.54)**	(2.60)***	(2.69)***	(2.58)***
	[14.44]***	[14.42]***	[9.84]***	[9.85]***	[14.59]***	[14.57]***	[10.11]***	[10.11]***
Loglikelihood	-1778.5	-1777.3	-2292.4	-2287.8	-2125.7	-2124.4	-2682.6	-2677.9
Wald chi2	28.32	27.13	81.20	104.28	26.48	26.34	76.72	93.43
Prob＞chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Groups	37	37	37	37	37	37	37	37
Observations	403	403	399	403	403	403	403	403

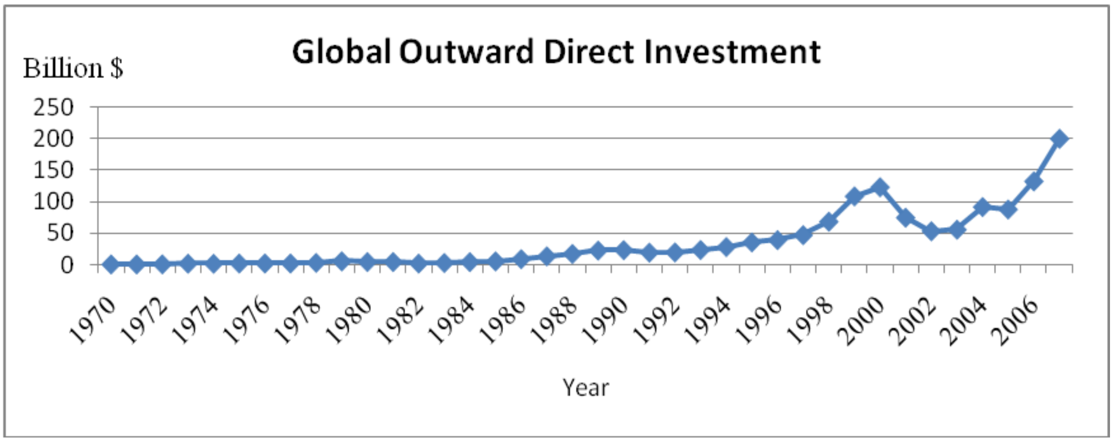
Note: Bootstrapping *t*-statistics are in parentheses and *t*-statistics without bootstrapping appear in square brackets. The asterisks ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table 10. Model 4 - Effects of Using Different Patent Data (under BERD)

	Fixed Effects				Random Effects			
	TRI_PATENT		EPO_PATENT		TRI_PATENT		EPO_PATENT	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L1_EXP	1.440	1.444	1.770	1.802	1.465	1.467	1.824	1.855
	(1.38)	(1.44)	(2.85)***	(2.84)***	(1.41)	(1.43)	(2.70)***	(2.74)***
	[3.59]***	[3.57]***	[4.66]***	[4.74]***	[3.60]***	[3.57]***	[4.72]***	[4.79]***
L1_IM	-0.191	-0.183	-0.481	-0.438	-0.30	-0.291	-0.615	-0.572
	(-0.12)	(-0.12)	(-0.37)	(-0.35)	(-0.20)	(-0.20)	(-0.50)	(-0.48)
	[-0.43]	[-0.41]	[-1.14]	[-1.04]	[-0.67]	[-0.64]	[-1.44]	[-1.33]
L1_ODI	1.305	1.224	1.508	1.361	1.354	1.273	1.598	1.448
	(3.27)***	(3.24)***	(3.19)***	(2.96)***	(3.51)***	(3.14)***	(3.24)***	(3.15)***
	[2.33]**	[2.20]**	[2.55]**	[2.38]**	[2.41]**	[2.29]**	[2.71]***	[2.54]**
L1_IDI	-0.940		-0.159		-0.966		-0.197	
	(-1.46)		(-0.29)		(-1.50)		(-0.36)	
	[-1.73]*		[-0.28]		[-1.76]*		[-0.34]	
L1_M&A_SALE		-0.206		1.423		-0.217		1.392
		(-0.33)		(1.87)*		(-0.36)		(2.14)**
		[-0.28]		[1.94]*		[-0.29]		[1.90]*
L1_PRIVATE		-1.422		-1.243		-1.467		-1.30
		(-1.43)		(-1.80)*		(-1.39)		(-1.81)*
		[-2.20]**		[-1.83]*		[-2.25]**		[-1.90]*
L1_BERD	14.344	13.720	25.609	24.274	15.014	14.396	25.917	24.599
	(1.14)	(1.09)	(2.38)**	(2.12)**	(1.22)	(1.16)	(2.34)**	(2.21)**
	[3.67]***	[3.46]***	[6.71]***	[6.24]***	[3.88]***	[3.66]***	[6.84]***	[6.37]***
CONSTANTS	1.982	1.986	1.329	1.331	1.996	1.999	1.351	1.353
	(2.70)***	(2.76)***	(2.98)***	(2.94)***	(2.78)***	(2.77)***	(3.05)***	(3.17)***
	[15.96]***	[15.89]***	[12.18]***	[12.07]***	[16.12]***	[16.05]***	[12.47]***	[12.36]***
Log likelihood	-1747.4	-1746.5	-2256.2	-2252.1	-2094.1	-2093.1	-2646.0	-2641.8
Wald chi2	23.87	25.32	70.11	96.54	24.43	22.62	71.78	92.77
Prob＞chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Groups	37	37	37	37	37	37	37	37
Observations	399	399	399	399	399	399	399	399

Note: Bootstrapping *t*-statistics are in parentheses and *t*-statistics without bootstrapping appear in square brackets. The asterisks ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Figure 1. Global Outward Direct Investment

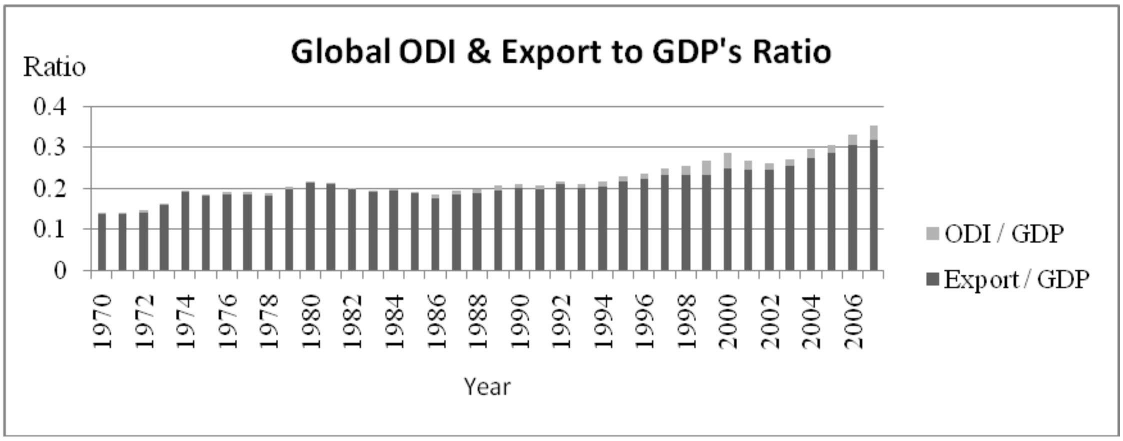


Source: UNCTAD

Figure 2. Global Exports

Source: World Bank

Figure 3. Global ODI & Exports to GDP Ratio



Source: World Bank and UNCTAD