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THE ROLE OF INTERNATIONALIZATION AS A DETERMINANT OF INNOVATION PERFORMANCE. AN ANALYSIS OF 42 COUNTRIES

by

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Abstract

This paper analyses the impact of internationalization on the innovation performance of 42 countries. Innovation performance – the dependent variable – is measured by the number of triad patents and PCT applications that originate from a country. The following internationalization variables – independent variables – are used: inward and outward stock of FDI, exports and imports as well as the number of parent companies in a country. Information on patents and the internationalization variables, together with further explanatory variables, including the number of scientific articles in a country, the number of Internet users, the R&D intensity and the share of value added in services, are collected for the years 1990 to 2008. Regressions are performed for all countries together, and, then, for two groups of countries clustered on the basis of their GDP per capita. We estimate two linear models, one based on pooled data estimating the classic linear model, and one on panel data, estimating a fixed effects linear model. The values of our dependent variables lead by up to six years for two reasons: to account for the time that elapses between an invention and the recording of the patent statistic, and, to address at least to some extent, issues associated with endogeneity in our independent variables. The paper finds support for a positive impact of internationalization on countries' innovation performance. Our analyses suggest that competing in international markets via outward FDI and exports increases the scope of learning and the need to innovate. We find evidence of a negative relationship between patenting and inward FDI as well as imports. We interpret our results to indicate that (a) the inward inflow of investment or products can be less innovation-intensive than a country's domestic activities which would be the case for more advanced and innovation-active countries; or (b) that a country does not have a sufficient absorption capacity to benefit from inflows.

Keywords: FDI, trade, triadic patents, PCT applications
JEL classification codes: F20, O30, O57

1. Introduction

The aim of this study is to examine the relevance of internationalization in innovation performance in the context of 42 countries. A positive impact of internationalization on innovation performance is found in several studies (Castellani and Zanfei 2006; Frenz and Ietto-Gillies 2007, 2009), including a study focusing on the financial services sector in the UK (Frenz et al. 2005). However, all these works relate to specific countries. As far as we know, there are no studies of many countries together that support the existence of such a relationship. Filippetti et al. (2010) find strong correlations between innovation performance and several internationalization variables in a study of 32 European countries. On the basis of the theoretical analysis – which points to possible causal mechanisms – the study concludes that the association between innovation and internationalization is not spurious, but is very likely to be a sign of a causal relationship between internationalization and innovation performance. The current study builds on that work by expanding on the depth of analysis, the data and the empirical techniques as well as on the number of countries considered. Specifically we: (i) deepen the analysis by moving from association to explanation; (ii) extend the range of variables that capture the knowledge context, the innovation infrastructure and the sectoral context; (iii) extend the analysis to 42 countries (listed in Table 1); (iv) group the countries into two clusters according to their GDP per capita.

For these 42 countries we collected measures of innovation, internationalization and other relevant variable over a 19-year time period from1990 to 2008. The key data sources are the United Nations' Conference on Trade and Development, the World Bank's World Development Indicators, and Main Science and Technology Indicators published by the Organization for Economic Cooperation and Development.

The measures used as a proxy for countries' innovation performance are triadic and domestic patents. Patents are one of the key measures used in innovation research because of the good availability and reliability of long time-series data and the comparability of data across countries, and these are the reason why our study relies on patents as a proxy for innovation. However, there are problems associated with the use of patent data. In particular, not all inventions are patented and an invention does not always lead to a successful commercialisation of a new good or service. Moreover, there may be a sectoral bias because the use of patents is less pronounced in some industries, including many service industries.

Internationalization is measured by the following variables: stock of inward and outwards foreign direct invest (FDI); imports and exports and, in some models, the number of parent transnational corporations in the country. The models control for the following other time variant factors influencing countries' innovation performance: journal publications, Internet users, service intensity and expenditure on R&D.

In terms of methodology, internationalization is linked to innovation using pooled regressions and panel estimations. In both cases we introduce different time lags between the internationalization variables and innovation variables. In a further step the 42 countries are clustered into two groups depending on their GDP per capita, and we analyse, separately, the relationship between internationalization and innovation of countries for the two clusters

The contribution of the paper is in the following: (i) an assessment of the impact of internationalization on indicators of innovation performance in the context of a model that includes other relevant variables; (ii) the use of several internationalization variables to allow for the impact of the flow of capital, goods and services; (iii) analysis for 42 countries at different level of development over a 19 year period; (iv) the separate assessment of the relationship between internationalization for different groups of countries clustered by their GDP per capita.

The paper proceeds as follows. The next section discusses theoretical and empirical findings on the relationship between innovation and internationalization. Section 3 considers the possible impact of the country's contexts; Section 4 presents variables, data and methodology; Section 5 and 6 present and discuss the results; Section 7 summarises and concludes.

2. Internationalization and innovation: the background

The possible relationship between innovation performance and internationalization is complex and there are strong theoretical arguments why causation could go both ways: from innovation to internationalization and/or from internationalization to innovation. It is indeed very likely that the two phenomena are linked by a cumulative causation mechanism. More innovative firms can better compete and thus become more internationalized. Moreover, internationalized firms are exposed to diverse cultures and innovation environments from which they can learn. Both these processes are likely to enhance their innovation performance. Both internationalization and innovation at the level of firms affect the countries in which the firms are based or in which they operate.

The impact of innovation on internationalization has been explored in various studies. Posner (1961) and Hufbauer (1966) found that trade performance and, specifically, exports were related to the technological gap between countries. Posner's work formed the background to Vernon (1966) in which the innovation performance of firms and countries determines their exports performance, then – in a time sequence – their propensity to foreign direct investment and, eventually, both their exports and imports propensities. More recent works linking international variables to innovation include Amendola et al. (1993), Cantwell (1989, 1994), Cantwell and Sanna Randaccio (1993), Fageberger (1996) and Krugman (1995).

However, the impact of innovation on international performance is not the subject of this paper. We are interested in the possible impact of internationalization on innovation performance. How can such an impact come about? Innovation can be wide ranging and include both technological and organizational innovation. These two types of innovation are often interconnected and complementary and both impact on performance. They both depend on a variety of elements ranging from type of inputs to macro and industry environments to government policies to the degree of internationalization of the firms.

As mentioned above, a high degree of internationalization – particularly in terms of the numbers of countries in which they operate[1] – exposes companies to diverse innovation environments and helps them to learn from these different contexts. Knowledge transmission at both national and international levels can take place via products and processes or via interaction between institutions and between people in institutions. They can be interactions between customers and suppliers (Crone and Roper 2001; Saliola and Zanfei 2009) or contractors and principals or partners in joint ventures (Lyles and Salk 1996) or industry and universities.[2]

Another link between internationalization and innovation is identified in the growth literature. For instance, Grossman and Helpman (1991) show that international integration has a sizeable effect on economic growth. According to this research, trade integration has a positive effect on productivity for different reasons. Having access to a larger market increases the profitability of innovation activities and encourages investment in R&D. Further, the international competition encourages innovation activities because international integration exposes domestic firms to foreign and potentially stronger competition. Finally, access to foreign suppliers provides access to specialized intermediate inputs and capital goods.

Knowledge can be tacit or codified. The former plays a key role in the development of innovation (Polanyi, 1966, 1967) and it can also assist in the acquisition and transmission of codified knowledge (Uzzi 1997). The transmission of tacit knowledge is facilitated by spatial proximity (Criscuolo et al 2005)[3]; by social embeddedness (Dhanaraj et al 2004; Uzzi, 1997); and by mobility of employees across firms as well as across units of the same firm.

In all these mechanisms of transmission, networks play a key role (Uzzi and Lancaster 2003). Spatially diversified companies develop a variety of networks some internal and some external to the company. Among the spatially diversified companies a special role in knowledge transmission is played by transnational companies (TNCs). Their activities span several countries, and they have, therefore, access to more diverse knowledge and innovation contexts compared to companies whose networks span a single country.

The theoretical underpinnings to the links between transnationalization and innovation can be found in the evolutionary theory of the firm (Nelson and Winter 1982; Nelson and Rosenberg 1993). This theory led to developments and applications to the TNCs in which the

[1] An index of internationalization based on the number of countries in which TNCs have direct business activities is developed in Ietto-Gillies (1998 and 2009).
[2] See Boradman (2009) as well as various articles in the Special Section on University-Industry Linkages in *Research Policy (*2008).
[3] Narula and Santangelo (2009) find that spatial proximity affects the choice of partners in R&D alliances.

behaviour and performance of the latter is linked to their capability for the development, absorption and diffusion of innovation activities (Cantwell 1989; Kogut and Zander 1993, 2003[4]).

The role of TNCs' internal and external networks in knowledge transfer and innovation has been examined in several works (Castellani and Zanfei 2004, 2006; Hedlund and Rolander, 1990; Frenz et al. 2005; Frenz and Ietto-Gillies, 2007, 2009; Zhara, Ireland and Hitt, 2000). Their internal network is constituted by headquarters and all the affiliates many of them scattered in various countries of the world characterized by diverse business and organizational cultures as well as by diverse technological environment. Each unit of the TNC can transmit and receive knowledge to/from other parts of the company via the internal network.

Moreover, each unit is part of various external networks within the environment in which it operates. These networks range from contacts with customers or suppliers or business partners or local universities and research centres. The range and extent of external networks the TNC is involved in vary according to the type of modality(ies) it uses to operate in foreign countries: from foreign direct investment (FDI) to trade to licensing or franchising to sub-contracting to joint ventures. TNCs are likely to use different modalities for different activities and/or host countries. Whichever the modality, the external networks it gives rise to can become channels for the acquisition of knowledge whose diffusion across the TNCs and countries will then be facilitated by the internal networks of the TNC.[5]

Thus, each unit of the TNC acquires knowledge from its environment and then transmits all or some of it to other parts of the company and thus to other countries. Moreover, knowledge from the unit – whether it is self-generated or acquired via the internal or external networks – spills over to the local environment via the same transmission mechanisms which lead to the acquisition of knowledge by the unit.

There are various issues connected to these mechanisms which have an impact on the degree of absorption and transmission of knowledge. First, the degree to which knowledge spills over from the unit of the TNC to the local environment depends on the strength of external networks, and, thus, on the degree of embeddedness[6] of the unit in the locality. On the latter point, Uzzi (1997) finds that, beyond a certain threshold, embeddedness can have negative effects on performance and knowledge transmission by insulating the business unit from information external to the local environment, and, therefore, making it more vulnerable to external shocks.

Second, the extent of knowledge transfer from the unit to the locality depends also on the absorption capacity of the locality. Similarly, the absorption capacity of the TNC's unit affects the degree to which it can acquire knowledge from the environment. Third, the degree to which knowledge is transmitted across units of the TNC may partly depend on the internal organizational structure of the TNC. A more decentralized structure may facilitate the unit's interaction with its external environment, and, thus, facilitate acquisition of knowledge. A more centralized structure facilitates exchanges between units internal to the TNC including internal knowledge transfer (Bartlett and Ghoshal, 1989; Gupta and Govinbdarajan 1991, 2000; Hedlund, 1986).

The learning processes that TNCs' activities and organizations can be involved in, can come about via both its outward and inward FDI. However, in the case of inward FDI, the learning is also linked to the type of investment the country attracts. If the inward FDI is knowledge intensive relatively to the structure and development of the country, then the

[4] Cantwell's and Kogut and Zander's works are summarized and commented on in Ietto-Gillies (2012: Ch. 11)
[5] Alvarez et al (2009) stress the relevance of internal and external networks also for the competitiveness of the firm.
[6] On the concept of embeddedness see Granovetter (1985).

impact of inward FDI on innovation is likely to be positive. But, if it is less knowledge intensive, the impact is likely to be low. The absorption capacity and capabilities of the host country are also strong elements in the positive contribution to innovation that inward flows of both FDI and importation of products are likely to make to a country[7].

The above points consider the role of TNCs' activities and structures in the potential effects of internationalization on innovation. However, there are many more international activities that take place independently of TNCs or via the operation of other actors as well as the TNCs. We refer particularly to trade, most of which, worldwide, originates with TNCs.[8] Trade – whether it originates with a TNC or not – may contribute to the development of innovation capabilities by increasing the degree of competition as well as by exposing firms to new products and processes.

Exports encourage/force firms to innovate by exposing them to stronger competition as well as to the requirements and innovation environment of diverse markets and customers. Keller (2004) in his survey of diffusion of international technology reports evidence of learning-by-exporting in case studies though less conclusive evidence from econometric studies.

Imports increase the firm's exposure to new products and possibly processes. New knowledge is often embedded in new machinery and products and their availability via importation facilitates learning in countries other than the one where they were produced. Moreover, the firm importing intermediate products may have to adjust its production processes to accommodate them. Thus, imports of innovative products[9] may contribute to innovation by: (a) increasing the absorption capacity of the firm; and (b) by forcing the firm to innovate in order to accommodate the new product within its production processes.[10]

These possible positive effects rely on (a) the assumption that the imported products are innovation-based or – at any rate – more innovation-based than the corresponding domestic products. They also rely on (b) the assumption that the importing country has the adequate absorbing capacity to receive innovation. If these assumptions do not correspond to the real conditions in the country, then we would expect no effect or a negative effect of imports on the innovation performance of a country.

Over and above the role of cross-country movements of capital (via the activities of TNCs), of goods and services (via imports and exports), the transmission of knowledge is also facilitated by the movement of personnel and human resources (Salt, 1991, 1997; OECD, 2002). Some movements of highly skilled people take place internally to companies operating across countries. Other exchanges of tacit knowledge take place via international collaboration between researchers whether the exchanges are institutionalized or not. Filippetti et al. (2010) in an analysis of 32 countries used data on the mobility of employees, the mobility of students in tertiary education and the mobility of research students across countries as a proxy for possible exchanges of tacit knowledge via the movement of human resources. However, we could not get the relevant data for the sample of countries in this study and therefore no variable on the international movement of human resources is used.[11]

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[7] A positive contribution to knowledge, innovation and capabilities in the host country is, of course, made by inward FDI in R&D on which see the evidence and analysis in European Commission (2013).

[8] UNCTAD (1999, 2002) estimate that two-thirds of world trade originates with TNCs. Moreover, estimates give at one-third the share of world trade which is intra-firm, i.e. trade that takes place between units of the same TNC located in different countries.

[9] Coe and Helpman (1995) find positive effects on productivity of imports weighted by R&D expenditure in the country where the imports originate from.

[10] Cohen and Levinthal (1989 and 1990) develop these arguments in relation to increased R&D capacity while Filippetti et al. (2011) extend them to increased capacity via the importation of innovative products.

[11] The variable on foreign research students as percentage of total research students did show strong association with innovation variables in Filippetti et al. (2011).

3. Internationalization and innovation in the context of countries' innovation environments

Though the main subject of our study is the impact of internationalization on innovation, we are aware that there are several other elements that affect the innovation performance of a country by their impact on the innovation environment. We single out, in particular, the following. The knowledge context which we proxy via a variable on the number of publications in scientific journals; the innovation infrastructure context which we proxy via a variable on the number of Internet users;[12] the sectoral structure context which we proxy via a variable on the ratio of value added in services over value added in manufacturing; and the overall country's commitment to innovation which we proxy via a variable on R&D expenditure.

The sectoral structure and the proxy used in this study need further clarification. Our study involves many countries at different stages of development and with different sectoral structures. In this context it is possible to see the service intensity of the countries representing a structural feature of development with implications for innovation. However, there may be several indicators for the sectoral structure. A possible one is related to the relative weight of employment in services and manufacturing. We discarded this type of indicator because it represented different economic structures and because it gives mixed signals in terms of innovation performance. This is because the service sector comprises very diverse activities characterized by different labour intensities: from domestic or hotels and restaurant services – which are labour intensive – to the less labour intensive activities of financial and software services. In terms of capturing the innovation context the latter are clearly more relevant. We felt that a variable focused on the value added of services versus manufacturing would better capture the innovation context we are interested in. In fact, a large services sector in terms of value added is a feature of the most highly developed countries, the ones most likely to have a record of large number of patents filed. Moreover, it can be argued that advanced services like software development and generally those connected with IT developments are needed for good innovation performance in both services and manufacturing (Alic 1994).

However, it can also be argued that a relatively large service sector is less likely to highlight innovation particularly because, due to data availability for all the selected countries, we are measuring innovation performance only via number of patents. Patents are often used in innovation studies though they are an inaccurate indicator of innovation as already pointed out. The traditional motive to patent is to protect innovations from imitations, but a much wider range of motives to patent is likely to play a role (e.g. patenting can be used within the firm as a measure of the performance of staff in R&D departments; it can also be use to assess the performance of collaborations agreement etc.). Moreover, a much wider range of strategies to protect innovation from imitations can be used such as lead-time advantages, complexity of design, secrecy (Nelson 1992; Cohen, Nelson, Walsh 2000; Bind et al. 2006). Both motives for patenting and strategies to protect innovation from imitation differ by industry/sector, partly because the propensity to patent is linked to the complexity of products and to the technological field and technological intensity in a sector.

Service firms are comparatively less likely to rate the importance of patenting high (Cohen et al. 2000). From a legal point of view, computer software, unless it brings about an improvement in the functioning of hardware cannot be patented outside the US (EPO, 2012). In the US around 15% of all patents are software patents, with the caveat that only 5% of

[12] Both variables are frequently used in studies that examine the innovation capabilities of countries (see Archibugi and Coco, 1994).

these patents are held by software developers (in the services sectors), while the remaining, larger share is held by manufacturing firms (Bessen and Hunt 2007).

4. Variables, data and methodology

This section consists of two parts. In the first subsection we shall discuss the variables we are going to use and the related data. The second sub-section is devoted to a discussion of the methodology. Before delving into the main body of this section we would like to discuss briefly the selected 42 countries.

Table 1 Countries included in the study

Argentina	Denmark	Ireland	Norway	Spain
Australia	Estonia	Israel	Poland	Sweden
Austria	Finland	Italy	Portugal	Switzerland
Belgium	France	Japan	Romania	Turkey
Brazil	Germany	Korea	Russian Federation	United Kingdom
Bulgaria	Greece	Lithuania	Singapore	United States
Canada	Hungary	Mexico	Slovakia	
China	Iceland	Netherlands	Slovenia	
Czech Republic	India	New Zealand	South Africa	

The main criterion that led to the inclusion into our sample has been availability of data. Nonetheless it should be noted that all continents and most regions within them are represented though the sample is not representative of the world either in terms of income per capita nor in terms of population. Over a third of the countries are from Europe. If Eastern Europe is included the percentage rises to over 50. The countries represent a large spectrum in terms of GDP per capita and this feature will be further exploited in the cluster analysis.

4.1. Variables and data

Three types of variables were collected for the 42 countries and for the period 1990 to 2008: (i) dependent variables, i.e. patent applications, as proxy for countries' innovation performance; (ii) internationalization variables, namely FDI stocks ; trade flows and the number of parent TNCs located in the country; and (iii) a set of control variables related to the following contexts. The knowledge context represented by the variable 'articles in scientific journals; the innovation infrastructure context represented by the variable 'Internet users'; a country's level of investment in innovation measured by 'R&D as a proportion of GDP'; and the structural context represented by the variable 'value added of services over value added in manufacturing'. Table 2 provides an overview of the variables, their unit of measurement and the data source. Descriptive statistics and correlations among the variables are provided in the Appendix A (Tables A1 and A2).

Table 2 Overview of the variables, their unit of measurement and original source

Variable	*Unit of measurement*	*Source*
Dependent variable: Innovation		
Triadic patents	Number of triadic patents per million people in t	Organisation for Economic Cooperation and Development: Main Science and Technology Indicators
PCT applications	Number of patents filed under the patent cooperation treaty per million people in t	World Intellectual Property Organization: Statistics on the PCT system

Independent variables: Internationalization		
FDI outward stock	FDI outward stock as a percentage of GDP* in t, t-1 and t-2	The World Bank's World Development Indicator
FDI inward stock	FDI inward stock as a percentage of GDP in t, t-1 and t-2	The World Bank's World Development Indicator
Exports	Exports as a percentage of GDP in t, t-1 and t-2	The World Bank's World Development Indicator
Imports	Imports as a percentage of GDP in t, t-1 and t-2	The World Bank's World Development Indicator
Control variables		
Scientific articles	Number of scientific articles per million people	The World Bank's World Development Indicator
Internet users	Number of Internet users per thousand people	The World Bank's World Development Indicator
R&D	R&D expenditure as a percentage of GDP in t, t-1 and t-2	The World Bank's World Development Indicator
Services intensity	Value added in services over value added in manufacturing in t	The World Bank's World Development Indicator

*GDP is measured at current prices and using current exchange rates.

4.1.1 Dependent variables

Patent statistics are among the most frequently used measures in innovation research because of their good availability and reliability of long time-series data, and their comparability across countries. This is the reason why our study relies on patent statistics as a proxy for innovation.

There are three main types of patent statistics: patents filed with individual countries' patent offices; international patent applications, also referred to as Patent Cooperation Treaty (PCT) applications; and triadic patent families. Both PCT applications and triadic patents tend to be preferred over the use of data on the first type - i.e. data on patents filed with different patent offices - for two main reasons. Firstly, data published by different patent offices are not necessarily comparable across countries and within countries over time, due to differences in legal and administrative practices as well as changes in government policies. For example, in China part of the recent patent surge can be explained through increasingly pro-patent policies (Hu and Jefferson, 2009). Secondly, because of a home bias in the filing of domestic applications; in other words, more patents are filed by residents of a country compared with non-residents (e.g. OECD, 2009). For these reasons we shall here use data from triadic patents and from PCT.

PCT applications are patent applications filed with a patent office under the Patent Cooperation Treaty. A PCT application provides the option to file the same patent with the national offices of the member states at a later stage (i.e. within 30 months).[13] Triadic patent families are patents filed by the same inventor for the same invention at the European, Japanese and US Patent Office. To be recorded as a triadic patent the invention to which it refers has to be the subject of a patent application at the European Patent Office (EPO) and the Japan Patent Office (JPO), and the subject of a patent granted at the United States Patent Office (USPTO). In our dataset, the reference country for both triadic patents and PCT applications is the inventor's country of residence. There are on average 1,000 triadic patents and just over 2,000 PCT applications recorded in the 42 countries in our sample over the period 1990 to 2008.

[13] The filing can be done with a national office or the WIPO, and can be done immediately or within a 12-months priority period from an initial filing of a domestic patent. PCT applications undergo an international search, while domestic patents undergo a national search only.

Triadic patents and PCT applications have different strengths and weaknesses related (a) to quality/relevance; and (b) to the time that elapses between filing and the recording of the patent statistic. Referring to point (a), the value distribution of patents tends to be very skewed, with a few patents that have a high economic value, and a tail of many patents that are never used. The degree of skewness tends to be higher for PCT applications compared to triadic patents. This is because, compared with the parallel application of triadic patents, the initial costs of filing PCT applications are low. Triadic patents, with the higher costs incurred due to the parallel applications to three patent offices, tend to capture higher value inventions aimed at international markets (OECD, 2009). Referring to point (b), PCT applications record information on the invention nearer the actual time of invention, compared with triadic patents. Specifically, and as it is the case for our data, the PCT statistics are recorded with reference to the first filing with the first receiving office.[14] The first filings of a patent application are published 18 months after filing. Thus, the time lag between invention and our PCT data is 18 months. Triadic patents, on the other hand, have, on average, a 35-months and a maximum of 44 months, time-lag caused by the time that elapses between filing and the United States Patent and Trademark Office US Patent Office granting the patent (OECD, 2009). Because the strength and weaknesses of triadic patents and PCT applications are quite different, we report results on both types of data.

The empirical literature tends to normalize country level patent data by either using population or GDP values. For example, Castellacci (2011) uses US patents per million people and Schneider (2005) uses US patent applications per residents. We use triadic patents and PCT applications per million people.

4.1.2 Independent variables

We use FDI stocks and trade flows to capture countries' internationalization. We also use a variable related to number of parent TNCs in a country. The reason for the inclusion of the latter variables is the following. We are aware that the outward FDI variable already represents direct business activities of TNCs from their home country. However, for any given country home to TNCs the distribution of FDI in terms of origin from the investing TNC may be different from the distribution of patent filing by the same set of TNCs. In other words with this additional variable we aim to capture the possibility that not all companies that substantially contribute to filing patent, substantially contribute to outward FDI; i.e. patent filing and outward FDI may have different distributions among the set of TNCs from any particular country. Take the example of country X (for example, the UK) with a large (financial) services sector relative to its manufacturing sector. Most financial service companies are large, tend to operate transnationally and invest heavily abroad. However, compared to manufacturing companies, the financial services ones contribute relatively little to patenting. So, we could have a situation of large outward FDI from a relatively small number of large TNCs who contribute little to patenting.[15]

FDI and trade are broadly available in a comparable form across countries and over time. In the case of outward and inward FDI, we use stock data which are less volatile from year to year compared with flow data. The trade variables are annual flows. We normalize these internationalization variables by GDP (see Appendix A.1 for average values). The number of TNCs in a country, taken from United Nations' World Investment Reports is normalized by the number of companies in a country. The reference years are 1990 to 2006.

[14] The PCT procedure to file a patent is divided into two phases: The first phase is filing at a national level (in other words, the filing with the receiving office), while phase two refers to filing at the international level (with a second or more patent offices). Stage two might or might not take place. Once a PCT application is filed, applicants have up to thirty months to file patents with additional patent offices.

[15] This work is in progress and the results are not presented here.

The data series used compared with the data series on patent statistics are different because of time lags introduced to the regression analyses.

4.1.3 Control variables

We employ the following set of control variables in the regressions. (i) The number of scientific articles per million people as a proxy for the knowledge context; (ii) the number of Internet users per thousand people as a proxy for the technological infrastructure context; and (iii) the share of value added in services over the share of value added in manufacturing as a proxy for the sectoral structure context. In addition, in some models we also used the variable R&D as a proportion of GDP as a proxy for the country's commitment to innovation. The estimations with R&D as a control variable are based on fewer observations because of (a) missing values and (b) colinearity issues.[16]

4.2 Methodology

We examine the impact of countries' internationalization on innovation using two linear models, one based on pooled data estimating the classic linear model (OLS), and one on panel data, estimating a fixed effects (FE) linear model. We chose to report on both estimation techniques for the following reasons. On the one hand, the FE model requires the explanatory variables to vary within countries over time, and low variability in our independent variables within a country can be seen as a problem. On the other hand, the FE model controls for unobserved heterogeneity across countries, while the OLS model does not. This can cause a bias in the OLS estimator (e.g. Greene, 2003; Kennedy, 2003).[17] The models can be described as follows:

$$Y_{i,t+k} = ß_0 + ß_1 W_{i,t} + ß_2 X_{i,t} + a_t + \varepsilon_{i,t} \quad (1)$$

$$Y_{i,t+k} = ß_0 + ß_1 W_{i,t} + ß_2 X_{i,t} + f_i + a_t + \varepsilon_{i,t} \quad (2)$$

$Y_{i,t+k}$ is the number of PCT applications or triadic patents filed by country i in year t. The values of our dependent variables lead by k years with k taking values of 2, 3, 4, and 5 in the case of PCT applications and 3, 4, 5 and 6 in the case of triadic patents. For example, if k=2 then the dependent variable might be measured in 2008 and this is associated with values of our independent and control variables in 2006. The forward leads in the dependent variables are introduced for two reasons. Firstly, PCT applications are recorded 18 months after the invention is filed and triadic patents are recorded on average 35 months after the invention is filed. Thus, to match invention and the degree of internationalization at approximately that same point in time, we use the two year lead in the PCT applications and the three year lead in the triadic patents. Secondly, we have mentioned in Section 2 the possible effect of innovation on internationalization: firms that are highly innovative are better equipped to internationalise compared with firms that are less innovative. This two-way causality renders our models open to endogeneity problems. To address this we extend the lead in the values of our dependent variables of up to five years in the case of PCT applications and six years in the case of triadic patents.

In the models (1) and (2) above, $W_{i,t}$ is a vector that combines our independent variables related to internationalization. It includes countries' FDI outward stocks, inward stocks, exports and imports. We estimate a further additional model, where FDI outward

[16] The corresponding results can be made available upon request from the authors.

[17] Schneider (2005) in her analysis based on panel data of countries' innovation and internationalization performance reports on pooled OLS and FE models, while Chang et al. (2010) report on the FE and random effect models.

stocks are replaced with the number of TNCs relative to the total number of companies in a country.

$X_{i,t}$ is a vector of exogenous independent variables that are linked with increased patenting activities in a country. These include: the share of value added within the services sectors in each country; the number of scientific articles published in a country and the number of Internet users as an indicator of the general IT infrastructure in the country. In some regression models we also use the R&D expenditures relative to GDP as an independent variable. The results of the latter are reported in Appendix B.

In equation (2) f_i are country specific fixed effects that account for any unobserved and time invariant country factors. In equations (1) and (2) a_t are year dummies included to account for any shocks and $\varepsilon_{i,t}$ the error terms.

We further grouped the countries into comparatively higher and lower income countries and repeated the full set of regressions. We did this to further investigate if the relationship between countries' internationalization variables and patenting differs across these two groups of countries. The grouping is informed by the data itself. We performed a two-step cluster analysis of our data, using GDP per capita as the clustering variable. The groups of countries are reported in Table 3 below, while the regression results are reported in Appendix B.

Table 3 Grouping of countries by GDP per capita for the years 1990 to 2007

Countries with a comparatively lower GDP/capita between 1990 and 2007		*Countries with a comparatively higher GDP/capita between 1990 and 2007*	
Argentina	Mexico	Australia	Italy
Brazil	Poland	Austria	Japan
Bulgaria	Portugal	Belgium	Netherlands
China	Romania	Canada	Norway
Czech Republic	Russian Federation	Denmark	Singapore
Estonia	Slovak Republic	Finland	Sweden
Greece	Slovenia	France	Switzerland
Hungary	South Africa	Germany	United Kingdom
India	Spain	Iceland	United States
Korea, Rep.	Turkey	Ireland	
Lithuania		Israel	

5. Results

Four sets of regression results are presented in Tables 4 and 5 and discussed in this section: (i) results of the pooled OLS regressions are presented in Table 4; (ii) results of the FE model are presented in Table 5. The two estimation models should be considered together as a means of sensitivity analyses. On average, and for the reasons discussed in Section 4 above, we might lean towards considering the FE model the more robust estimation. In interpreting the results it is worth keeping in mind the following. Our study relates to the country as a whole, not to specific industries or case studies of firms. Due to data limitations we represent innovation by number of patents filed. This is a departure from our previous study (Filippetti et al. 2011) where several variables are used to represent innovation performance. This work uses composite indices, based on the European Innovation Scoreboard: a range of measures feed into the indices including the share of product and process innovators in a country and the average turnover from innovation generated by the firms within a country. Such data, however, is only available for a few points in time.

Table 4 The impact on countries' innovation activity of internationalization using OLS on pooled data

Variables	*PCT applications*				*Triadic patents*			
	2 years lead	3 years lead	3 years lead	3 years lead	3 years lead	4 years lead	5 years lead	6 years lead
Outward FDI	80.74***	61.45***	61.45***	61.45***	61.45***	63.49***	66.69***	69.96***
	(11.15)	(6.25)	(6.25)	(6.25)	(6.25)	(6.91)	(7.95)	(9.37)
Inward FDI	-84.42***	-48.80***	-48.80***	-48.80***	-48.80***	-50.45***	-53.43***	-58.10***
	(9.96)	(6.07)	(6.07)	(6.07)	(6.07)	(6.44)	(7.09)	(8.05)
Exports	109.52***	8.38	8.38	8.38	8.38	9.67	10.83	9.80
	(17.86)	(10.03)	(10.03)	(10.03)	(10.03)	(10.98)	(12.26)	(13.50)
Imports	-136.94***	-11.90	-11.90	-11.90	-11.90	-13.65	-14.99	-13.94
	(20.00)	(13.50)	(13.50)	(13.50)	(13.50)	(14.76)	(16.24)	(17.99)
Scientific articles	0.13***	0.06***	0.06***	0.06***	0.06***	0.06***	0.06***	0.06***
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
Internet users	0.13***	-0.00	-0.00	-0.00	-0.00	-0.01	-0.01	-0.01
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Services intensity	-8.49***	-4.99***	-4.99***	-4.99***	-4.99***	-5.17***	-5.16***	-5.41***
	(2.30)	(1.25)	(1.25)	(1.25)	(1.25)	(1.33)	(1.44)	(1.60)
Year dummies	Included	Included	Included	Included	Included	Included	Included	Included
Constant	-3.39	8.39**	8.39**	8.39**	8.39**	10.37**	11.49**	13.97***
	(5.56)	(3.98)	(3.98)	(3.98)	(3.98)	(4.28)	(4.65)	(5.29)
Observations	593	554	554	554	554	514	473	432
R-squared	0.827	0.625	0.625	0.625	0.625	0.620	0.613	0.609
F-statistic	89.72***	91.66***	93.53***	97.41***	65.32***	65.85***	65.62***	68.15***

Robust standard errors are reported in parentheses. Observations are based on yearly data from 1990 to 2008.
*** p<0.01, ** p<0.05, * p<0.1

Table 5 The impact on countries' innovation activity of internationalization estimating FE model on panel data

Variables	*PCT applications*				*Triadic patents*			
	2 years lead	3 years lead	4 years lead	5 years lead	3 years lead	4 years lead	5 years lead	6 years lead
Outward FDI	69.89*	68.96*	63.24*	52.59	-10.86	-7.94	-7.78	-6.43
	(35.57)	(35.44)	(36.25)	(36.89)	(10.22)	(10.28)	(9.57)	(8.74)
Inward FDI	-48.54**	-43.54**	-33.90*	-20.65	-0.85	-0.02	1.03	-0.86
	(21.30)	(19.79)	(19.58)	(18.17)	(4.86)	(4.59)	(4.50)	(5.60)
Exports	85.05***	76.94**	57.27*	44.19	15.94**	10.82	11.52	10.00
	(30.72)	(31.07)	(29.96)	(32.54)	(7.65)	(8.78)	(12.83)	(15.66)
Imports	-63.27***	-69.90***	-70.25***	-81.05***	-19.79**	-13.02	-16.44	-13.29
	(22.81)	(23.37)	(24.09)	(24.05)	(8.05)	(8.87)	(11.78)	(12.52)
Scientific articles	0.08**	0.11***	0.11***	0.11***	0.01	0.01	-0.00	0.00
	(0.04)	(0.04)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)
Internet users	0.14***	0.12***	0.11***	0.10***	0.02*	0.01	0.01	0.01
	(0.02)	(0.02)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)
Services intensity	3.14	4.73	2.14	0.77	1.76	1.49	1.35	1.36
	(8.31)	(8.22)	(8.47)	(8.65)	(2.19)	(2.11)	(2.32)	(2.07)
Year dummies	Included	Included	Included	Included	Included	Included	Included	Included
Constant	-23.67	-27.86	-14.40	-1.98	9.83*	14.30***	18.54***	19.84***
	(22.06)	(22.34)	(23.15)	(23.59)	(5.15)	(5.00)	(5.61)	(5.37)
Observations	593	554	514	473	554	514	473	432
R-squared	0.756	0.741	0.709	0.672	0.290	0.189	0.134	0.083
Number of id	41	41	41	41	41	41	41	40
F-statistic	26.46***	24.35***	26.68***	23.35***	5.34***	7.04***	6.56***	3.42***

Robust standard errors are reported in parentheses. Observations are based on yearly data from 1990 to 2008.
*** p<0.01, ** p<0.05, * p<0.1

From Tables 4 and 5 we take the following observations. Firstly, we find positive correlations between outward measures of internationalization (FDI and exports) and innovation performance of countries, while we find negative correlations between inward FDI stock, imports and PCT applications. The positive correlations of patent applications with outwards FDI stocks and exports are in line with our expectations discussed in Section 2. The negative correlations with inward FDI stocks and imports can be explained with the discussion we presented in Section 2 that relates to (a) the degree of innovation intensity of products and investments that a country attracts; and (b) a country's absorption capacity.

A country that is involved in innovation-based outward investment and exports is likely to be an advanced, innovative country that might import and attract inward investment of a less innovative nature compared to what it exports and the investment it attracts. Our sample includes also countries at lower levels of development. They may be the ones with low absorption capacity, and, thus, may be the ones that find it difficult to learn from inward FDI and from imported products. We run the same regressions for two clusters to which countries were allocated on the basis of their GDP per capita. The results (presented in Appendix B) on the whole are not very impressive nor are they exclusively pointing towards explanation (a) or (b) above. On the one hand, the OLS results for the high GDP per capita cluster (Table B.3) show very similar results for inward FDI and imports to those we had when all the countries were considered together (in Table 4), both in terms of the size of the coefficients and their significance. This is, in our view, an indication that explanation (a) drives the results: i.e. the countries most innovative are those involved in outward FDI and exports flows and they are also the ones more likely to import products and attract investment of the less innovative type. On the other hand, the results of the FE models suggest that it is the low income countries that exhibit negative associations between inward FDI, imports and innovation, pointing towards explanation (b) above, i.e. the role of countries' ability to assimilate and benefit from the inflow of potentially more innovative, compared with local, products and investments.

As discussed in Section 2, we are well aware that the relationship innovation-internationalization is one of cumulative two-way causation. We addressed endogeneity in our models by lagging the independent variables. However, there may still be structural elements in the relationship leading to our results for inward FDI and for imports and to the possible effects just discussed.

Secondly, and in particular with reference to Table 4, we observe that the coefficients increase in size the greater the lead in the dependent variables, supporting our claim that we pick up on the link from internationalization to innovation.

Thirdly, we find that the number of scientific articles and Internet users are positively correlated with PCT applications. Service intensity – measured as value added in services over value added in manufacturing – is negatively associated with patent applications. There are two alternative possible explanations as highlighted in Section 3: manufacturing firms are more likely to patent compared with services; and service economies tend to be more advanced, and firms located in more advanced countries are more likely to patent. The results, on average, appear to point towards the first explanation.

We observe a very similar pattern for both PCT applications and triadic patents: positive correlations for outward FDI and exports, and negative correlations for inward FDI and imports. Finding the same pattern is within expectations; both dependent variables are used to proxy countries' innovation performance. The advantage of triadic patents is that they lean towards recording higher value patents compared with PCT applications, but they are recorded with a much greater delay that can take up to 44 months. For the triadic patents we find that the two FDI variables remain significant, but the trade variables do not.

One possible explanation for this is the fact that triadic patents data relate to the most innovative patenting activities with high value attached to them. Thus the companies and countries involved in them do so independently of any learning and relationship with the trade pattern of the country. In other words, the patenting activities is a sign of strong innovation drive that takes place independently of possible learning from exportation activities. The outward FDI pattern is still very relevant and shows the same sign as in the PCT applications (Table 4).

Our results are mirrored by those in other studies. Chang et al (2011) use annual FDI flows as a percentage of GDP – inward and outward – as well as exports, but not imports for 37 countries for the years 1994 to 2005. They find that outward FDI and exports are positively associated with triadic patents, and that inward FDI is negatively correlated. Schneider (2005) uses per capita flow data for 47 countries on imports and FDI and averages the data over four five-year periods. She finds that high-tech imports from developed countries positively correlate with US patents, and finds a negative coefficient close to zero and not significant with FDI inflows.

We observe a broadly similar pattern in Table 4 using OLS on pooled data and Table 5 using FE on panel data. In the OLS model we are examining differences in internationalization and innovation across countries and in the FE models we are examining differences within countries over time. While we see a broadly similar picture, positive correlations for outward FDI and exports and negative correlations for inward FDI and imports, the significance levels tend to be lower and the coefficients smaller in the FE models, specifically around trade and within trade in exports. Further, we do not observe the same strong increase in the coefficients size with greater leads in the dependent variable, although the coefficients remain largely significant. The coefficients of the control variables are similar, with the exception of the industry mix, which has positive coefficients in the FE model, albeit non-significant. The non-significant pattern could arise when there is little variation over time in the industry mix for most of the countries.

We computed the same regressions, but with an additional control variable: R&D over GDP. In the relevant regressions the number of observations is much smaller ranging between 204 and 354 observations based on between 5 to 9 years. This is compared to between 432 to 593 observations reported in Tables 4 and 5. We find, in the case of PCT applications the same pattern and significant associations as reported in Table 4. For triadic patents, we find positive and significant correlations in the case of outward FDI stocks which are in line with Table 5, different to Table 4 the negative coefficient for inward FDI stocks is now not significant. One interesting pattern emerges from this exercise: when we control for R&D, the control variable service intensity becomes positively and significantly related to patenting. This seems to indicate that those advanced countries – the ones with high services to manufacturing ratios – that have a high commitment to innovation – expressed by the expenditure on R&D – will have also a high innovation performance.

6. Discussion, limitations and plan for further work

The main purpose of the paper is to test whether internationalization has a positive impact on the innovation performance of countries. Innovation performance is proxied by two sets of data on patents: triadic patents and PCT applications. The independent variables related to internationalization include: outward and inward direct investment; exports and imports. The control variables include a variety of country-context elements and specifically: number of papers in scientific journals as proxy for the country's knowledge context; number of Internet users as proxy for the country's technological infrastructure context; the ratio of value added in services and manufacturing as proxy for the industrial structure; and – in some estimates – expenditure on R&D as proxy for the country's commitment to innovation. The estimates are carried out for 42 countries all together and for two separate country groups selected on the basis of countries' GDP per capita.

The paper finds support for a positive impact of internationalization on countries' innovation performance, specifically with respect to outward looking international linkages. In Section 2 we discussed the possible ambiguous relationship between inward flows of investment and products (via FDI and imports respectively) on innovation. One possible scenario we expected was that these inward flows would only impact positively on innovation, provided the following conditions are satisfied: (a) that the type of investment or imports is innovation intensive compared to the domestic activities; and/or (b) that the receiving country – whose innovation performance via patenting activities is being explained – has enough capabilities and absorption capacity to benefit from innovation-intensive inward FDI and/or imports. Were these conditions not to be satisfied, one would expect no impact or a negative impact from these inward flows on innovation.

Our hypotheses are confirmed. Outward FDI and exports are found to strongly impact on patenting activity. For inward FDI and imports the results are negative. We interpret this to mean that one (or both) of the two conditions above is not satisfied. This may be taken to mean: either that (a) the inward inflow of investment or products is less innovation-intensive than the country's domestic activities which would be the case for more advanced and innovation active-countries; or (b) that the country does not have a sufficient absorption capacity to benefit from inflows.

The results based on low and high income country groups on the whole are not very significant. They point towards a combined role of explanation (a) and (b) above driving our overall results. The cluster for the high GDP per capita countries shows – in the pooled OLS regressions – the same strong negative relationship between inward flows (of FDI and imports) and patenting as we saw when all countries were analysed together, pointing towards explanation (a). The cluster for the low GDP per capita countries shows – in the FE regressions – negative relationships between inwards flows and patenting, pointing towards explanation (b). With regards to the signs on the FDI variables – positive for outward and negative for inward – there may be an additional reason for them. Our dependent variable is patents, and TNCs are more likely to file patents in the home country, and indeed to carry out the research – leading to patenting – in the home country where research laboratories tend to be located (Patel and Pavitt 1991).

There are limitations in a study of this sort. First, there are limitations on the side of the dependent variables. They derive from the measuring of innovation performance via patenting activity as has been pointed out throughout the paper. Our proxy for innovation performance – number of patent applications – while readily available, only partially captures innovation performance (see our discussion in Section 2). Further work is needed that expands on the range of innovation performance variables as well as on countries and time periods. Second, there are also limitations deriving from the independent variables specifically from their internationalization component. Data availability has constrained our analysis to a consideration of inflows and outflows of investment and products. Other major elements of internationalization such as the movements of human resources could not be used for lack of data. Yet these components are bound to be very important.[18] Third, there are

[18] In a study, that uses a much shorter time period, fewer countries as well as a different methodology, it was found that human resources variables are strongly correlated with countries' innovation performance (Filippetti et al. 2011).

limitations also on the side of the control variables. The expenditure on R&D variable is only available for all the countries in our sample for a limited number of years.

The work presented here is ‘in-progress’ as we are still developing and refining it. Specifically we are currently working in the following direction. We are going to use the variable number of TNCs in a country as a ratio of total number of companies as a substitute for outward FDI for the reasons explained in Section 4.1.2.

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Appendix A Descriptive and correlation statistics

Table A.1 Descriptive statistics of the variables

Variables	Observations	Mean	SD	Min	Max
PCT applications	756	54.21	72.59	0.00	347.36
Triadic patents	756	21.10	28.69	0.00	120.00
FDI outward stock	768	0.20	0.26	0.00	1.58
FDI inward stock	770	0.27	0.29	0.00	1.90
Exports	743	0.38	0.26	0.07	2.43
Imports	737	0.31	0.23	0.03	1.67
Scientific articles	698	397.71	320.59	1.33	1181.11
Internet users	732	205.37	244.14	0.00	887.71
R&D intensity	485	1.55	0.97	0.31	4.86
Services intensity	730	2.09	0.62	0.53	3.83

Table A.2 Correlations among the variables

Variables		1	2	3	4	5	6	7	8	9
1	PCT applications	1.00								
2	Triadic patents	0.81	1.00							
3	FDI outward stock	0.62	0.52	1.00						
4	FDI inward stock	0.22	0.05	0.70	1.00					
5	Exports	0.15	0.03	0.45	0.74	1.00				
6	Imports	0.01	-0.06	0.35	0.70	0.94	1.00			
7	Scientific articles	0.81	0.73	0.60	0.22	0.17	0.04	1.00		
8	Internet users	0.67	0.40	0.61	0.46	0.29	0.18	0.48	1.00	
9	R&D intensity	0.87	0.83	0.41	0.04	0.05	-0.04	0.80	0.52	1.00
10	Services intensity	0.39	0.35	0.42	0.17	-0.07	-0.06	0.49	0.36	0.29

Appendix B Additional regressions for two clusters of countries grouped by GDP per capita

Table B.1 The impact on countries' innovation activity of internationalization using OLS on pooled data. Regressions for lower income countries.

Variables	*PCT patents*				*Triadic patents*			
	2 years lead	3 years lead	4 years lead	5 years lead	3 years lead	4 years lead	5 years lead	6 years lead
Outward FDI	14.83	17.32	18.62	22.67	0.32	0.84	2.15	-3.01
	(13.05)	(13.96)	(15.16)	(16.08)	(5.00)	(5.49)	(6.00)	(6.07)
Inward FDI	-37.98***	-39.02***	-37.37***	-37.16***	-17.17***	-16.58***	-16.66***	-17.16***
	(8.93)	(9.55)	(10.03)	(11.59)	(3.85)	(4.30)	(5.22)	(6.45)
Exports	-5.42	-5.05	-4.06	3.43	-0.84	0.59	3.68	7.82
	(12.24)	(14.15)	(16.15)	(16.90)	(5.78)	(6.55)	(7.37)	(7.85)
Imports	-2.35	-3.17	-5.72	-13.34	-3.93	-5.59	-8.29	-12.55
	(13.29)	(15.23)	(17.14)	(18.53)	(6.06)	(6.93)	(7.98)	(8.74)
Scientific articles	0.04***	0.04***	0.04***	0.04***	0.00	0.00	0.00	-0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Internet users	0.12***	0.14***	0.17***	0.20***	0.06***	0.07***	0.08***	0.10***
	(0.02)	(0.02)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)
Services intensity	-4.83***	-5.11***	-5.52***	-5.73***	-1.68***	-1.85***	-1.94***	-1.93***
	(0.84)	(0.85)	(0.96)	(1.06)	(0.34)	(0.39)	(0.43)	(0.50)
Year dummies	Included	Included	Included	Included	Included	Included	Included	Included
Constant	8.88***	9.51***	10.17***	10.72***	4.97***	5.19***	5.42***	5.68***
	(2.43)	(2.35)	(2.57)	(2.73)	(0.96)	(1.06)	(1.16)	(1.26)
Observations	299	278	258	237	278	258	237	216
R-squared	0.702	0.714	0.710	0.691	0.641	0.610	0.562	0.520
F-statistic	14.21***	14.10***	16.13***	13.27***	4.18***	4.24***	4.03***	3.55***

Robust standard errors are reported in parentheses. Observations are based on yearly data from 1990 to 2008.
*** p<0.01, ** p<0.05, * p<0.1

Table B.2 The impact on countries' innovation activity of internationalization estimating FE model on panel data. Regressions for lower income countries.

Variables	*PCT applications*				*Triadic patents*			
	2 years lead	3 years lead	4 years lead	5 years lead	3 years lead	4 years lead	5 years lead	6 years lead
Outward FDI	-19.86	-16.15	-17.37	-10.62	-10.74	-8.79	-4.94	-12.97
	(32.07)	(29.93)	(32.86)	(31.75)	(11.73)	(12.48)	(11.36)	(11.15)
Inward FDI	-39.75**	-41.76*	-35.74*	-32.39	-18.05**	-15.61*	-15.29*	-13.92*
	(17.90)	(20.14)	(20.12)	(19.30)	(8.46)	(8.17)	(8.22)	(7.65)
Exports	37.55*	36.09	29.27	35.63	13.82*	15.19	19.76	23.20
	(20.09)	(22.25)	(23.03)	(26.42)	(7.82)	(10.40)	(14.31)	(16.07)
Imports	-25.47	-27.26*	-32.14*	-43.53*	-12.57*	-14.34	-17.00	-18.71
	(16.32)	(15.34)	(17.07)	(25.12)	(6.26)	(8.81)	(12.98)	(14.83)
Scientific articles	0.04	0.04	0.03	0.03	0.00	0.00	-0.00	-0.00
	(0.03)	(0.03)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Internet users	0.11**	0.13**	0.14**	0.16***	0.05**	0.05**	0.05**	0.06***
	(0.04)	(0.05)	(0.05)	(0.05)	(0.02)	(0.02)	(0.02)	(0.01)
Services intensity	0.54	0.01	-1.66	-2.62	-0.19	-0.56	-0.80	-1.02
	(2.37)	(2.66)	(3.21)	(3.63)	(0.90)	(0.99)	(1.07)	(1.32)
Year dummies	Included	Included	Included	Included	Included	Included	Included	Included
Constant	-5.23	-2.91	2.28	5.54	0.91	1.23	1.37	1.19
	(5.56)	(6.38)	(7.08)	(7.01)	(2.10)	(2.10)	(2.27)	(2.47)
Observations	299	278	258	237	278	258	237	216
R-squared	0.686	0.714	0.722	0.721	0.660	0.638	0.608	0.580
Number of id	21	21	21	21	21	21	21	21
F-statistic			54.58***	189.07***		124.34***	29.42***	123.64***

Robust standard errors are reported in parentheses. Observations are based on yearly data from 1990 to 2008.
*** p<0.01, ** p<0.05, * p<0.1

Table B.3 The impact on countries' innovation activity of internationalization using OLS on pooled data. Regressions for higher income countries.

Variables	*PCT patents*				*Triadic patents*			
	2 years lead	3 years lead	4 years lead	5 years lead	3 years lead	4 years lead	5 years lead	6 years lead
Outward FDI	80.36***	97.50***	104.75***	107.86***	99.60***	102.88***	108.27***	115.67***
	(19.18)	(20.94)	(23.84)	(26.01)	(12.78)	(14.43)	(16.50)	(18.84)
Inward FDI	-114.91***	-127.10***	-143.47***	-158.93***	-68.42***	-70.15***	-72.18***	-78.85***
	(17.74)	(18.13)	(20.16)	(21.99)	(10.54)	(11.28)	(12.43)	(14.56)
Exports	262.03***	292.32***	322.51***	348.35***	4.58	4.57	-3.05	-9.11
	(44.48)	(46.94)	(54.35)	(60.46)	(26.81)	(31.27)	(34.62)	(38.59)
Imports	-329.03***	-364.22***	-389.75***	-400.18***	-21.63	-24.74	-18.42	-13.10
	(59.53)	(63.40)	(71.01)	(78.43)	(36.96)	(43.59)	(48.75)	(58.88)
Scientific articles	0.15***	0.15***	0.16***	0.16***	0.03***	0.03***	0.03**	0.03**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Internet users	0.11***	0.10***	0.08*	0.09	-0.03*	-0.05**	-0.04*	-0.03
	(0.03)	(0.04)	(0.05)	(0.06)	(0.02)	(0.02)	(0.03)	(0.03)
Services intensity	-4.24	-4.66	-7.42	-8.18	-15.94***	-17.31***	-18.50***	-20.52***
	(6.31)	(6.54)	(7.05)	(7.56)	(3.86)	(4.14)	(4.52)	(4.95)
Year dummies	Included	Included	Included	Included	Included	Included	Included	Included
Constant	-29.29*	-25.56	-14.95	-8.76	49.59***	56.64***	62.98***	72.51***
	(17.02)	(17.53)	(19.27)	(19.87)	(11.34)	(12.17)	(13.39)	(15.05)
Observations	280	262	243	224	262	243	224	205
R-squared	0.722	0.704	0.681	0.659	0.389	0.387	0.379	0.381
F-statistic	33.42***	32.97***	30.25***	27.84***	12.30***	11.18***	9.52***	8.22***

Robust standard errors are reported in parentheses. Observations are based on yearly data from 1990 to 2008.
*** p<0.01, ** p<0.05, * p<0.1

Table B.4 The impact on countries' innovation activity of internationalization estimating FE model on panel data. Regressions for higher income countries.

Variables	*PCT applications*				*Triadic patents*			
	2 years lead	3 years lead	4 years lead	5 years lead	2 years lead	3 years lead	4 years lead	5 years lead
Outward FDI	23.26	29.85	33.95	28.28	-10.32	-5.00	-3.26	-3.45
	(55.19)	(60.43)	(63.48)	(63.84)	(12.08)	(11.87)	(12.40)	(12.88)
Inward FDI	-11.95	-9.21	-7.70	3.75	8.25	6.94	6.47	6.75
	(29.85)	(32.26)	(33.64)	(30.35)	(8.95)	(9.18)	(8.87)	(10.68)
Exports	46.94	33.77	-3.90	-35.78	7.36	-2.22	-2.65	-14.87
	(75.55)	(71.57)	(74.76)	(88.10)	(16.26)	(16.30)	(22.54)	(32.03)
Imports	32.00	39.96	57.79	11.66	8.55	23.07	-1.41	2.29
	(67.11)	(80.10)	(95.37)	(95.43)	(29.82)	(35.46)	(38.90)	(39.81)
Scientific articles	0.11	0.13**	0.11**	0.10**	-0.01	-0.02	-0.02	-0.01
	(0.07)	(0.06)	(0.05)	(0.04)	(0.01)	(0.02)	(0.02)	(0.02)
Internet users	0.11**	0.08*	0.04	0.01	-0.00	-0.01	-0.02	-0.02*
	(0.04)	(0.04)	(0.05)	(0.05)	(0.01)	(0.01)	(0.01)	(0.01)
Services intensity	14.25	19.68	15.28	13.52	4.93	3.81	3.32	2.35
	(21.50)	(19.76)	(20.28)	(22.70)	(5.41)	(5.43)	(5.86)	(6.09)
Year dummies	Included	Included	Included	Included	Included	Included	Included	Included
Constant	-75.15	-86.06	-52.34	-14.19	24.09*	34.00**	47.54***	51.27***
	(60.96)	(51.06)	(54.72)	(64.07)	(11.89)	(12.79)	(16.35)	(15.95)
Observations	280	262	243	224	262	243	224	205
R-squared	0.813	0.802	0.777	0.748	0.353	0.259	0.202	0.130
Number of id	19	19	19	19	19	19	19	18
F-statistic								

Robust standard errors are reported in parentheses. Observations are based on yearly data from 1990 to 2008.
*** p<0.01, ** p<0.05, * p<0.1