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Inventing Together: Exploring the Nature of International Knowledge Spillovers in Latin America

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Abstract

This paper studies the nature, sources and determinants of international patenting activity in Latin American countries (LACs) and examines the extent to which LACs benefit from R&D that is performed in the G-5 countries (France, Germany, Japan, the United Kingdom, and the United States). By using patents and patent citations from the United States Patent and Trademark Office we trace intra-sectoral knowledge flows from G-5 countries to LACs. We study the impact of three channels of knowledge flows: foreign R&D, patent citation-related spillovers and face-to-face contact spillovers. Our results, based on data for Argentina, Brazil, Chile, Colombia and Mexico, suggest that international knowledge spillovers from the G-5 countries are a significant determinant of inventive activity during the period 1988-2003. We find that the stock of ideas produced in the USA has a strong impact on the international patenting activity of these countries. Moreover, controlling for US-driven R&D effects, bilateral patent citations and face-to-face relationships between inventors are both important additional mechanisms of knowledge transmission. Some of our results suggest that the latter mechanism is more important than the former.

1. Introduction

International flows of technological knowledge have an important effect on the ability of developing countries to learn and innovate. Knowledge transmission from developed countries creates conditions for developing countries to catch up with the technological frontier, but, on the contrary, technological isolation slows down the development process and is conducive to technological and economic divergence. This paper studies the importance of patents and interpersonal links for technology diffusion across countries and asks to what extent international technology spillovers are mainly driven not only by the free flow of knowledge but also by interpersonal links and face-to-face contacts across countries.

This has important policy implications. If international interpersonal links and person-to-person contacts play a prominent role in fostering innovative domestic capacity, R&D subsidies could be effective only as long as they favour the international expansion of the network relations of local inventors. This has relevant consequences for the effectiveness of science and technology policies.

This paper is one of the first attempts to extend the economic analysis of R&D knowledge spillovers (at country and industry level) to developing countries and investigates empirically the determinants of international patent production in a selected number of Latin American countries (LACs). We ask whether foreign R&D activity affects the innovative performance of LACs at industry level via different channels of international knowledge flows. In particular, we focus on three mechanisms: foreign R&D, patent citation-related spillovers, and face-to-face contact spillovers based on co-inventorship relations. Of course, there are also other important channels of technological transmission that we do not deal with in this study, such as FDIs and bilateral trade. However, these channels affect, in particular, countries' total factor productivity.[1]

We are interested in studying whether the *international patenting activity* of LACs responds to international knowledge flows and we measure knowledge flows using patent citations and analysing the network of co-inventors from the patent documents. Assuming that inventors listed on the same patent know each other, if knowledge has at least a degree of tacitness we expect a positive effect on the innovative activity of personal contacts. This in turn implies that the international mobility of inventors may play a crucial role in domestic innovative performance.

We use data for five big industrial sectors (Textiles and Food, Chemicals and Pharmaceuticals, Metals, Instruments Electronic and Non-Electrical Machinery, and Transportation), five Latin American countries (Argentina, Brazil, Chile, Colombia and Mexico) and the G-5 countries (France

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[1] Among others, Coe et al. (1997) consider the importing of goods a fundamental channel of north-south knowledge spillovers and find that total factor productivity in developing countries is positively related to R&D performed in the industrialized ones. Keller (1998) calls into question the claim that patterns of international trade are important in driving R&D spillovers; a reply is contained in Coe and Hoffmaister (1999). Moreover, Keller (2004) provides a survey of the literature on international technology diffusion.

Germany, Japan, the UK and the USA) in the years between 1988 and 2003. We process the information contained in the US Patent and Trademark Office (USPTO) patent documents and their citations to build up the different indexes of R&D spillovers. Also, we match USPTO patent data with economic data taken from different sources at a sectoral level and control for the dynamics of domestic value added and past innovative activity. In order to have a more complete picture of the patenting activities of the Latin American countries we also provide some descriptive evidence on European Patent Office applications.

Overall, this paper provides a detailed account of the nature, sources and determinants of international patenting activity in Latin American countries. We show that a large part of the Latin American-invented patents belong to foreign companies with a foreign address or to a foreign subsidiary with a Latin American address, and top applicants at the USPTO and EPO are mainly US and German multinationals and the big Latin American patenters are active in a set of heterogeneous sectors of activity that are not considered very R&D-intensive (e.g. Oil, Glass, Electric, Metals and Machinery). Secondly, econometric analysis shows that international knowledge spillovers from the G-5 countries are a significant determinant of inventive activity in the period considered. In particular, we find that, controlling for direct foreign R&D effects, both bilateral patent citations and face-to-face relationships between inventors are important *additional* mechanisms of knowledge transmission. Some of our results suggest that the latter is more important than the former.

In Section 2 we provide a short overview of the theoretical background of this study and justify the use of patent-based data to measure knowledge spillovers. In Section 3 we perform a descriptive analysis of the international patent activity in Latin American countries and network of knowledge relations across countries using patent citations and co-inventorship behaviour. To have a clearer picture we use data from different sources (i.e. the US *and* European Patent Offices). In Section 4 we construct our empirical model and in Section 5 we describe the data we will use and our empirical strategy. More details are provided in the Appendix. Section 6 reports the main results from the estimation of different econometric specifications. In the final section we conclude, discuss some important limitations and propose some directions for future work.

2. Background

This paper extends current studies on the economic impact of knowledge spillovers to developing countries and in particular to Latin American countries. We assess directly the determinants of innovative activity using a knowledge production function (KPF) (Pakes and Griliches 1984). The KPF is a methodological tool that tries to map research efforts into new knowledge. In the KPF baseline version, patent counts are used to approximate the production of new knowledge and R&D

expenditure measures the R&D effort. However, in dealing with developing countries, external sources of knowledge - that originate spillover or are transferred to developing countries - are particularly important. Actually, much of the current debate about technology policy in developing countries is based on the assumption that a country's innovative performance depends significantly on its relative technological capacities, ability to absorb foreign (costly and specialized) knowledge and learn how to adapt it to local needs (Cimoli and Dosi 1995; Cimoli et al. 2006.

R&D efforts either aim at lowering the costs of production (process-oriented R&D) or at producing new products or higher quality varieties of existing products (product-oriented R&D). Process-oriented R&D is often protected by secrecy (Mansfield 1986; Levin et al. 1987) and therefore it can be considered a minor source of spillovers, whereas product-oriented R&D generates spillovers through various channels like the trade of goods which incorporate the innovation, and the generation of patent documents which allows other firms to collect relevant information.

Within the broad spectrum of product-oriented R&D, when new or improved goods are developed and traded, an increased price-quality ratio leads to so-called *rent spillover* (Griliches 1979; van Meijl 1997); at the same time, when knowledge is mainly codified in publicly available sources such as scientific and technical literature (or also industrial espionage, reverse engineering), knowledge spills over between firms and countries, leading to so-called *knowledge spillovers*. Existing knowledge that is not perfectly protected may evoke new ideas which in turn lead to innovations (*idea-creating spillovers*) or may be simply absorbed and used to imitate (*imitation-enhancing spillovers*) (Los and Verspagen 2003). In the latter case, knowledge spillovers result in higher productivity, while in the former, they have a direct effect on innovative activity. Patent documents, as well as the mobility of R&D employees, are potential sources of *idea-creating knowledge spillovers*. Clearly, we focus on the role of foreign spillovers on innovative activity capturing the effect of *foreign idea-creating knowledge spillovers*.

It is worthwhile remarking that in this paper rent spillovers are not considered and that patent citations and face-to-face interactions between inventors capture only a specific form of knowledge spillovers. For example, patent citations and inventors' collaborations take place only if both spillover-source countries and spillover-receiving countries are actively engaged in R&D and apply for an international patent.

There is a vast literature that assesses international knowledge spillovers among developed countries.[2] Estimated international R&D spillover effects are typically significant and positive.[3] Recent

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[2] Three channels of knowledge spillovers are typically emphasized: international trade that assures free access to knowledge embodied in imported goods (Coe and Helpman 1995) and knowledge in global export markets through 'learning by exporting' (Bernard and Jensen 1999) and the contact with advanced foreign firms; labour mobility that is a source of knowledge exchange because workers are endowed with specific know-how (Rhee 1990; Pesola 2007); and finally foreign direct investment (Blomstrom and Kokko 1998; Aitken and Harrison 1999; Crespo and Fontoura 2007) represents an important source of technological spillovers although the empirical evidence remains mixed with regards to the distributions of benefits between multinational and domestic companies (Katrak 2002).

[3] Some recent empirical works have analysed whether knowledge flows cross national borders in a knowledge production framework (KPF) in order to test the existence of international spillover. Bottazzi and Peri (2003) estimate the elasticity of

empirical works show that extremely relevant sectoral knowledge flows cross national borders (Malerba et al. 2007). Bottazzi and Peri (2007) find that internationally generated ideas significantly affect innovation in a country. Branstetter (2006) uses a patent function to estimate firm-level spillovers. Based on a panel of 205 firms in five high R&D-sales ratio industries in the period 1985-1989, he provides strong evidence for Japanese intra-national knowledge spillovers and limited evidence that Japanese firms benefit from knowledge produced by American firms.

In the case of developing countries there is a large literature on the microeconomic effects of FDI spillovers on total factor productivity[4] but there is still scant aggregate evidence of R&D spillovers on countries' innovative outputs at sectoral and national levels. This paper focuses on two specific vehicles of knowledge spillovers: patent citations and collaboration via co-inventorship.

2.1 Patent citations as channels of knowledge flows

Patent citations are included in a patent document to delimit the scope of the property right and mention the relevant prior art. Citations are particularly reliable because they have a legal value. If patent A cites patent B it can be reasonably assumed that B is a technological antecedent of A and that the knowledge embedded in B has been developed by A. Trajtenberg (1990) and Albert et al. (1991) are among the first scholars who empirically demonstrated that highly cited patents have higher economic and technological importance. If a patent is cited it can also generate technological spillovers. Jaffe et al. (2000) tested this conjecture using USPTO patents and surveyed approximately 380 citing and cited inventors. Their results suggest that 'communication between inventors is reasonably important, and that patent citations do provide an indication of communication, albeit one that also carries a fair amount of noise' (p. 215). In addition, a consolidated stream of literature uses patent citations to track knowledge flows and spillovers (Jaffe et al. 1993; Jaffe and Trajtenberg 1996; Jaffe and Trajtenberg, 1999; Maurseth and Verspagen 2002; Malerba and Montobbio 2003; Peri 2005; Malerba et al. 2007).

Given that knowledge flows are inherently difficult to measure and that it is often problematic to assess the relevance of the source of knowledge and to evaluate the direction and the impact of the generated knowledge, patent citations have often been used to identify the direction of these knowledge spillovers between countries. If, for example, a patent with an inventor's address from Argentina cites a patent with an inventor's address in the USA, we could assume that some knowledge created in the USA has been used in Argentina and as a result patent citations could track the direction of knowledge spillovers between the two inventors and the two countries.

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innovation to R&D done in other regions at various distances, finding that the effects of R&D in generating innovation are quite localized (see also Keller 2002; Maurseth and Verspagen 2002; Peri 2005).

[4] For a survey see also de Mello (1997)

2.2 Patent co-inventors as channels of knowledge flows

The second major channel of knowledge transfer we consider in this paper passes through collaborations and face-to-face contacts. Processes of knowledge creation are importantly affected by the inventors' community and network relationships (Breschi and Lissoni 2001). Similarly, research collaborations create fundamental social networks, in particular for developing countries: inventors that have studied or worked abroad, not only benefit from the high standard of top international universities and companies, but also continue to rely on free information in subsequent research projects after the collaboration itself is finished. Therefore, research collaborations can indicate relational proximity and capture the spillover stemming from collaborative networks between regions and countries (Hoekman et al. 2008).

Singh (2005) has examined whether social networks of inventors are a significant mechanism for diffusion of knowledge and found that the existence of co-inventorship relations is associated with a higher probability of knowledge flows (measured in terms of citations): the probability of knowledge flows between inventions is a decreasing function of the social distance. Gonzalez-Brambilla et al. (2008) emphasized the relationship between social capital and knowledge creation, underlying the role of exchange and combination processes. In particular, using a database of international scientific publications and citations they found that scientists in embedded networks have superior success because of better communication skills.

Citation patterns and co-inventor relations measure different kinds of disembodied knowledge flows. On the one hand, citations are able to measure flows of codified knowledge, that is, knowledge acquired by direct reading and comprehension of written and available documents such as publications and patents. On the other hand, if we assume that inventors listed on the same patent know each other, co-inventor relationships can be seen as a diffusion mechanism of non-codified knowledge (e.g. technical know-how, non-standardized production procedures, etc.). In fact, diffusion of non-codified knowledge requires face-to-face interactions, at least periodically, and it is likely to have a great impact on the inventive activity.

In this paper we apply this theoretical background to analyse international patenting in Latin America and the impact of international knowledge spillovers. We are aware that international patenting is a tiny portion of the innovative activity of these countries and, exactly for this reason, it is important to stress the peculiarities and specificities of international patenting before laying down the details of the empirical exercise. The next section is therefore dedicated to the precise understanding of the object of enquiry of this paper (see Montobbio 2007 for a broader discussion and comparison with other developing countries).

3. International Patenting in Latin America

For this analysis we use standard patent data sources from the European and US Patent Offices. Data sources and sectors of analysis are carefully explained in the Appendix. Table 1 lists the total number of Latin American granted patents at the USPTO by year (the country is assigned using the residence of the inventors). These numbers are small relative to the overall numbers in other countries. Top Latin American countries at the USPTO are Brazil and Mexico with respectively 2155 and 2102 patents[5] in the period 1968 to 2003. Argentina and Venezuela follow with 1037 and 704 patents respectively. At the EPO, for the period 1978-2003, Brazil has the highest share with 1688 patent applications, Mexico, Argentina and Venezuela follow with 678, 575 and 176 patent applications respectively (see Table 2). It is important to note that at the USPTO, Brazil and Mexico have almost the same number of patents whereas at the EPO, Brazil has a total number of patents which is almost three times that for Mexico. This indicates that geographical proximity and economic agreements play a very important role and Mexican inventors tend to protect their innovations much more in the US market compared to the EU.[6] In recent years, no remarkable structural break is observable after the changes in domestic legislations due to the implementation of the TRIPs agreement in many countries.

The rise in patent numbers documented in Tables 1 and 2 can be seen as the combined result of an increased propensity to patent world-wide and the increased use of international patents in LACs. Many authors have documented the explosion of patent activity world-wide and in the USA, in particular in semiconductors. This is related to a general reinforcement of IPR legislation (mainly but not only in the USA) and to institutional changes in the early 1980s[7] that favoured changes in firm appropriability and IP strategies (e.g. Hall 2003). However it can be noted that on average the growth of LAC patents is higher than the average growth of patents. This happens at both the USPTO and EPO during the 1990s (see Table A1 in the Appendix and Montobbio 2007).

[Table 1 about here]

[Table 2 about here]

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[5] A patent is assigned to a LAC if there is at least one inventor with an address in that country. As a result, a patent is assigned to all the listed LACs (and therefore counted more than once) when the signing inventors come from different LACs.

[6] Evidence that Mexican innovative activities are relatively more related to US activity also emerges below in Table 5 where the share of foreign co-inventors from the USA is equal to 83 per cent for Mexican patents and 53 per cent for Brazilian patents. Moreover, Montobbio et al. (2009) estimate in a gravity model that geographical distance plays a significant role in determining bilateral technological collaborations and bilateral patterns of citations.

[7] For example, creation of a Court of Appeals for the Federal Circuit in the USA '[..] transformed the legal environment from one that was generally sceptical of patents to one that promoted the broad, exclusive rights of patent owners' (see also Adelman 1987; Merges 1997).

It is important to underline that an increasing share of the total Latin American-invented patents filed in the USA is the result of collaborative activity with foreign (in particular US, see Section 3.4) laboratories, companies and inventors (Figure 1). It is worthwhile noting that these patents are mainly owned by US companies (like Syntex USA, Delphi Technologies, Procter & Gamble, IBM, Hewlett-Packard and General Electric). Moreover, there is a non-negligible number of patents owned by US universities and research laboratories (e.g. Universities of Pennsylvania, California and Texas).

[Figure 1 about here]

3.1 Latin American-owned vs. Latin American-invented patents

The patent count, based on the inventor's address, reflects more directly the inventive activity of laboratories and researchers in a given country. If a country's patents are counted using the applicant's address, results reflect 'ownership'. Of course, this counts the inventive activity of a given country's firms, even if their research facilities are located elsewhere. Typically, countries like the United States or the Netherlands, where many multinational companies are located, have a relatively higher patent share when country is assigned on the basis of the applicant's address (Dernis et al. 2001). The opposite occurs in most developing countries.

USPTO data do not report the applicant's country, but it is possible to use EPO data on patent applications to understand the difference it makes to count patents using the applicant's address.[8] As expected, counting patents with the applicant's address reduces the number of patents in the main countries by approximately 41 per cent (from 2636 to 1565, in the period 1977-2001, EPO data) with respect to patents with the inventor's address. It is worthwhile noting that out of 2636 Latin American-invented patents there are only 1520 (56 per cent) Latin American-owned patents[9] (i.e. patents in which the applicant's address is in a Latin American country). The rest is owned by foreign companies (1213 – 44 per cent)[10] (i.e. the company's address is not in a Latin American country). Finally, it is important to note that if we consider Latin American-'owned' patents, the share of patents with at least one foreign

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[8] For simplicity we use the term 'Latin American-owned patents' to refer to patents assigned to countries using the applicants' address and the term 'Latin American-invented patents' to refer to patents assigned to countries using the inventors' address. It must be emphasized that use of the term 'Latin American-owned patent' refers to the *legal address* of the owner and not to the nationality of *ownership of the company*.

[9] The difference between this number (1520) and the total number of Latin American-owned patents (1565) is generated by 45 Latin American-owned patents that do not have Latin American inventors.

[10] The sum is not 2636, because we counted patents more than once in cases of co-applicants from different countries.

inventor is significantly lower (9 per cent) than in the case of Latin American-'invented' patents. This indicates a low degree of internationalization of patentees resident in LACs.

Colombia, Mexico and Venezuela have the highest percentage difference between Latin American-owned and Latin American-invented patents. This means that in particular for these countries, a considerable part of the national inventors' activity is performed in companies or institutions that do not have a legal address in the country. This asymmetry may partly reflect the internationalization of research and location of research and legal facilities by multinational firms and partly the fact that some Latin American inventors may be temporarily (or in some cases even permanently) active abroad but declare their address in Latin America.

3.2 Sectoral differences

Patents are classified according to very specific technological classes and therefore can be used to measure innovative activities in specific sectors of economic activity.[11] Table A1 shows the number and distribution of patents granted at the USPTO at a sectoral level. We observe that Chemicals and Pharmaceuticals, and Instruments, Electronics and non-Electrical Machinery are the two sectors that capture 80 per cent of the total patents in Latin America, while not surprisingly in traditional sectors such as Textiles and Food, the number of patents represents only 4 per cent of the total. Table A2 also shows the number and distribution of patents by country: Chile seems to have a comparatively good production of patents in Metals, while Brazil displays a considerably high share of patents in Transportation.[12]

3.3 Individual inventors

A more detailed look at these patents shows that many patent assignees are individual inventors. If we assign a patent to a country using the applicant's address, 41.5 per cent of Latin American patents at the EPO are owned by individual inventors. At the USPTO 37.3 per cent of the 'Latin American-invented' patents granted are 'individually owned'.[13] These shares are considerably higher than average,

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[11] We use the US Patent Classification in order to re-aggregate patents into five classes (Textiles and Food, Chemicals and Pharmaceuticals, Metals, Machinery, and Transportation) and match them with data on economic activity (see Table A5 in the Appendix for the concordance table).

[12] Montobbio (2007) demonstrates in detail how the sectoral distribution of LAC technological activities differs from general patterns. He calculates the indexes of revealed technological comparative advantages, showing that in the period 1995-99, Latin American countries are specialized (*vis à vis* the rest of the world) in Chemicals, Drugs & Medical and 'Others'. At the same time they are heavily de-specialized in Electrical and Electronics and Computer & Communications. However, if we consider all Latin American countries together, the specialization pattern of the Latin American area seems to broaden throughout the 1990s. Results for the EPO and USPTO are very similar.

[13] Moreover, in LACs there is quite a high heterogeneity across countries. The countries with the highest share of patents owned by individual inventors are Argentina (72 per cent), Colombia (73 per cent) and Chile (59 per cent). Of course if we

considering that for all patents at the USPTO and EPO the shares of individually-owned patents are respectively 23 and 11 per cent.[14] Typically, less developed countries and regions have a relatively higher share of individual inventors because firms, universities and research centres are less aware of the patent system and have relatively fewer resources to invest (relative to firms in advanced countries). Therefore, it is more likely that individuals decide to bear the expenses and file their own patents. Typically, these patents are considered less economically and technologically valuable because they are often the result of occasional activities and do not originate from well-funded R&D projects.

Some of these patents may actually belong to companies but are registered in the name of the owner as the applicant. This could be the case with micro companies, family companies or partly-informal companies. Given the great uncertainty of survival of small and medium companies – in a macro-economic context that is often unstable – companies prefer not to have the patent registered under the name of the company but rather under the name of the owner (for Argentina, see López et al. 2005). There may, however, be some exceptions to this negative interpretation. Some inventors, who are active abroad, keep the address of their home country. This inventive activity could be valuable, and these individual patents could signal cooperation with foreign countries and be an important vehicle of knowledge transfer[15] as emphasized in previous sections.

3.4 Applicants

The concentration of assignees or applicants of international patents at the USPTO and EPO in Latin America is not very high. Many assignees or applicants are, in large number, different individual inventors[16] and among the top applicants we find many US and German multinational companies. There are some big Latin American patenters, like Petrobras, Embraco and Intevep-Pdvsa, that are active in a set of heterogeneous sectors of activity that are not considered very R&D-intensive (e.g. Oil, Glass, Electric, Metals and Machinery). Almost no Latin American companies are active in the high tech and high growth sectors like Electronics, Telecommunications or Pharmaceuticals.

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look again at EPO data and consider Latin American-invented patents, we discover that the share of Latin American-invented drops to 25.2 per cent. Again, the countries with the highest share are Argentina (46 per cent), Chile (40.5 per cent), Colombia (37.7 per cent) and Uruguay (33.3 per cent). This means that very few foreign assignees of Latin American-invented patents are individual inventors. Looking at USPTO data Argentina (61.7 per cent), Colombia (55.1 per cent), Uruguay (52.5 per cent) and Mexico (42.4 per cent) have 'individually-owned' patent shares that are higher than average in number.

[14] The higher share of individually-owned patents at the USPTO is due to the 'first to invent' rule. The assignee can be declared in a second stage after registration at the patent office.

[15] See for example the case of Dr. Juan Carlos Parodi at the Washington School of Medicine in St. Louis (USA) with the following highly cited patents: "Aortic graft for repairing an abdominal aortic aneurysm – US005360443A" and "A balloon device for implanting an aorta [...] - US5219355".

[16] Individually-owned patents remain dispersed across a large number of individuals with few patents. This suggests that they patent occasionally. The individual inventor owning the largest number of patents at the EPO is Juan Carlos Parodi with 13 patents and the second highest is Luiz Carlos Oliveira Da Cunha Lima with 6 patents.

The top 10 Latin American applicants (inventor's country) at the EPO (for the period 1978-2001; company's country address in parenthesis) are: Empresa Brasileira De Compressores (Brazil), Petroleo Brasileiro s.a. – Petrobras (Brazil), Centro de Ingenieria Genetica y Biotecnologia (Cuba), Bayer (Germany), Unilever (UK and the Netherlands), Hylsa (Mexico), Praxair Technology (USA), Procter and Gamble (USA), INTEVEP (PDVSA - Venezuela) and finally Johnson and Johnson (Brazil and USA). Table 3 shows the top 16 applicants and their patent numbers.

The top ten patenting companies at the USPTO are (for the period 1978-2001, excluding 'individually-owned patents'; in parenthesis there is the country of the inventors, not the address of the company which is not available in the USPTO database) INTEVEP (Venezuela), Petroleo Brasileiro s.a. – Petrobras (Brazil), Empresa Brasileira De Compressores (Brazil), Hylsa (Mexico), Carrier (Brazil), Syntex USA (Mexico), Vitro Tec Fideicomiso (Mexico), Hewlett-Packard (Mexico), Bayer (Brazil, Mexico and a few from Colombia and Argentina), Delphi Technologies (Mexico). The picture at the USPTO is quite similar to the EPO with a lower presence of German firms and a higher presence of US companies like HP, IBM, Carrier or Colgate-Palmolive.

[Table 3 about here]

3.5 Citations

In order to address the issue of knowledge flows, in this section we track citation flows between Latin American countries and other geographical areas in the world. Using USPTO citation data from the period 1975-2000, we build a matrix of citation flows across areas (*CIT*). Each element of this matrix { CIT_{jk} } represents the number of patent citations flowing from country j into country k (i.e. the number of times patents with the inventors' address in country j cite patents with an inventor's address in country k). Note that *CIT* is squared and asymmetric and the elements on the main diagonal { CIT_{jj} } are the number of citations that remain in the same specific country. Table 4 illustrates the matrix from the USPTO dataset. Each column represents the citing country and the rows are cited countries[17] (e.g. Latin American patents cite Chinese patents ten times, equivalent to 3 per cent of the total Latin American backward citations).

[Table 4 about here]

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[17] When patents have inventors from different countries, patents have been assigned to all the different countries listed in the inventors' addresses.

Table 4 shows a very low share of citations among Latin American countries (4.29 per cent of citations). This is similar to other countries like China and India. Approximately 70 per cent of the citations made and received are from US patents.[18] Finally, it can also be noted that knowledge flows from Latin American patents to patents invented in other regions are also extremely low. Our evidence shows that citations to Latin America from EU and US patents appear to be equal to 0.14 per cent of the total outflow of their citations.

3.6 Co-inventors

Our second measure of knowledge flows is based on collaboration patterns between inventors. Table 5 shows the number of co-inventors and share by countries and sectors at the USPTO for five LACs (Argentina, Brazil, Chile, Colombia, and Mexico). In columns (1) and (2), we show the total number of inventors of USPTO patents that declare their residence respectively in a Latin American country and in a foreign country. In the other columns, the share of co-inventors resident in a foreign country is displayed. We consider only the co-inventors resident in the G-5 countries (USA, Japan, Germany, UK, and France).

[Table 5 about here]

Mexico has more international collaborations than the other LACs in terms of patenting activities: the G-5 co-inventors represent 31 per cent of the total inventors of Mexican patents. At the opposite end we find Argentina where the G-5 co-inventors represent only 22 per cent of the total number of inventors. Looking at the bilateral relationship, it is worth noting that the great majority of foreign inventors come from the USA: in all the LACs considered, the lowest share is for Brazilian patents with 56 per cent. However, it is possible to distinguish different patterns of *co-inventorship*. Brazil has a higher co-inventors' network with Germany (31 per cent) and France (6 per cent) with respect to other LACs, while Chile seems to have a significant collaboration with the UK (especially in Chemicals and Pharmaceuticals). Finally, if we consider sectoral differences, we find that more or less in all the countries, Chemicals and Pharmaceuticals and Instruments, Electronic and non-Electronic Machinery are the sectors with more international co-inventors.

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[18] We have also built up the same matrix using EPO data. Interestingly, these shares drop to approximately 36 per cent if we consider EPO patents. At the same time, within the USPTO data knowledge flows with Europe are approximately 12 per cent of the total, and at the EPO are approximately 42 per cent of the total. This may be the result of a home bias effect by patent examiners. For a discussion on this point, see Montobbio (2007) and Bacchiocchi and Montobbio (2009).

4. The Empirical Model

This section outlines the empirical model we use to estimate international knowledge spillovers and in particular, the effects of R&D performed in industrialized countries on the innovative activity of Latin American countries. Following Malerba et al. (2007) we start from the following KPF that relates R&D investments and the production of technological output:

$$Q_{h,i,t} = f(\overline{R}_{h,i,t}, \alpha, v_{h,i}) = \overline{R}_{h,i,t}^{\alpha} v_{h,i} \tag{1}$$

where $Q_{h,i,t}$ is a latent measure of technological output in field i (i=1,..5), country h and period t. In addition, α represents the unknown technological parameter, and $v_{h,i}$ captures the country and technological field specific effects. We assume that R&D is composed of domestic R&D efforts and international R&D efforts that produce usable knowledge at an international level. As emphasized in the previous section we compare three different modes of knowledge flow. The first mode is pure spillover (IS_1), the second one is knowledge spillover through patent citations (IS_2) and, finally, the third one is knowledge spillover that is related to collaboration activities and face-to-face contacts (i.e. co-inventorship) (IS_3):

$$\overline{R}_{h,i,t}^{\alpha} = R_{h,i,t}^{\alpha 1} IS_{1h,i,t}^{\beta 1} IS_{2h,i,t}^{\beta 2} IS_{3h,i,t}^{\beta 3} \tag{2}$$

Moreover, we use patents as a noisy indicator of technological output:

$$P_{h,i,t} = Q_{h,i,t} e^{\theta_t} u_{h,i} \tag{3}$$

We take into consideration possible common time effects in patenting (θ_t) and differences in country-specific propensity to patent in each technological field ($u_{h,i}$). Combining equation (3) with (2) and (1) results in the following patent equation:

$$P_{h,i,t} = R_{h,i,t}^{\alpha 1} IS_{1h,i,t}^{\beta 1} IS_{2h,i,t}^{\beta 2} IS_{3h,i,t}^{\beta 3} e^{\theta_t} \xi_{h,i} \tag{4}$$

We cannot directly estimate (4) because we do not have data on national R&D efforts at the sectoral level over time. However, even if we are interested in the effect of international spillovers on international patenting, we have to take into account some economic measures related with the trend in

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the size of the different industries in each country and national R&D investment in order to avoid omitted variable problems in the econometric approach. For this reason we control national economic activity with data on value added (an additional specification includes the lagged dependent variable, see below), captured by the variable $X_{h,i,t}$:

$$P_{h,i,t} = X_{h,i,t}^{\alpha 1} IS_{1h,i,t}^{\beta 1} IS_{2h,i,t}^{\beta 2} IS_{3h,i,t}^{\beta 3} e^{\theta_t} \xi_{h,i} \tag{5}$$

In general formulation international knowledge spillovers are typically expressed as follows:

$$IS_{h,i,t} = \prod_f R_{f,j,t}^{\lambda_{h,f,j,t}} \tag{6}$$

where $\lambda_{h,f,j,t}$ weights the impact of R&D expenditures from foreign countries. R is the knowledge source and λ is the vehicle of knowledge spillovers. In our case subscript f refers to the USA, the UK, Japan, France, and Germany, and h to Argentina, Brazil, Chile, Colombia, and Mexico. Our weights are sector-specific (sector j) and vary over time. Note that we adopt very large sectors and therefore we feel it legitimate to focus only on intra-sectoral R&D spillovers, neglecting inter-industry knowledge flows.

5. Data and Methodology

Our econometric exercise uses different databases for five Latin American countries (Argentina, Brazil, Chile, Colombia, and Mexico) and five industrial sectors (Textiles and Food, Chemicals and Pharmaceuticals, Metals, Instruments Electronic and Non-Electrical Machinery, and Transportation) in the period 1988-2003. We exclude Cuba and Uruguay from the econometric analysis and focus on the five countries with the highest number of patents. In particular, we use the USPTO-CESPRI database for patents and patent citations, the PADI-CEPAL database for value added and the OECD-ANBERD database for R&D data. We use USPTO data for the econometric exercise as the US market is particularly relevant for Latin American countries, because there are more observations that can be used and finally because in USPTO data there are many more patent citations.[19] Data sources and sectoral aggregations are thoroughly explained in the Appendix. Equation (5) captures the effect of the R&D effort performed in foreign countries in the production of USPTO patents by Latin American inventors. Taking logs of (5) we propose to estimate the following logarithmic specification:

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[19] Bacchiocchi and Montobbio (2009) address at length the issue of the differences between patent citations at the EPO and USPTO.

$$\ln P_{h,i,t} = \alpha_1 \ln X_{h,i,t} + \beta_1 \ln IS_1 + \beta_2 \ln IS_2 + \beta_3 \ln IS_3 + \theta_t + \varsigma_{h,i,t} \qquad (7)$$

where the dependent variable is the log of the number of USPTO patents in county h (h=1,..5), sector i(i=1,..5), and time t (t=1,..16 for the period 1988-2003). Note that our observational unit refers to industries (sectors) in different countries for a total of 25 different groups.

The R&D stock in country f and sector i is calculated using the *perpetual inventory method* and, following the standard practice in the literature, we set the rate of depreciation δ at 0.12 (see Appendix).[20] Central to this paper is the calculation of international spillover variables. We measure three different channels of international knowledge spillovers. The first international spillover variable measures knowledge spillovers when knowledge is a public good and once it is produced it is freely available. Under this assumption US$1 in R&D will have a direct impact on the knowledge production in other countries. We call this variable:

$$\ln IS_1 = foreignR \& D\_tot_{h,j,t} = \sum_f \ln R \& D_{f,j,t} \qquad (8)$$

foreignR&D_tot is equal to the sum of the logarithm of R&D stocks in the main G-5 industrialized countries: USA, JP, UK, FRA and DE.[21] In this case, all weights $\lambda_{h,f,j,t}$ are set equal to 1. In addition, we have shown that the USPTO activity of Latin American countries is tightly linked to the activity of US companies and universities. Therefore, R&D expenditures in the USA are particularly important in terms of spillovers generated to Latin American countries. Then, in our regressions we control for this aspect and also consider only the *US R&D stock*.

The second spillover effect is captured by patent citations. Patent citations are a paper trail that may signal that some knowledge flow occurs. Knowledge remains a public good but travels embedded in codified documents such as patents. We use USPTO citations to build a set of matrices that map citations between our five LAC countries and the G5 countries we considered. Each cell of the matrix is the number of citations in patents with at least one inventor resident in a LAC country to patents with at least one inventor resident in a specific G5 country. We build these matrices for each sector and for each year. Then we construct the weight $\lambda_{h,f,j,t}=cit_{h,f,j,t}$, which is the ratio of the number of citations flowing from country h to country f in sector j at time t over the total number of citations flowing from country h to all the G-5 countries in sector j at time t. As a result, our index of citation-based international knowledge spillovers (*foreignR&D_cit*) is calculated as follows:

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[20] It is important to point out that an arbitrary assumption about the size of the depreciation rate does not have any important effects on the results. We have re-run all the regressions with δ=0.08 but results do not change. The estimated values with R&D stocks calculated with δ=0.08 are not displayed but are available from the authors on request.

[21] It is customary in the modern literature on R&D spillovers to convert R&D stocks into US$ using purchasing power parities (PPP) (e.g. Keller 2000). PPP bases are more informative on the real value of R&D which depends upon the relative cost of living and the inflation rates of the countries.

$$\ln IS_2 = foreignR \& D\_cit_{h,j,t} = \sum_f cit_{h,f,j,t} \ln R \& D_{f,j,t} \qquad (9)$$

The third spillover effect is related to interpersonal links and possibly face-to-face contacts. In this case, the fact that inventors work together on the same invention signals that some knowledge exchange takes place. We again use USPTO patent data to build up a second set of matrices. In this case, each cell *(h,f)* of the matrix is the number of patents with at least one inventor resident in country *h* and one inventor resident in country *f*. Again, we build up these matrices for each sector *i* and for each year *t* in the sample. Then we construct the weight $\lambda_{h,f,j,t}$=*coinv*$_{h,f,j,t}$, as the ratio of the number of patents with co-inventors in country *h* and country *f* in sector *j* at time *t* over the total number of patents with inventors in country *h* and all the G-5 industrialized countries in sector *j* at time *t*. As a result our index of international knowledge spillover (*foreignR&D_coinv*), based on co-inventorship behaviour, is calculated as follows:

$$\ln IS_3 = foreignR \& D\_coinv_{h,j,t} = \sum_f coinv_{h,f,j,t} \ln R \& D_{f,j,t} \qquad (10)$$

Table 6 displays summary statistics on the economic and patent data variables.

[Table 6 about here]

6. Estimation results

Our estimation strategy follows three steps. First, we run simple fixed effect OLS regressions. We use fixed effects because they ensure consistency in the presence of correlation between the explanatory variables and the individual effects.[22] Therefore, we start with a set of *static* regressions using fixed effect models. Secondly, we control for possible spurious results due to common trends and test for the stationarity of the time series in the panel. Third, we use a lagged dependent variable to control for domestic innovative activity. In this last step we estimate a *dynamic* panel using Within Group (Fixed Effect) estimation and GMM following Arellano and Bond (1991). Results are based on the assumption of stationarity consistent with the second step of this econometric exercise.

6.1 Static panel

We then start estimating Equation (7) using Fixed Effects. Heteroskedasticity robust standard errors are applied. We take the log to have variables more closely distributed to normality and estimated coefficients expressed in terms of elasticity. In some cases the number of patents is zero and the log of zero is not defined; therefore we set zeroes equal to one and allow the corresponding observations to have a separate intercept (zero dummy) as in Pakes and Griliches (1984). In Section 6.2 we also perform a robustness check in this respect. In all specifications we also include time dummies to control for common economic changes related to the calendar year.

Table 7 reports the robust Fixed Effect estimates of the parameters. All the specifications explain approximately 90 per cent of the variation in international patenting. The first column includes only total foreign R&D stock (i.e. USA, Japan, Germany, UK, and France) as input of the innovation function: an increase of one per cent in total foreign R&D stock increases the innovative activity by 0.095 per cent in terms of international patenting of our LACs. In Column 2 we assume that only R&D expenditures in the USA have a spillover effect on international patenting. Results show a strong positive spillover effect from the US R&D stock: the estimated coefficient is equal to 0.3 and statistically significant at the one per cent level. Note that the size of this estimated coefficient is three times higher than in the case of total foreign R&D. This variable controls for foreign knowledge input effects as in Bottazzi and Peri (2007): US-generated ideas widen the basis of usable knowledge and generate further innovation based in LACs.

Controlling for the effects of available ideas in a specific industry measured by US R&D stock we proceed in columns (3), (4), and (5), adding as regressors the other 'embedded' international

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[22] Random-effects estimates are more efficient, but require the individual specific effect to be uncorrelated with explanatory variables. In any case, the Hausman test (not reported) supports the fixed-effects specification rather than the random-effects model.

spillover mechanisms measured by the variables IS_2 and IS_3. These coefficients show that external R&D has a significant additional impact on patent production and in particular, that *citations* and *co-inventorship* patterns are relevant channels of knowledge flows. The two estimated coefficients have similar sizes, being respectively 0.032 and 0.027, and are significant at the one per cent level. Our results suggest that a significant portion of international knowledge spillover is embedded or in codified documents, such as patents that are publicly available, or in interpersonal links and contacts, such as cross-country collaborative efforts on specific innovations.

[Table 7 about here]

Finally in column (6) we test the robustness of our results running a *Fixed Effect Negative Binomial model* in order to take into account that patents are a count variable and the results related to citation-based spillovers and co-inventorship-based spillovers do not change substantially. Conversely the US R&D stock is smaller and not statistically significant. As we will see in the next paragraph, this variable is non-stationary and this may crucially affect the results.

6.2 First Robustness Check

We have 85 observations out of 400 in which the number of patents is zero: in this case when the spillover effect passes through patent citations or patent co-inventors the source of external R&D is zero by definition (it is not possible to have citations or co-inventors without patents). In order to check if the previous results are driven by this effect we ran the fixed-effect model, dropping the observations where the number of patents is zero. Results do not change substantially. The coefficients associated with the spillover measured by citations and by co-inventors are significant and positive. In particular, a one per cent increase in citation-weighted R&D generates a 0.029 per cent increase in the domestic innovative output, while for the co-inventors'-weighted R&D we get a significant coefficient of 0.024 per cent. The R&D performed in the USA has a greater impact with an estimated elasticity of 0.24 per cent (see Table A4 in the Appendix).

6.3 Stationarity tests

Our estimates rely on the assumption that our variables are stationary or co-integrated and it is possible that serial correlation is spuriously driving the above results. We therefore perform the panel unit root test developed by Im et al. (2003). If it is assumed that the time series are independent across *i*, the null hypothesis is that all the series are non-stationary; if the contrary is assumed, some of the

individual time series have unit roots. Table 8 shows the results. We find that the dependent variable and our measures of R&D spillovers weighted by citations and co-inventors are indeed stationary.[23] At the same time, the null hypothesis of unit root cannot be rejected for the other measures of foreign R&D we have used. Total foreign R&D stock and US R&D stock are therefore both non-stationary. For this reason, the estimations presented in Table 7 may be biased. In the following section we check the robustness of our results excluding Total Foreign R&D and US R&D in order to obtain consistent estimates. In addition, we add a lagged dependent variable in order to estimate a dynamic version of our empirical model.

[Table 8 about here]

6.4 Dynamic panel

This section is therefore devoted to control the robustness of our results. We control for an additional potential source of omitted variable bias including a lagged dependent variable. This leads us to estimate a more general dynamic version of our empirical model. It is reasonable to think that international patenting is a cumulative and past-dependent process. Accordingly, we assume that the production of patents is an AR(1) process, and the number of patents at time *t* is also a function of the number of patents produced in the previous period, *ceteris paribus*. This helps controlling together with value added for domestic past innovative effort. Including a lagged dependent variable we therefore have the following dynamic specification:

$$\ln P_{h,i,t} = \gamma \ln P_{h,i,t-1} + \alpha_1 \ln X_{h,i,t} + \beta_1 \ln IS_1 + \beta_2 \ln IS_2 + \beta_3 \ln IS_3 + \theta_t + \varsigma_{h,i,t} \qquad (11)$$

The errors $\varsigma_{h,i,t}$ are decomposed into time invariant individual specific effects $\eta_{h,i}$ (in our case 25 country-sector pairs), and the random noise $\nu_{h,i,t}$ so that $\varsigma_{h,i,t} = \eta_{h,i} + \nu_{h,i,t}$. One implication of model (11) is that the lagged dependent variable is correlated with the idiosyncratic disturbance - even if the disturbance is itself not serially correlated – because of a possible bias by the omitted individual specific effects (Greene 2003). The Ordinary Least Squares (OLS) estimates of γ in Equation (11) are inconsistent, since the explanatory variable is positively correlated with the error term due to the presence of individual effects. The Within Group estimator eliminates this source of inconsistency by transforming the equation in order to eliminate the individual (country-sector) effect $\eta_{h,i}$. Specifically,

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[23] The stationarity of R&D weighted by citations is accepted if we do not consider two lags.

the mean values of the variables are calculated across the T-1 observations for each unit, and the original observations are expressed as deviations from these means. Since the mean of the time invariant $\eta_{h,i}$ is itself $\eta_{h,i}$, these individual effects are eliminated. Then we use OLS to estimate the transformed equation. Nevertheless, this transformation induces a possible correlation between the transformed lagged dependent variable and the transformed error term, especially in panels where the number of time periods available is small, so that the WITHIN estimator could also be inconsistent (Bond 2002).

Arellano and Bond (1991) propose an alternative estimation technique based on the GMM that corrects the bias introduced by the lagged dependent variable. In a dynamic panel model with unobserved individual heterogeneity, the idea is first-differencing Equation (11) in order to eliminate the individual dummies (unobserved individual and time-invariant effects). However, this transformation implies that OLS estimates in the first-differenced model are inconsistent because of the dependence with the disturbance. So, sequential moment conditions are used where lagged variables or lagged differences of the dependent variables are instruments for the endogenous differences, while the other variables can serve as their instruments. Instruments are required to be correlated with the instrumented variable and not correlated with the disturbance. In Arellano and Bond estimators of the instruments are 'internal', that is, based on lags of the instrumented variables. In particular, in our case the lags of the dependent variables or the lags of first differences must be correlated with the first difference and uncorrelated with the disturbance.[24]

Table 9 shows the results. We compare WITHIN estimations with GMM estimations. Since GMM estimations are based on the assumption of stationarity, we cannot include foreign R&D stocks and US R&D stocks in the specification. This would return biased results. The Sargan test of over-identifying restrictions satisfies the underlying assumptions of the Arellano and Bond approach, suggesting that estimates reported are consistent and efficient.[25] Our results suggest that it is indeed important to control for a lagged dependent variable that is always statistically significant. International patenting is a cumulative and past-dependent process. Moreover, the estimated coefficients indicate that on the one hand, the spillover effect measured by citations is still positive but not statistically significant, and on the other hand, the estimated coefficient for international spillovers captured by co-inventors is still positive and significant. This result is important because it emphasizes the role played in international technological transmission by collaborations and person-to-person contacts.

[Table 9 about here]

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[24] Only 4th, 5th and 6th lags of dependent variables are used.

[25] We also ran 'System GMM' obtaining similar results: the estimated values are not displayed but are available from the authors. This Blundell-Bond (1998) estimator makes the additional assumption that first differences of instrumenting variables are not correlated with the unobserved fixed effects. This allows the introduction of more instruments improving efficiency.

In this section we look at the differences in terms of types of knowledge spillovers across sectors. We assume that parameters $\gamma, \alpha_1, \beta_1, \beta_2$ and β_3 in Equation [11] are industry-specific. Table 10 shows the spillover estimates obtained from separate regressions on our five sectors. We run both a static fixed effect model and a dynamic model, using the GMM technique used in the previous section. Due to the limited number of observations, these results have to be handled with care. However, we show that the effects of international spillovers may differ across sectors. Focusing in particular on the more general dynamic specifications, our GMM results show that citation-based spillovers are positive and significant in all sectors. The values of the estimated coefficients range between 0.05 and 0.07. Secondly, knowledge flows measured through co-inventorship play a sensible and positive role mainly in the Chemicals and Pharmaceuticals sector, Instruments and Machinery, and Metals with estimated elasticities equal respectively to 0.06, 0.04 and 0.03. It is worthwhile noting that value added has an important effect on international patenting only in Metals.

[Table 10 about here]

7. Conclusions

A large body of literature emphasizes that international flows of technological knowledge have an important effect on countries' ability to learn and innovate. This paper provides one of the first attempts to study different mechanisms of knowledge transmission from developed countries to developing countries at the industry level. In particular, we focus on the determinants of international patent production in a selected number of Latin American countries (LACs) and explore the role of three channels of R&D spillovers: foreign R&D, patent citations-related spillovers and face-to-face contact spillovers based on co-inventorship relations. In the econometric analysis we use data for five big industrial sectors (Textiles and Food, Chemicals and Pharmaceuticals, Metals, Instruments Electronic and Non-Electrical Machinery, and Transportation) from five LACs (Argentina, Brazil, Chile, Colombia and Mexico) and the G-5 countries (France, Germany, Japan, UK and USA) in the years between 1988 and 2003.

Overall, this paper provides a detailed description of the nature and characteristics of international patenting (EPO and USPTO) in LACs. We show that a large part of the Latin American-invented patents belong to foreign companies with a foreign address or to a foreign subsidiary with a

Latin American address, and top applicants at the USPTO and EPO are mainly US and German multinationals and the big Latin American patentees are active in a set of heterogeneous sectors of activity that are not considered very R&D-intensive (e.g. Oil, Glass, Electric, Metals and Machinery). We also show that individual inventors play a prominent role that is difficult to interpret but it is linked to the fragile structure of many innovative activities in these countries.

Second, we apply GMM methods to estimate the effect of the three different types of knowledge spillovers. We find that international knowledge spillovers from the G-5 countries are a significant determinant of inventive activity during the period considered. In particular, the stock of ideas produced in the USA seems to have a strong impact on the international patenting activity of these countries. Moreover, controlling for these US-driven R&D effects, bilateral patent citations and face-to-face relationships between inventors are both important *additional* mechanisms of knowledge transmission. Some of our results suggest that the latter is more important than the former. Finally, we find some sectoral differences: knowledge flows measured through co-inventorship play a particularly important role mainly in the Chemicals and Pharmaceuticals sector, Instruments and Machinery and Metals.

These results have relevant policy implications. The relative weakness in many sectors of the LACs' technological capabilities goes hand in hand with the lack of international integration of their inventive activities. The effectiveness of science and technology policies may depend upon the degree of internationalization of inventors' activity and their international mobility. If international face-to-face contacts and collaborations display a positive marginal effect on domestic innovative activity, R&D subsidies and fiscal R&D policies should be complemented with policies oriented at the international expansion of network relationships of local inventors and companies.

However, these policy conclusions need to be handled with extreme care due to some important limitations of this study. First of all, we consider an extremely small portion of the LACs' innovative activities. The absolute numbers displayed in Section 3 clearly indicate that few companies and individuals patent their technologies internationally. An alternative strategy could be to look at national patents at domestic patent offices. A first attempt to look at Brazilian data is provided in Laforgia et al. (2008). National patents are however heavily influenced by changes in national patent legislations.

A second important limitation of the paper, which is left to be addressed by future work, relates to the analysis of other important channels of technological transmission that we do not consider here, such as FDIs and bilateral trade. Future work should be able to compare the relative importance of these different channels. Finally, this paper addresses only the R&D impact on international patenting. More evidence is needed to fully understand the final impact on fundamental economic variables like labour or total factor productivity or patterns of trade. Montobbio and Rampa (2005) describe different types of relations between technological activity (using a similar set of USPTO patents) and

export gains in nine large developing countries and show that they are heavily influenced by the sectoral structure of the economy.

Acknowledgements

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Appendix.

Data.

Our study starts using different databases for eight Latin American countries (Argentina, Brazil, Chile, Colombia, Cuba, Mexico, Uruguay and Venezuela) and five industrial sectors. In the econometric analysis we consider only five countries: Argentina, Brazil, Chile, Colombia and Mexico. Patent data are collected from the EPO-CESPRI and USPTO-CESPRI databases, and R&D expenditure in the private business sector from the OECD-ANBERD, and OECD STAN (2005) databases. Economic data are taken from the PADI-CEPAL database (Programa de Análisis de la Dinámica Industrial) that consistently processes economic data at a sectoral level from national statistical sources. In particular, we use the value added in real terms (millions of US$1985).

Manufacturing sectors are defined following the International Standard Industrial Classification (ISIC – Rev.3). Our analysis is at industry level and we consider five technological fields (see Table A4 for details on conversion from US patent classification to ISIC 3 classification). This analysis uses the patent and citation databases from the USPTO-CESPRI database and from the EPO-CESPRI database. The USPTO (2007) database contains 3,583,811 patents from 1963 to 2003. The EPO-CESPRI database contains 1,656,074 from 1978 to 2003.

The following patent characteristics are particularly relevant. First, patents are dated with a priority date which is the closest date to the year of invention. Priority dates are used for the EPO patents. For the USPTO-CESPRI database, priority dates are not available and therefore the application date has been used. Second, the country of a patent, as explained in Section 3, can refer to the address of the inventors or to the address of the applicants (or assignees). In this study we use both inventors' and applicants' addresses, as the results obtained are different and enable us to draw some interesting conclusions (in the econometric analysis we refer to inventors' addresses). It should also be noted that patents include information on the stated address (and country of residence) of the inventor rather than his or her nationality. Third, patents are classified using classification systems which facilitate the identification of the technological field. In this study, the International Patent Classification (IPC) is used for EPO patents, while the US patent classification is used for USPTO patents.

R&D Capital stock

Total business enterprise expenditure on R&D at industry level comes from the OECD-ANBERD (2005) dataset. We use R&D flows, valued in US purchasing power parity, and convert them into constant 1995 prices. The deflators used for this are output deflators. The output deflators are derived from figures on value added both in current as well as constant 1995 prices, both included

in the OECD STAN-Industry database. The R&D capital stocks are then estimated using the perpetual inventory method.[26]

$$R \& D \_ stock_t = (1 - \delta) R \& D \_ stock_{t-1} + R \& Dflow_{t-1}$$
t=1,2..16,

where $R \& D \_ stock$ denotes the R&D capital stock in the business sector and $R \& Dflow$ is business sector R&D expenditure in constant 1995 prices valued at US purchasing power parity. The rate of depreciation δ is set at 0.12.[27] The benchmarks are calculated as:

$$R \& D \_ stock_{1988} = \frac{R \& Dflow}{(g + \delta)}$$

where g_v is the annual average logarithmic growth rate of R&D spending over the period 1988-2003.

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[26] Other studies (Bitzer and Stephan 2007) show that different methods for constructing R&D capital stock give more robust estimates.

[27] First estimates and previous empirical works (see for instance, Coe et al. (2008) and Keller (2000)) find that results are robust to different calibrations of the depreciation rate.

Table A1. Growth rate of patents by country and patent office[a]

	USPTO DATA								All Latin American patents	All patent applications at USPTO
Year (application year)	Argentina	Brazil	Chile	Colombia	Cuba	Mexico	Uruguay	Venezuela		
1988-1991*	1%	48%	59%	67%	33%	6%	167%	10%	22%	23%
1992-1995	96%	56%	48%	64%	200%	49%	0%	23%	54%	11%
1996-1999	42%	44%	88%	-17%	50%	59%	0%	24%	44%	31%
2000-2003	18%	33%	-4%	29%	-6%	20%	25%	-19%	19%	26%
	EPO DATA								All Latin American patents	All patent applications at EPO
Year (priority year)	Argentina	Brazil	Chile	Colombia	Cuba	Mexico	Uruguay	Venezuela		
1988-1991*	123%	32%	80%	100%	1200%	53%	50%	108%	63%	33%
1992-1995	34%	72%	0%	150%	69%	71%	-33%	-4%	56%	7%
1996-1999	126%	81%	100%	15%	14%	75%	550%	150%	87%	44%
2000-2003	16%	51%	78%	61%	140%	11%	77%	-46%	34%	22%

[a]The growth rates *g* are calculated as follows: g=(Pt-Pt-1)/Pt-1. t refers to the different four-year sub-periods

* Reference period: 1984-1987; Patents are assigned by inventor address.

Table A2. Number and distribution of USPTO patents by sector and country

	Textiles and Food	Chemicals and Pharmaceuticals	Metals	Instruments, Electronics and non-Electr. Machinery	Transportation	Total
Argentina	34	226	3	261	50	574
	(6%)	(39%)	(1%)	(45%)	(9%)	(100%)
Brazil	34	521	68	464	158	1245
	(3%)	(42%)	(5%)	(37%)	(13%)	(100%)
Chile	8	91	15	46	16	176
	(5%)	(52%)	(9%)	(26%)	(9%)	(100%)
Colombia	4	51	2	53	5	115
	(3%)	(44%)	(2%)	(46%)	(4%)	100%)
Mexico	55	388	77	458	94	1072
	(5%)	(36%)	(7%)	(43%)	(9%)	(100%)
Total	*135 (4%)*	*1277 (40%)*	*165 (5%)*	*1282 (40%)*	*323 (10%)*	*3182*

Patent data refer to 1988-2003 period, for 5 LACS: Argentina, Brazil, Chile, Colombia, and Mexico.

Table A3. Regression variables: correlation matrix

	Log (Pa)	Foreign R&DTot	US R&D	Foreign R&D cit	Foreign R&D coinv
Log (Pa)	-				
Foreign R&D Tot	0.4881*	-			
US R&D	0.4073*	0.9598*			
Foreign R&D cit	0.6710*	0.3318*	0.3243*	-	
Foreign R&D coinv	0.7280*	0.3813*	0.3022*	0.4674*	-
Value added	0.3740*	-0.3885*	-0.3821*	0.1696*	-0.1922*

Table A4. Robustness check. Dependent variable: log of the number of patents excluding observations where the number of patents is zero

	(1) Fixed effect	(2) Fixed effect	(3) Fixed effect	(4) Fixed effect	(5) Fixed effect	(6) FE Negative Binomial
Total foreign R&D	0.084***				0.075***	
	(0.019)				(0.019)	
US R&D		0.27***	0.26***	0.24***		0.15**
		(0.072)	(0.072)	(0.072)		(0.070)
Foreign R&D_cit			0.031***	0.029***	0.029***	0.019*
			(0.0099)	(0.0087)	(0.0087)	(0.011)
Foreign R&D_coinv				0.024***	0.024***	0.021***
				(0.0060)	(0.0060)	(0.0077)
Value added	0.36**	0.39**	0.43**	0.40**	0.37**	0.22*
	(0.18)	(0.18)	(0.18)	(0.19)	(0.18)	(0.13)
Constant	-5.59***	-4.72***	-4.91***	-4.66**	-5.56***	-1.31
	(1.76)	(1.75)	(1.82)	(1.87)	(1.89)	(1.38)
Observations	315	315	315	315	315	315
Number of i	25	25	25	25	25	25
Year dummy	Yes	Yes	Yes	Yes	Yes	yes
R-squared (within)	0.350	0.342	0.365	0.404	0.411	-

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 All variables are in logarithm. R&D depreciation rate 12%.

Table A5. Concordance table

Class	SubCat	Cat	ISIC rev 2	ISIC rev 3	sector
19, 43, 99, 127, 426, 442, 449, 452	11, 61	1, 6	310, 320	15-16-17-18-19	TEXTILES AND FOOD
8, 23, 34, 44, 48, 55, 71, 95, 96, 102, 106, 117, 118, 149, 156, 162, 196, 201, 202, 203, 204, 205, 208, 210, 216, 349, 351, 366, 401, 416, 422, 423, 424, 427, 430, 433, 435, 436, 494, 501, 502, 504, 510, 512, 514, 516, 518, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 534, 536, 540, 544, 546, 549, 552, 554, 556, 558, 560, 562, 564, 568, 570, 585, 588, 623, 800	11, 12, 13, 14, 15, 16, 19, 31, 33, 39.	1, 3	351, 352	24	CHEMICALS AND PHARMACEUTICALS
29, 72, 75, 76, 140, 147, 148, 163, 164, 178, 228, 245, 266, 270, 333, 340, 342, 343, 358, 367, 370, 413, 419, 420,	21, 52, 69	2, 5, 6	370-381	27-28	METALS
7, 16, 33, 42, 49, 51, 59, 60, 65, 73, 74, 81, 82, 83, 86, 89, 100, 124, 125, 128, 136, 141, 142, 144, 157, 173, 174, 178, 181, 184, 191, 193, 194, 198, 200, 209, 212, 218, 219, 221, 225, 226, 227, 234, 235, 236, 239, 241, 242, 250, 254, 257, 264, 267, 271, 290, 291, 294, 307, 310, 313, 314, 315, 318, 320, 322, 323, 324, 326, 327, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 340, 342, 343, 345, 346, 347, 348, 352, 353, 355, 356, 358, 359, 360, 361, 362, 363, 365, 367, 368, 369, 370, 372, 374, 375, 376, 377, 378, 379, 380, 381, 382, 384, 385, 386, 388, 392, 395, 396, 399, 400, 402, 406, 411, 407, 408, 409, 141, 425, 429, 438, 439, 445, 451, 453, 454, 470, 482, 483, 492, 493, 503, 505, 508, 600, 601, 602, 604, 606, 607, 700, 701, 702, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714,	21, 22, 23, 24, 32, 41, 42, 43, 44, 45, 46, 49, 51, 54, 59, 69	2, 3, 4, 5, 6	382-383-385	30-31-32-33	INSTRUMENTS, ELECTRONIC AND NON-ELECTRONIC MACHINERY
91, 92, 104, 105, 114, 123, 152, 180, 185, 187, 188, 192, 213, 238, 244, 246, 251, 258, 280, 293, 295, 298, 301, 303, 305, 410, 415, 417, 418, 440, 464, 474, 475, 476, 477	53, 55	5	384	34-35	TRANSPORTATION

TABLES AND FIGURES

Table 1 Patents at the USPTO by inventor's country

Year*	Argentina	Brazil	Chile	Colombia	Cuba	Mexico	Uruguay	Venezuela
1968	0	0	0	0	0	1	0	0
1969	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	2	0	0
1971	0	2	1	0	0	3	1	0
1972	7	5	0	0	0	10	0	1
1973	11	12	4	1	0	38	1	5
1974	27	21	6	7	0	72	0	3
1975	24	30	2	2	2	70	1	10
1976	23	25	3	8	1	45	1	9
1977	26	30	2	10	1	42	0	12
1978	22	32	5	4	1	46	0	13
1979	22	27	4	2	1	47	0	15
1980	25	31	2	6	0	43	1	14
1981	19	22	3	4	1	48	0	6
1982	16	27	2	7	1	49	0	10
1983	12	27	2	9	1	31	1	15
1984	15	34	4	3	0	42	0	17
1985	15	36	3	3	2	41	1	19
1986	21	38	9	5	0	52	0	29
1987	28	41	1	4	1	35	2	26
1988	13	38	3	9	0	42	2	17
1989	13	73	9	2	1	47	3	19
1990	29	46	7	9	0	45	1	30
1991	25	63	8	5	3	46	2	34
1992	27	66	13	13	3	55	2	34
1993	39	71	10	3	1	50	2	31
1994	49	115	5	13	6	70	2	28
1995	42	92	12	12	2	93	2	30
1996	53	90	24	5	4	91	2	34
1997	58	126	19	7	4	92	2	42
1998	63	124	13	9	4	113	0	43
1999	49	154	19	13	6	130	4	34
2000	76	163	13	15	10	138	2	40
2001	82	166	20	14	4	148	4	42
2002	60	191	20	9	3	108	4	28
2003	46	137	19	6	0	117	0	14
TOTAL	1037	2155	267	219	63	2102	43	704

Note: when the patent is a co-invention by inventors from different countries it is counted more than once
*application year
Source: USPTO-CESPRI

Table 2 Patents at the EPO by inventor's country

Year*	Argentina	Brazil	Chile	Colombia	Cuba	Mexico	Uruguay	Venezuela
1977	0	6	0	1	0	1	0	1
1978	0	15	0	0	0	1	1	1
1979	1	18	0	0	0	8	0	2
1980	14	16	1	1	0	7	0	2
1981	5	22	1	2	0	4	0	1
1982	6	23	0	7	0	14	0	1
1983	6	21	1	9	0	4	2	2
1984	6	24	4	0	0	4	0	4
1985	7	36	2	1	0	13	1	2
1986	7	18	1	1	0	9	1	5
1987	6	27	3	2	1	17	0	2
1988	10	27	2	0	0	18	1	6
1989	14	26	5	4	1	18	1	6
1990	19	51	6	3	9	14	1	3
1991	15	35	5	1	3	16	0	12
1992	17	58	1	5	3	24	0	4
1993	24	59	2	4	8	22	1	5
1994	16	46	6	6	6	35	0	9
1995	21	76	9	5	5	32	1	8
1996	40	68	11	2	5	56	2	10
1997	36	108	14	6	10	48	2	20
1998	48	115	6	5	6	55	4	17
1999	52	141	5	10	4	39	5	18
2000	59	136	12	9	14	59	5	14
2001	38	171	18	11	11	68	4	12
2002	53	152	17	6	20	78	7	2
2003	55	193	17	11	15	14	7	7
TOTAL	575	1688	149	112	121	678	46	176

Note: when the patent is a co-invention by inventors from different countries it is counted more than once
*priority date
Source: EPO-CESPRI
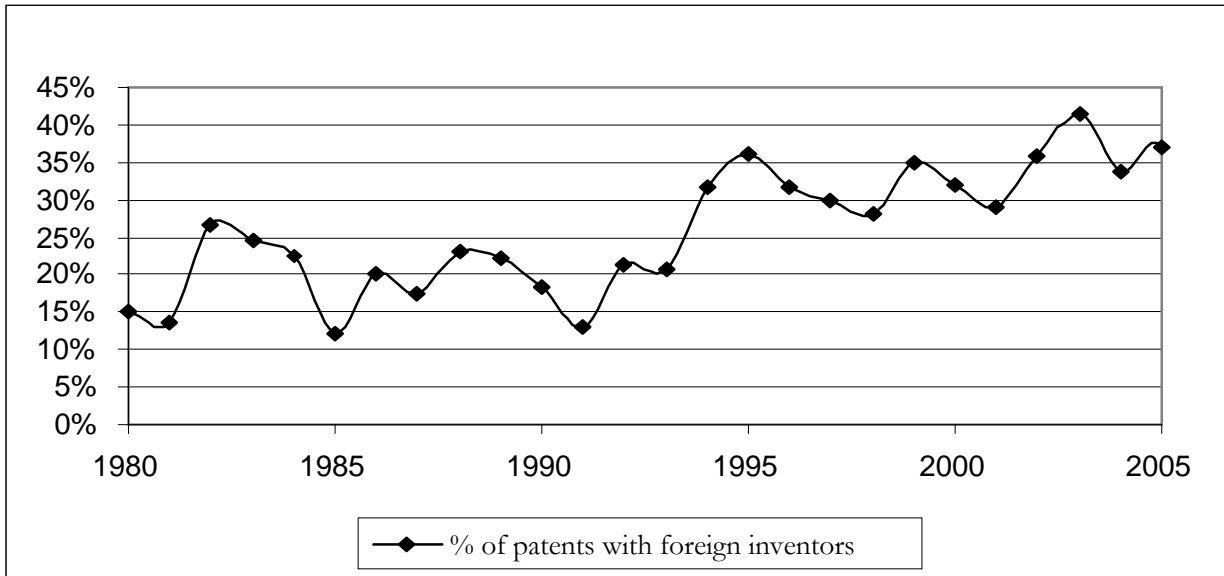
Fig. 1 Share of international co-invented patents in the total Latin American patents by inventors (USPTO)

Table 3 Top 16 applicants at the USPTO (1978-2001) and relative numbers of patents

Company	# of patents
INTEVEP	243
PETROLEO BRASILEIRO S.A. PETROBRAS	157
EMPRESA BRAZILEIRA DE COMPRESSORES S/A EMBRACO	70
HYLSA	66
CARRIER	51
HEWLETT-PACKARD	41
BAYER AKTIENGESELLSCHAFT	37
DELPHI TECHNOLOGIES	37
SYNTEX USA	34
VITRO TEC FIDEICOMISO	33
METAL LEVE	30
PROCTER & GAMBLE	30
METAGAL INDUSTRIA E COMERCIO	30
INTERNATIONAL BUSINESS MACHINES	24
PRAXAIR TECHNOLOGY	19
GENERAL ELECTRIC	18

Table 4 Share of backward citations of different regions by destination country (USPTO data)

	Citing Country										
Cited Country	Latin America	Canada	Europe 4	Japan	USA	Australia and New Zealand	East Europe	Four Tigers	India	Malaysia and Thailand	China
Latin America	**4.29**	0.17	0.14	0.06	0.14	0.28	0.22	0.13	0.22	0.37	0.25
Canada	2.53	**10.85**	1.68	0.96	2.06	3.27	1.98	1.81	1.80	1.83	1.97
Europe 4	14.34	11.26	**30.30**	9.69	9.88	13.10	17.11	7.56	16.71	10.04	11.20
Japan	9.08	9.60	1466	**50.01**	11.12	9.66	13.60	16.35	13.44	15.66	14.56
USA	*67.70*	*66.22*	*51.86*	*38.15*	*75.21*	*66.31*	*57.34*	*55.06*	*63.16*	*64.71*	*60.54*
Australia and New Zealand	0.87	0.78	044	0.20	0.47	**6.19**	0.49	0.42	0.51	0.43	0.44
East Europe	0.16	0.15	0.19	0.09	012	0.16	**8.72**	0.05	0.30	0.06	0.23
Four Tigers	0.89	0.88	0.64	0.78	0.92	0.95	0.36	**18.37**	0.76	4.92	8.01
India	0.07	0.04	0.04	0.02	0.04	0.04	0.10	0.03	**2.96**	0.06	0.05
Malaysia and Thailand	0.04	0.02	0.02	0.01	0.02	0.02	0.01	0.09	0.01	**1.83**	0.13
China	0.03	0.04	0.03	0.03	0.03	0.02	0.07	0.15	0.13	0.11	**2.61**
Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*

Source: own elaboration on USPTO-CESPRI. EU4 countries are: UK, Germany, France and Italy; East Europe: Lithuania, Latvia, Estonia, Belarus, Ukraine, Poland, Czech Republic, Hungary, Romania, Bulgaria; Four Tigers: Taiwan, Singapore, South Korea and Hong Kong.

Table 5 Number of co-inventors and share by countries and sectors

country	sector	Domestic inventors (a)	Foreign co-inventors(b)	SHARE of foreign inv. (b/a+b)	Share_Germany	Share_France	Share_UK	Share_Japan	Share_USA
AR	Textiles and Food	46	6	12%	0%	17%	0%	0%	83%
AR	Chemicals and Pharma	277	115	29%	17%	6%	1%	1%	75%
AR	Metals	4	0	0%	0%	0%	0%	0%	0%
AR	Instruments, electronics and non-electr. machinery	306	113	27%	0%	1%	0%	0%	99%
AR	Transportation	63	0	0%	0%	0%	0%	0%	0%
AR	Other	178	13	7%	0%	0%	0%	0%	100%
AR	**total**	**874**	**247**	**22%**	**8%**	**4%**	**0%**	**0%**	**87%**
BR	Textiles and Food	50	23	32%	0%	4%	4%	0%	91%
BR	Chemicals and Pharma	666	487	42%	43%	6%	4%	1%	47%
BR	Metals	112	10	8%	20%	0%	10%	0%	70%
BR	Instruments, electronics and non-electr. machinery	566	185	25%	10%	8%	3%	9%	70%
BR	Transportation	230	50	18%	38%	6%	4%	0%	52%
BR	Other	560	75	12%	15%	7%	7%	0%	72%
BR	**total**	**2184**	**830**	**28%**	**31%**	**6%**	**4%**	**3%**	**56%**
CL	Textiles and Food	19	2	10%	0%	0%	0%	0%	100%
CL	Chemicals and Pharma	112	57	34%	11%	0%	12%	0%	77%
CL	Metals	39	6	13%	0%	0%	0%	0%	100%
CL	Instruments, electronics and non-electr. machinery	51	17	25%	12%	0%	0%	0%	88%
CL	Transportation	19	0	0%	0%	0%	0%	0%	0%
CL	Other	29	7	19%	0%	0%	0%	0%	100%
CL	**Total**	**269**	**89**	**25%**	**9%**	**0%**	**8%**	**0%**	**83%**
CO	Textiles and Food	6	3	33%	0%	0%	0%	0%	100%
CO	Chemicals and Pharma	83	42	34%	36%	0%	2%	0%	62%
CO	Metals	3	2	40%	0%	0%	0%	0%	100%
CO	Instruments, electronics and non-electr. machinery	56	13	19%	0%	15%	8%	0%	77%
CO	Transportation	4	0	0%	0%	0%	0%	0%	0%
CO	Other	28	8	22%	0%	0%	0%	0%	100%
CO	**total**	**180**	**68**	**27%**	**22%**	**3%**	**3%**	**0%**	**72%**
MX	Textiles and Food	94	31	25%	0%	0%	0%	0%	100%
MX	Chemicals and Pharma	622	383	38%	18%	4%	2%	3%	72%
MX	Metals	172	40	19%	0%	0%	10%	0%	90%
MX	Instruments, electronics and non-electr. machinery	554	270	33%	5%	2%	1%	3%	90%
MX	Transportation	101	66	40%	11%	0%	0%	0%	89%
MX	Other	386	81	17%	1%	2%	1%	1%	94%
MX	**total**	**1929**	**871**	**31%**	**11%**	**3%**	**2%**	**2%**	**83%**

Table 6 Summary statistics for the regression variables

Variable	Number of observations	Mean	Std. Dev.	Min	Max
Patents	*400*	*7.9475*	*11.99121*	*0*	*69*
Foreign R&D tot	*400*	*51.35638*	*4.972934*	*43.33293*	*61.94098*
US R&D	*400*	*11.58586*	*1.398821*	*9.921598*	*14.11394*
Foreign R&D cit	*400*	*8.559491*	*5.028881*	*0*	*13.78447*
Foreign R&D coinv	*400*	*5.317824*	*5.824937*	*0*	*14.11394*
Value added	*400*	*5830.125*	*5984.256*	*101*	*24424*

Table 7 Estimation results of Equation 7. Dependent variable: log of the number of patents

	(1) Fixed Effect	(2) Fixed Effect	(3) Fixed Effect	(4) Fixed Effect	(5) Fixed Effect	(6) FE Negative Binomial
Total foreign R&D						
	0.095***				0.081***	
	(0.018)				(0.017)	
US R&D		0.301***	0.289***	0.246***		0.060
		(0.065)	(0.064)	(0.065)		(0.071)
Foreign R&D_cit			0.034***	0.032***	0.032***	0.064***
			(0.009)	(0.008)	(0.008)	(0.012)
Foreign R&D_coinv				0.027***	0.027***	0.028***
				(0.005)	(0.005)	(0.008)
Value added	0.191	0.251	0.286**	0.263*	0.213	0.182
	(0.150)	(0.146)	(0.145)	(0.145)	(0.143)	(0.130)
Constant	--4.99***	-3.83**	--4.60***	-4.05**	-4.66***	-0.670
	(1.45)	(1.46)	(1.55)	(1.59)	(1.40)	(1.35)
Observations	400	400	400	400	400	400
Number of i	25	25	25	25	25	25
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-squared (total)	0.8990	0.8971	0.9014	0.9086	0.9103	-
R-squared (within)	0.5062	0.4967	0.5177	0.5529	0.5612	-

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1 All variables are in logarithms. R&D depreciation rate 12%. We set zeros equal to one and allow the corresponding observations to have a separate intercept (zero dummy).

Table 8 Results for the IPS (2003) unit root test for panel data

Variable	lags	t-bar	W[t-bar]	Obs.	P-value
Log of patents	1	-2.358	-4.399	350	0.000
US R&D	1	1.866	17.679	350	1.000
Foreign R&D_cit	1	-2.120	-3.156	350	0.001
Foreign R&D_coinv	1	-2.042	-2.749	350	0.003
value_added	1	-2.095	-3.027	350	0.001
Total foreign R&D	1	3.532	26.388	350	1.000
Log of patents	2	-1.908	-2.440	350	0.007
US R&D	2	1.265	13.678	350	1.000
Foreign R&D_cit	2	-1.352	0.385	350	0.650
Foreign R&D_coinv	2	-2.007	-2.940	350	0.002
value_added	2	-2.084	-3.331	350	0.000
Total foreign R&D	2	1.389	14.309	350	1.000

Table 9 Dynamic panel, estimation of Equation 11. Dependent variable: log of the number of patents

	(1) WITHIN GROUP	(2) WITHIN GROUP	(3) GMM DIFF	(4) GMM DIFF
log_patents (t-1)	0.221***	0.240***	0.252*	0.211*
	(0.051)	(0.050)	(0.129)	(0.125)
Foreign_RD_cit	0.030***	0.029***	0.022	0.022
	(0.009)	(0.008)	(0.017)	(0.016)
Foreign_RD_coinv		0.029***		0.032***
		(0.005)		(0.006)
Value added	0.392*	0.312	0.308	0.203
	(0.220)	(0.212)	(0.266)	(0.248)
Observations	375	375	350	350
Number of i	25	25	25	25
Year dummies	Yes	Yes	Yes	Yes
R-squared (within)	0.5087	0.5522	-	
Sargan p-value	-	-	0.757	0.315
Sargan	-	-	25.24	34.24
Test AR(1) [p-value]	-	-	0.000	0.000
Test AR(2) [p-value]	-	-	0.524	0.359

Standard errors in parentheses. GMM results are one-step estimates. 4th, 5th, and 6th lags of dependent variable are used; other variables serve as their instruments. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. We set zeros equal to one and allow the corresponding observations to have a separate intercept (zero dummy).

Table 10 Estimation of Equation 7 and Equation 11 by sectors. Dependent variable: log of the number of patents

COEFFICIENT	Textiles and food		Chemicals and pharma		Metals		Machinery		Transport	
	static model (FE)	dynamic model (GMM)	static model (FE)	dynamic model (GMM)	static model (FE)	dynamic model (GMM)	static model (FE)	dynamic model (GMM)	static model (FE)	dynamic model (GMM)
log_patents (t-1)	-	0.23*	-	0.07	-	-0.08	-	-0.14	-	0.02
		(0.14)		(0.14)		(0.13)		(0.12)		(0.18)
Foreign R&D_cit	0.035***	0.07***	0.035	0.05***	-0.0061	0.05***	0.057**	0.07***	0.058***	0.07***
	(0.012)	(0.01)	(0.021)	(0.02)	(0.0099)	(0.01)	(0.028)	(0.01)	(0.021)	(0.01)
Foreign R&D_coinv	-0.0019	-0.00	0.050***	0.06***	0.018	0.03**	0.025**	0.04***	0.025**	0.01
	(0.011)	(0.01)	(0.015)	(0.01)	(0.015)	(0.01)	(0.012)	(0.01)	(0.012)	(0.01)
Value added	-0.15	0.18	0.40	0.70	0.96*	2.48***	0.13	0.47	0.24	0.06
	(0.32)	(0.89)	(0.42)	(0.86)	(0.48)	(0.61)	(0.27)	(0.37)	(0.18)	(0.29)
Constant	2.03		-2.12		-6.77*		1.06		-0.92	
	(2.94)		(3.24)		(3.91)		(2.06)		(1.33)	
Observations	80	70	80	70	80	70	80	70	80	70
Number of i	5	5	5	5	5	5	5	5	5	5
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sargan (p-value)		0.022		0.18		0.10		0.017		0.0038
R-squared (within)	0.656		0.631		0.637		0.735		0.705	
R-squared (total)	0.8530		0.8593		0.9077		0.9219		0.8965	

Standard errors in parentheses. GMM results are one-step estimates. *** p<0.01; ** p<0.05; * p<0.1. We set zeros equal to one and allow the corresponding observations to have separate intercept (zero dummy) estimates. 4th, 5th, and 6th lags of dependent variable are used.