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WP n. 225 **November 2008**

Stampato in proprio da:
Università Commerciale Luigi Bocconi – CESPRI Via Sarfatti, 25 20136 Milano
Anno: 2008

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

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November, 2008

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, United Kingdom, and United States). By using patents and patent citations at 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 spillovers: pure spillovers, patent citations 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 over the period 1988-2003. In particular we find that the stock of ideas produced in the US has a strong impact on the international patenting activity of these countries. Moreover controlling for US-driven pure spillover 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.

Jel Codes: O30, O10, O11

Keywords: Innovation, R&D Spillover, Knowledge flows, Latin America, Patents, Citations, Inventors

Acknowledgments: We would like to thank the participants to the WIPO-ECLAC Regional Expert Meeting on "Intellectual Property Systems and Technology Management in Open Economies: A Strategic Vision for Latin America" at the ECLAC in Santiago, Chile, the participants to the 12th International Schumpeter Society Conference, Brazil and the participants to the Workshop "Regional technological and industrial trajectories. Theoretical background and empirical observations" at the Max-Planck Institute of Economics, Jena. We would like also to thank Esteban Burrone, Mario Cimoli, Domenico Ferraro, Andrès Lopez, Annalisa Primi and Sebastiàn Vergara for useful comments and suggestions. The usual caveats apply.

1. Introduction

The international flows of technological knowledge affect importantly developing countries' ability to learn and innovate. Knowledge transmission from developed countries creates the conditions for developing countries to catch up with the technological frontier, 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 inter-personal 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 implications 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 the international patent production in a selected number of Latin American countries (LACs). We ask whether foreign R&D activity affects innovative performance of LACs at industry level via different channels of international knowledge flows. In particular we focus on three mechanisms: pure spillovers, patent citations related spillovers, and face-to-face contact spillovers based on co-inventorship relations[1]. Of course there are also other important channels of technological transmission we do not deal with, such as FDIs and bilateral trade. These channels affect in particular countries' total factor productivity.

However 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 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 (Textile 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 Germany, Japan, UK and US) in the years between 1988 and 2003. We process the information

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[1] Keller (2004) provides a survey of the literature on international technology diffusion. Among others, Coe et al. (1997) find empirical evidence that total factor productivity in developing countries is positively related to R&D preformed in industrialized countries and that the flows of knowledge is captured by bilateral trade.

contained in the US Patent and Trademark Office (USPTO) patent documents and their citations to build the different indexes of R&D spillovers. Also we match USPTO patent data with economic data taken from different sources at the sectoral level and control for the dynamics of domestic value added and past innovative activity.

Overall this paper provides a detailed account of the nature, sources and determinants of international patenting activity in Latin American countries at the descriptive level. 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 the 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 pure spillovers 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.

The reminder of the paper is as follows. In Section 2 we provide a quick 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 behaviours. To have a clearer picture we use data from different sources (i.e. the US *and* European Patent Office). 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 last Section we conclude, discuss some important limitations and propose some directions for future work.

2. Background

This paper extends the 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 country external sources of knowledge - that originates spillover or is 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 et al. 2005; Dosi and Cimoli, 1995).

There is a vast literature that assesses international knowledge spillovers among developed countries[2]. Estimated international R&D spillovers effects are typically significant and positive[3]. Recent 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 affect significantly 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[4].

In the case of developing country there is a large literature on the microeconomic effects of FDIs spillovers on total factor productivity[5] but still there is scant aggregate evidence of R&D spillovers on countries' innovative output at sectoral and national level. This paper focuses on two specific vehicles of knowledge spillovers: patent citations and collaboration via co-inventorship.

Patent citations as channel 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. Albert et al. (1991) and Trajtenberg (1990) 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 approx 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 consolidate stream of literature uses patent citations to track knowledge flows

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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 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 the multinational and domestic companies (Katrak 2002).

[3] Some recent empirical works have analyzed 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 innovation to R&D done in other regions at various distance, finding that the effects of R&D in generating innovation are quite localized (see also Keller 2002, Maruseth and Verspagen 2002, Peri 2005).

[4] For a survey see also Breschi et al. 2005.

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

and spillovers (Jaffe et al. 1993, Jaffe and Trajtenberg 1996, Jaffe and Trajtenberg, 1999; Maurseth and Verspagen 2002, Malerba and Montobbio 2003, Peri 2005).

Provided that knowledge flows are inherently difficult to measure and that 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 been often used to identify the direction of these knowledge spillovers among countries. If, for example, a patent with an inventor's address from Argentina cites a patent with an inventor's address in US, we could assume that some knowledge created in the US has been used in Argentina and as a result patent citations could track the direction of knowledge spillovers among the two inventors and the two countries.

Patent co-inventors as channel 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 collaboration 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 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, by 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 side 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 side, 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, at least periodically, face-to-face interactions 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 session 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 Appendix. Table 1 shows 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 patenters at the USPTO are Brazil and Mexico with respectively 1715 and 1783 patents granted in the period 1968 to 2001. Argentina and Venezuela follow with 881 and 640 patents. At the EPO, for the period 1978-2001, Brazil has the highest share with 1244 patent applications, Mexico, Argentina and Venezuela follow with 486, 445 and 160 patent applications, respectively (see table 2). 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.

[Table 1 about here]

[Table 2 about here]

It is important to underline that an increasing share of the total Latin American invented patents filed in the US are the result of a collaborative activity with foreign (in particular US see below 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. University 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 reflect 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, however it is possible to use EPO data on patent applications to understand what difference does it make to count patents using the applicant's address[6]. As expected counting patents with the applicant's address reduces the number of patents in the main countries of approx. 41% (from 2636 to 1565, in the period 1977-2001, EPO data) with respect to patents with inventor's address. It is worthwhile noting that out of 2636 Latin American invented patents there are only 1520 (56%) Latin American owned patents[7] (i.e. patents in which the applicant's address is in a Latin American country). The rest is owned by foreign companies (1213 – 44%)[8] (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 a foreign inventor is significantly lower (9%) than in the case of Latin American 'invented' patents. This points at a low degree of internationalization of patenters 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 internationalisation of research and the location of research and legal facilities by multinational firms and partly the fact the some Latin American inventors may be temporarily (or in some cases even permanently) active abroad and declare their address in Latin America.

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[6] For simplicity we use the term 'Latin American owned patents' to refer to patents assigned to countries using the applicants' address and the term 'Latina American invented patents' to refer to patents assigned to countries using the inventors' address. It has to be emphasized that the 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*.

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

[8] The sum is not 2636 because we counted the patents more than once in case of co-applicants from different countries.

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[9]. Table A1 shows the number and distribution of patents granted at the USPTO at the sectoral level. We observe that Chemicals and Pharmaceuticals and Instruments, Electronics and non Electrical Machinery are the two sectors that capture the 80% of the total patents in Latin America, while, not surprisingly in traditional sectors such as Textile and Food the number of patents represents only 4% of the total. Table A1 shows also the number and distribution of patents by country: Chile seems to have a comparative good production of patents in Metals, while Brazil displays a considerably high share of patents in Transportation.

3.3 Individual inventors

A more detailed look at these patents shows that many patents' assignees are individual inventors. If we assign a patent to a country using the applicant's address, 41.5% of Latin American patents at the EPO are owned by individual inventors. At the USPTO 37.3 % of the "Latin American invented" patents granted are 'individually owned' [10]. These shares are considerably higher than average, considering that for all patents at the USPTO and at the EPO the shares of individually owned patents are respectively 23% and 11%[11]. 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 less resources to invest (relatively to firms in the 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 such patents may actually belong to companies but have been put under the name of the owner as the applicant. This could be the case of micro companies, family companies or partly-informal companies. Given the great uncertainty of survival of small and medium companies - in a

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[9] We use the US Patent Classification in order to re-aggregate patents in five classes (Textile and Food, Chemicals and Pharmaceuticals, Metals, Machinery, and Transportation) and match them with data on economic activity (see Table A4 in Appendix for the concordance table)

[10] Moreover in LACs there is a quite high heterogeneity across countries. The countries with the highest share of patents owned by individual inventors are Argentina (72%), Colombia (73 %) and Chile (59%). Of course if we look again at the EPO data and consider Latin American invented patents, we discover that the share of Latin American invented drops to 25.2 %. Again the countries with the highest share are Argentina (46 %), Chile (40.5%), Colombia (37.7%) and Uruguay (33.3%). This means that very few foreign assignees of Latin American invented patents are individual inventors. Looking at the USPTO data Argentina (61.7 %), Colombia (55.1 %), Uruguay (52.5%) and Mexico (42.4%) have 'individually owned' patent shares that are higher than the average

[11] 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 the registration at the patent office.

macro-economic context that often is 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 might be some exceptions to this negative interpretation, though. Some inventors, active abroad, keep the address of their home country. This inventive activity could be valuable, and these individual patents could signal co-operation with foreign countries and be important vehicle of knowledge transfer[12] as emphasised in the previous sections.

3.4 Applicants

There is not a very high concentration of the assignees or applicants of international patents at the USPTO and EPO in Latin America. Many assignees or applicants are, in a large number, different individual inventors [13] and among top applicants we find many US and German multinational companies. There are some big Latin American patenters, like Petrobras, Embraco or 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 high tech and high growth sectors like Electronics, Telecommunications or Pharmaceuticals.

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

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 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.

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

[13] 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 one is Luiz Carlos, Oliveira Da Cunha Lima with 6 patents.

[Table 3 about here]

3.5 Citations

In order to address the issue of knowledge flows, in this section we track the citation flows between Latin American countries and other geographical areas in the world. Using USPTO citation data in 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 the patents with the inventors' 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 the cited countries[14] (e.g. Latin American patents cite ten times Chinese patents equivalent to the 3% of the total Latin American backward citations).

[Table 4 about here]

Table 4 shows a very low share of citations among Latin American countries (4.29% of citations). This is similar to other countries like China and India. Approximately 70% of the citations done and received are from US patents[15]. 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 the 0.14% 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 column (1) and (2) we show the number of inventors of USPTO patents that declare their residence respectively in the Latin American country and

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

[15] We have also build the same matrix using EPO data. Interestingly these shares drop to approximately 36% if we consider EPO patents. At the same time within the USPTO data knowledge flows with Europe are approximately 12% of the total, and at the EPO are approximately 42% of the total. This my be the result of a home bias effect by patent examiners. For a discussion on this point see Montobbio (2007) and Bacchiocchi and Montobbio (2008).

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 (US, 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 the 31% of the total inventors of Mexican patents. At the opposite end we find Argentina where the G-5 co-inventors represent only the 22% of the total number of inventors. Looking at the bilateral relationship it is worthwhile noting that the great majority of foreign inventors comes from the US: in all the LACs considered the lower share is for Brazilian patents with 56%. However it is possible to distinguish different patterns of *co-inventorship*. Brazil has a higher co-inventors network with Germany (31%) and France (6%) with respect to other LACs, while Chile seems to have a significant collaboration with 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.

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 Griliches (1984) and Malerba et al. (2007) we start from the following KPF that relates R&D investments and the production of technological output:

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

where $Q_{h,i,t}$ is some 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 $\nu_{h,i}$ 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 the international level. As emphasised in the previous section we compare three different modes of knowledge flows. 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):

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

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:

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

We cannot directly estimate (4) because we do not have data on national R&D effort 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 measure related with the trend in 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 $X_{h,i,t}$:

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

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

$$IS_{h,i,t} = \prod_{f} R^{\lambda_{h,f,j,t}}_{f,j,t} \tag{6}$$

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 US, 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 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, Mexico) and five industrial sectors (Textile and Food, Chemicals and Pharmaceuticals, Metals, Instruments Electronic and Non Electrical Machinery, and Transportation) in the period 1988-2003. 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. Data sources and sectoral aggregations are thoroughly explained in Appendix. Equation (5) captures the effect of the R&D effort performed in foreign countries on the production of USPTO patents by Latin American inventors. Taking logs of (5) we propose to estimate the following logarithmic specification:

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

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)[16]. Central to this paper is the calculation of the 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 1$ in R&D will have a direct impact on the knowledge production in other countries. We call this variable:

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

*foreign*R*&D_tot* is equal to the sum of the logarithm of R&D stocks in the main G-5 industrialized countries: US; JP, UK, FRA and DE. In this case all weights $\lambda_{h,f,j,t}$ are set equal to 1. In addition we

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[16] It is important to remark that the arbitrary assumption on the size of the depreciation rate does not affect importantly the results. We have re-run all the regressions with δ=0.08 but results do not change. The estimated values with a R&D stocks calculated with δ=0.08 are not displayed but are available from authors.

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 US are particularly important in terms of spillovers generated to Latin American countries. Therefore in our regressions we control for this aspect and consider also 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 LACs countries and the G5 countries we considered. Each cell of the matrix is the number of citations in patents with at least an inventor resident in a LAC country to patents with at least an 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 spillover (*foreign*R&D_*cit*) is calculated as follows:

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

The third spillover effect we consider is related to interpersonal links and possibly face-to-face contacts. In this case the signal that some knowledge flow occurs is that inventors have worked together on the same invention. We use USPTO patent data to build a second set of matrices. In this case each cell *(h,f)* of the matrix is the number of patents with at least an inventor resident in country *h and* an inventor resident in country *f*. Again we build 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 behaviours 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[17]. Therefore we start with a set of *static* regressions using fixed effect model. 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 consistently with the second step of this econometric exercise.

6.1 Static panel

We start then estimating equation (7) using Fixed Effect. Heteroskedasticity robust standard errors are applied. We take the log to have the 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 overall economic changes.

Table 7 reports the robust Fixed Effect estimates of the parameters. All the specifications explain approximately the 90% of the variation in international patenting. The first column includes only total foreign R&D stock (i.e. US, Japan, Germany, UK, and France) as input of the innovation function: an increase of 1% in total foreign R&D stock increases by 0.095% the innovative activity in terms of international patenting of our LACs. In Column 2 we assume that only R&D expenditures in the US have a spillover effect on international patenting. The result shows a strong positive spillover effect from US R&D stock: the estimated coefficient is equal to 0.3 and statistically significant at 1 percent level. Note that the size of this estimated coefficient is three time higher than in the case of total foreign R&D. This variable controls for pure spillover 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 the US R&D stock we proceed in columns (3), (4), and (5) adding as regressors the other 'embedded' international spillover mechanisms measured by the variables IS_2 and IS_3. These coefficients show that external R&D

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

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 size being respectively 0.032 and 0.027 and are significant at the 1% level. Our results suggest that a significant portion of international knowledge spillovers is embedded or in codified documents, such as patents that 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, but 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. But 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 over 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 have run the fixed effect model dropping the observations where the number of patents is zero. Results do not change substantially. The coefficients associated to the spillover measured by citations and by co-inventors are significant and positive. In particular a 1% increase in citation-weighted R&D generates a 0.029% increase in the domestic innovative output, while for the co-inventors-weighted R&D we get a significant coefficient of 0.024%. The R&D performed in US has the greater impact with a estimated elasticity of 0,24% (see Table A4 in the Appendix).

6.3 Stationarity tests

Our estimates rely on the assumption that our variables are stationary or cointegrated and it is in fact possible that serial correlation is spuriously driving the above results. We therefore perform the panel unit root test developed by Im, Pesaran, and Shin test (2003)[18]. Under the assumption that the

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[18] This test has the advantage of elasticity regarding the specification of individual time trend and length of time lags.

time series are independent across *i*, the null hypothesis is that all the series are non-stationary; under the alternative some of 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[19]. 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 the 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 a AR(1) process, and the number of patents at time *t* is also 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. Include a lagged dependent variable we have therefore 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 the 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 serial correlated – because of a possible bias by the omitted individual specific effects (Greene, 2003). The Ordinary Least Squares (OLS) estimator of γ in the equation (11) is inconsistent, since the explanatory variable is positively correlated with the error term due to the presence of the individual effects. The Within Group estimator eliminates this source of inconsistency

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

by transforming the equation in order to eliminate the individual (country-sector) effect $\eta_{h,i}$. Specifically 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 effect 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 be also 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 the 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 is 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 the instruments are "internal", that is based on lags of the instrumented variables. In particular in our case lags of the dependent variables or lags of first differences must be correlated with the first difference and uncorrelated with the disturbance [20].

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 in the specification foreign R&D stocks and US R&D stocks. This would return biased results. Sargan test of over-identifying restrictions satisfies the underlying assumptions of the Arellano and Bond approach suggesting that estimates reported are consistent and efficient[21]. Our results suggest that indeed it is important to control for a lagged dependent variable that is always statistically significant. International patenting is 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, on the other hand the estimated coefficient for international spillover captured by co-inventors is still positive and significant. This result is important because it emphasises the role played in international technological transmission by collaboration and person-to-person contact.

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[20] Only 4th, 5th and 6th lags of dependent variable are used.

[21] We have run also "System GMM" obtaining similar results: the estimated values are not displayed but are available from 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.

[Table 9 about here]

6.5 Differences across sectors

In this section we enquiry the differences in terms of types of knowledge spillovers across sectors. We assume therefore that parameters $\gamma, \alpha_1, \beta_1, \beta_2$ and β_3 in equation [11] are industry specific. Table 10 shows therefore 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 taken 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-inventorhip plays a sensible and positive role mainly in the Chemical and Pharmaceutical sector, Instruments and Machinery and Metals with estimated elasticities equal respectively to 0.06, 0.04 and finally 0.03. It's worthwhile noting that value added affects importantly international patenting only in Metals.

7. Conclusions

A large body of literature emphasizes that international flows of technological knowledge affect importantly 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 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: pure spillovers, 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 (Textile and Food, Chemicals and Pharmaceuticals, Metals, Instruments Electronic and Non-Electrical Machinery, and Transportation), five LACs (Argentina, Brazil, Chile, Colombia and Mexico) and the G-5 countries (France Germany, Japan, UK and US) 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 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). We show also that individual inventors play a prominent role that is difficult to interpret but it's linked to the fragile structure of many innovative activities in these countries.

Secondly 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 in the period considered. In particular the stock of ideas produced in the US seems to have a strong impact of the international patenting activity of these countries. Moreover, controlling for these US-driven pure spillovers effects, bilateral patent citations and face-to-face relationships between inventors are both important *additional* mechanisms of knowledge transmission. Some of our results suggests that the latter is more important than the former. Finally we find some sectoral differences: knowledge flows measured through co-inventorhip plays a particularly important role mainly in the Chemical and Pharmaceutical sector, Instruments and Machinery and Metals.

This has 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 and 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 the network relations of local inventors and companies.

However these policy conclusions have to be handled with extreme care due to some important limitations of this study. First of all we consider an extremely tiny 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 the other important channels of technological transmission we do not consider, 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 variable 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 different big developing countries and show that are importantly influenced by the sectoral structure of the economy. In this respect important complementarities should be developed with the large number of qualitative and quantitative studies that address the issues of knowledge transmission at the micro level (e.g. Crespo Fontuora, 2007 and footnote 2).

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Appendix.

Data.

Our study starts using different databases for eight Latin American countries (Argentina, Brazil, Chile, Colombia, Cuba, Mexico, Uruguay, Venezuela) and five industrial sectors. In the econometric analysis we consider only 5 countries: Argentina, Brazil, Chile, Colombia, Mexico. Patent data are collected from EPO-CESPRI and USPTO-CESPRI database, R&D expenditure in the private business sector from OECD-ANBERD, and OECD STAN (2005) database. Economic data are taken for the PADI-CEPAL database (Programa de Análisis de la Dinámica Industrial) that processes consistently economic data at the sectoral level from national statistical sources. In particular we use the value added in real terms (millions of $1985).

Manufacturing sectors are defined following the International Standard Industrial Classification (ISIC – Rev.3). Our analysis is at industry level and we consider 5 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 EP-CESPRI database. The USPTO database contains 3,583,811 patents from 1963 to 2002. The EP-CESPRI database contains 1,391,350 from 1978 to 2002.

The following characteristics of patents are particularly relevant. Firstly, patents are dated with the 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. Secondly, the country of a patent, as explained in Section 3, could 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' address). It should also be noted that patents include information on the stated address (and country of residence) of the inventor rather than her or his nationality. Thirdly, 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 OECD-ANBERD (2005) dataset. We use the R&D flows, valued in US purchasing power parity, and convert them into constant 1995 prices. The deflators used for that 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[22]:

$$R\&D\_stock_t = (1-\delta)R\&D\_stock_{t-1} + R\&Dflow_{t-1}$$

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[23]. 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.

Table A1. Number and distribution of USPTO patents by sector and country.

	Textile 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.

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

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

Table A2. Correlation matrix.

	Log (Pa)	ForeignR&D _Tot	US R&D	ForeignR&D _cit	ForeignR&D _coinv
Log (Pa)	-				
ForeignR&D _Tot	*0.4881**	-			
US R&D	*0.4073**	*0.9598**			
ForeignR&D _cit	*0.6710**	*0.3318**	*0.3243**	-	
ForeignR&D _coinv	*0.7280**	*0.3813**	*0.3022**	*0.4674**	-
value_added	*0.3740**	*-0.3885**	*-0.3821**	*0.1696**	*-0.1922**

Table A3. Robustness check

COEFFICIENT	(1) Fixed effect	(2) Fixed effect	(3) Fixed effect	(4) Fixed effect	(5) Fixed effect	(6) FE Negative Binomail
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 A4. 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	TEXTILE 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	INSTRUMENT, 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**	AR	BR	CL	CO	CU	MX	UY	VE
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**	AR	BR	CL	CO	CU	MX	UY	VE
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

Figure 1. Latin American Patents by inventors (USPTO): patterns of collaboration over time.

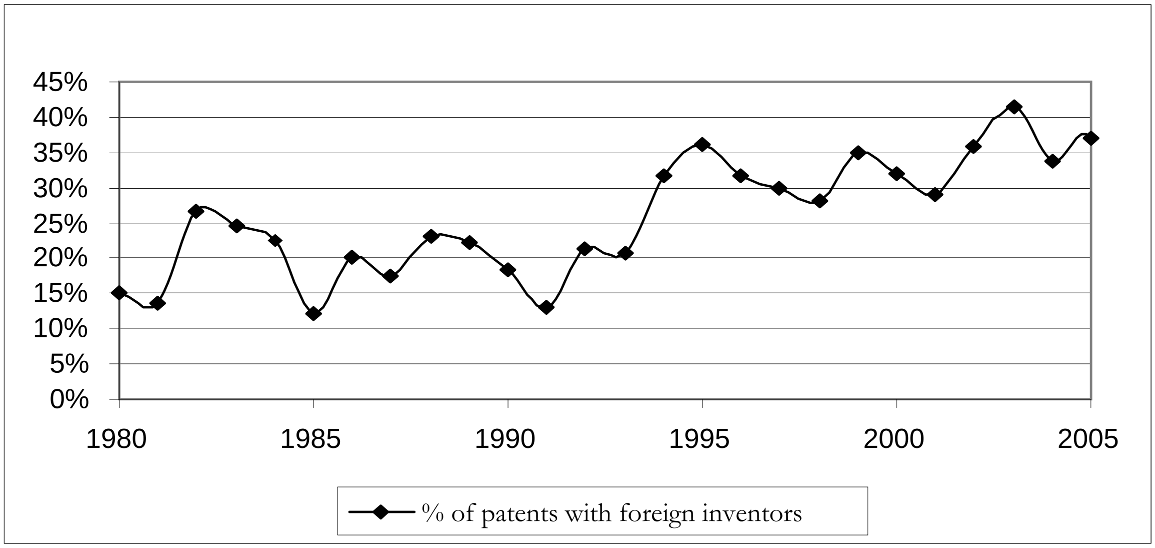

Table 3. Top 16 applicants at the Uspto (1978-2001) and relative number of patents.

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 U.S.A	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. Citations matrix: citations distribution by cited country for each citing country (USPTO data).

	Citing Country										
Cited Country_	**Latin_America**	CA	EU_4	JP	US	Australia_N	East_Europe	Four_Tigers	India	Malaysia_Th	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
CA	2,53	**10,85**	1,68	0,96	2,06	3,27	1,98	1,81	1,80	1,83	1,97
EU_4	14,34	11,26	**30,30**	9,69	9,88	13,10	17,11	7,56	16,71	10,04	11,20
JP	9,08	9,60	14,66	**50,01**	11,12	9,66	13,60	16,35	13,44	15,66	14,56
US	*67,70*	*66,22*	*51,86*	*38,15*	***75,21***	*66,31*	*57,34*	*55,06*	*63,16*	*64,71*	60,54
Australia_N	0,87	0,78	0,44	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	0,12	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_Th	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

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	Textile 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	Textile 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	Textile 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	Textile 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	Textile 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.

Variable	Obs	Mean	Std. Dev.	Min	Max
Patents	*400*	*7.9475*	*11.99121*	*0*	*69*
ForeignR&D_tot	*400*	*51.35638*	*4.972934*	*43.33293*	*61.94098*
US R&D	*400*	*11.58586*	*1.398821*	*9.921598*	*14.11394*
ForeignR&D_cit	*400*	*8.559491*	*5.028881*	*0*	*13.78447*
ForeignR&D_coinv	*400*	*5.317824*	*5.824937*	*0*	*14.11394*
Value added	*400*	*5830.125*	*5984.256*	*101*	*24424*

Table 7. Spillover determinants of patents (robust standard errors in parenthesis).

COEFFICIENT	(1) Fixed Effect Log (patents)	(2) Fixed Effect Log (patents)	(3) Fixed Effect Log (patents)	(4) Fixed Effect Log (patents)	(5) Fixed Effect Log (patents)	(6) FE Negative Binomail Number of patents
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 logarithm.
R&D depreciation rate 12%

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. Dep. Variable Log 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

Table 10. Spillover determinants of patents by sectors (robust standard errors in parenthesis).

COEFFICIENT	Textile and food		Chemicals and pharma		Metals		Machinery		Transports	
	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	

*** p<0.01, ** p<0.05, * p<0.1

All variables are in logarithm.

GMM results are one-step estimates, following Arellano-Bond (1991). 4th, 5th, and 6th lags of dependent variable are used; other variables serve as their instruments.