Knowledge Flows and International Patenting in Latin America

Bocconi

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Premise

- Three sources
  - Montobbio F. (2008); Patenting Activity in Latin American and Caribbean Countries. In World Intellectual Property Organization(WIPO) - Economic Commission for Latin America and the Caribbean (ECLAC) - Study on Intellectual Property Management in Open Economies: A Strategic Vision for Latin America".
  - Montobbio F., Sterzi V. (2008); Knowledge Flows and International Patenting Activity in Latin American Countries, Working Paper CESPRI 225
  - Montobbio F., Primi A., and Sterzi V. (2009); Meet me after the TRIPs. Does IPRs Reinforcement Facilitate International Technological Cooperation?

Outline of the presentation

- WIPO_ECLAC report on international patenting
  - Who patents internationally ?
  - In which sectors ?
  - Is there any process of structural change or specialization going on in the last two decades in Latin America ?

- Understanding knowledge flows for the subset of actors that patent abroad
  - A comparison of different types of knowledge flows
  - How international knowledge spillovers affect international patenting activity ?

- How IPRs reinforcement and TRIPs agreement affects different types of knowledge flows

Number of patents at the USPTO

*Year**	Argentina	Brazil	Chile	Colombia	Cuba	Mexico	Uruguay	Venezuela
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 1968-2003	*1037*	*2155*	*267*	*219*	*63*	*2102*	*43*	*704*

Number of patents at the EPO

*Year**	Argentina	Brazil	Chile	Colombia	Cuba	Mexico	Uruguay	Venezuela
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 1978-2003	*575*	*1688*	*149*	*112*	*121*	*678*	*46*	*176*

Latin American patents at the USPTO vis à vis other geographical areas (by inventor's country)

Geographical Area	_85_89	_95_99	Growth rates between the period 85-89 and 95-99.
Latin America	703	1673	81,65
East Europe	1009	971	-3,84
Malaysia & Thailand	42	383	160,47
Four Tigers	2774	21617	154,51
Australia & NZ	2462	4828	64,91
China	249	789	104,05
India	162	830	134,68
US	218059	434567	66,35
Japan	88707	161186	58,01

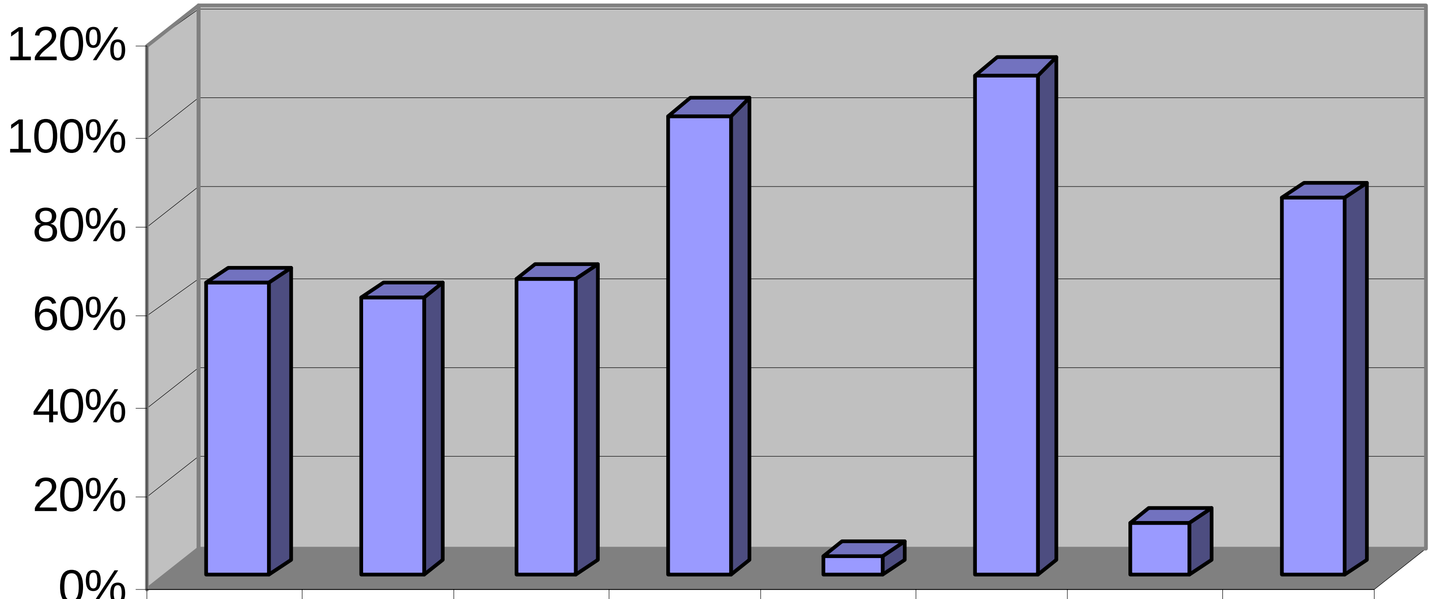
Inventors and Applicants

Latin America invented and Latin America owned patents

- *LA invented* patents
  - with at least an inventor with a LA address
  - It should reflect more directly the tech. activity of a country
- *LA owned:* patents
  - with at least an applicant with a LA address
  - It indicates ‘ownership’
  - Warning: often it is a foreign owned MNC
- **LA owned are 44% less than LA invented**

Latin American invented patents - Latin American owned patents

Latin American owned patents



	AR	BR	CL	CO	CU	MX	UY	VE
difference (%)	65%	62%	66%	102%	4%	111%	12%	84%

Inventors

- 35% of Latin American (owned) patents at the EPO are owned by *individuals*
  - 72% in Argentina, 73% in Colombia, 59% Chile
  - On average at the EPO is 11%
- Less economically valuable
- Small and medium enterprise
- Few important inventors ? (often active abroad)

Top applicants at the EPO

UNILEVER	NL and GB	79
EMPRESA BR. DE COMPR. - EMBRACO	*BR*	*69*
PETROBRAS	*BR*	*69*
INTEVEP	*VE*	*48*
BAYER	DE	39
PROCTER & GAMBLE	US	37
CENTRO DE ING. GENETICA Y BIOTEC	*CU*	*32*
JOHNSON & JOHNSON	*BR and US*	*27*
VOITH	DE	23
HYLSA	*MX*	*21*
PRAXAIR TECHNOLOGY	US	21
BASF	DE	20
MULTIBRAS S.A. ELETRODOMESTICOS	*BR*	*16*
METAGAL INDUSTRIA E COMERCIO	*BR*	*15*
CENTRO DE INMUNOLOGIA MOLECULAR	*CU*	*14*
ROBERT BOSCH	DE	14
HOECHST	DE	13
DELPHI TECHNOLOGIES	US	12
GENERAL ELECTRIC	US	12
SYNTEX	US	10
SERVICIOS CONDUMEX	*MX*	*10*

Top applicants at the USPTO

INTEVEP	243
PETROLEO BRASILEIRO S.A. PETROBRAS	157
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
INSTITUTO POLITECNICO NACIONAL	17
CARDIOTHORACIC SYSTEMS	17
COLGATE-PALMOLIVE	15
INDUSTRIAS ROMI	15
T & R CHEMICALS	15
VIDRIO PLANO DE MEXICO	15
SERVICIOS CONDUMEX	15

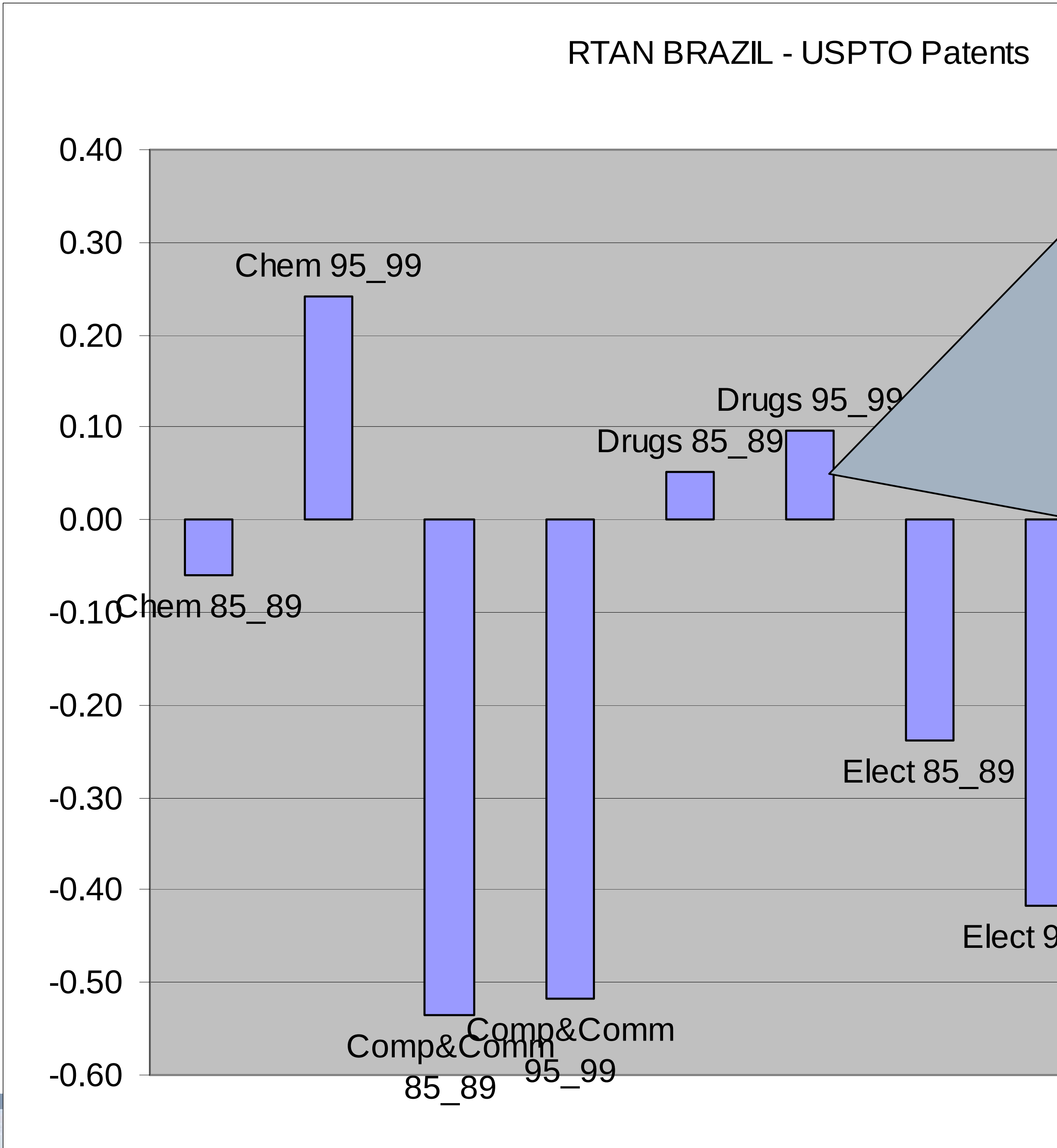
The technological specialization

World patent share in different sectors in two sub-periods (USPTO data)

	Latin America			China + India		
	85-89	*95-99*	*Diff.*	*85-89*	*95-99*	*Diff.*
Chemical	0,189	0,337	0,148	0,162	0,416	0,254
Computers & Communications	0,059	0,065	0,006	0,043	0,17	0,127
Drugs & Medical	0,268	0,372	0,104	0,184	0,403	0,219
Electrical & Electronic	0,071	0,080	0,009	0,077	0,141	0,064
Mechanical	0,191	0,222	0,031	0,073	0,108	0,035
Others	0,223	0,314	0,091	0,08	0,103	0,023

International Technological Specialization (ITS) in LACs

- In the period 95_99 LA countries are specialised in Chemicals, Drugs&Medical and 'Others'
- They are heavily de-specialised in Electrical and Electronics and Computer&Communications
- Mexico is the only Latin American country which improves its patent shares and ITS in both Electrical and Electronics and Computer&Communications
- Latin American countries have a very high degree of ITS
- There is a broad stability of technological specialization between 85 and 99
- We observe an increased level of overall specialization in particular for Chile and Venezuela but also for Argentina, Brazil and Uruguay



190 patents

Very dispersed ownership

Approx. 1/3 with l.a. address

Top patenters

Individually Owned (57)
Johnson & Johnson (10)
Fond. Osvaldo Cruz (5)
St.Jude Medical (4)

19 patents from US universities or medical schools

Knowledge Flows

Patent citations and network of coinventors

- Pure knowledge flows

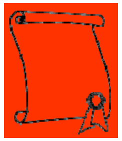
- USPTO patent citations as a noisy vehicle of knowledge spillovers (Jaffe et al. 2000, Hall et al. 2001, Jaffe et al. 2000)
  - Codified knowledge flows

- Social network as a significant mechanism for diffusion of knowledge (Singh, 2005; Breschi, Lissoni 2008)
  - Non codified knowledge flows: e.g technical know, non standard production

Stylized Facts (1) - Latin American patents: Forward and Backward Citations

Number of citing patents (%)

Latin_Am	1344	5,35
EU_4	2620	10,42
JP	1572	6,25
US	18090	71,98



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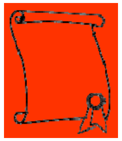
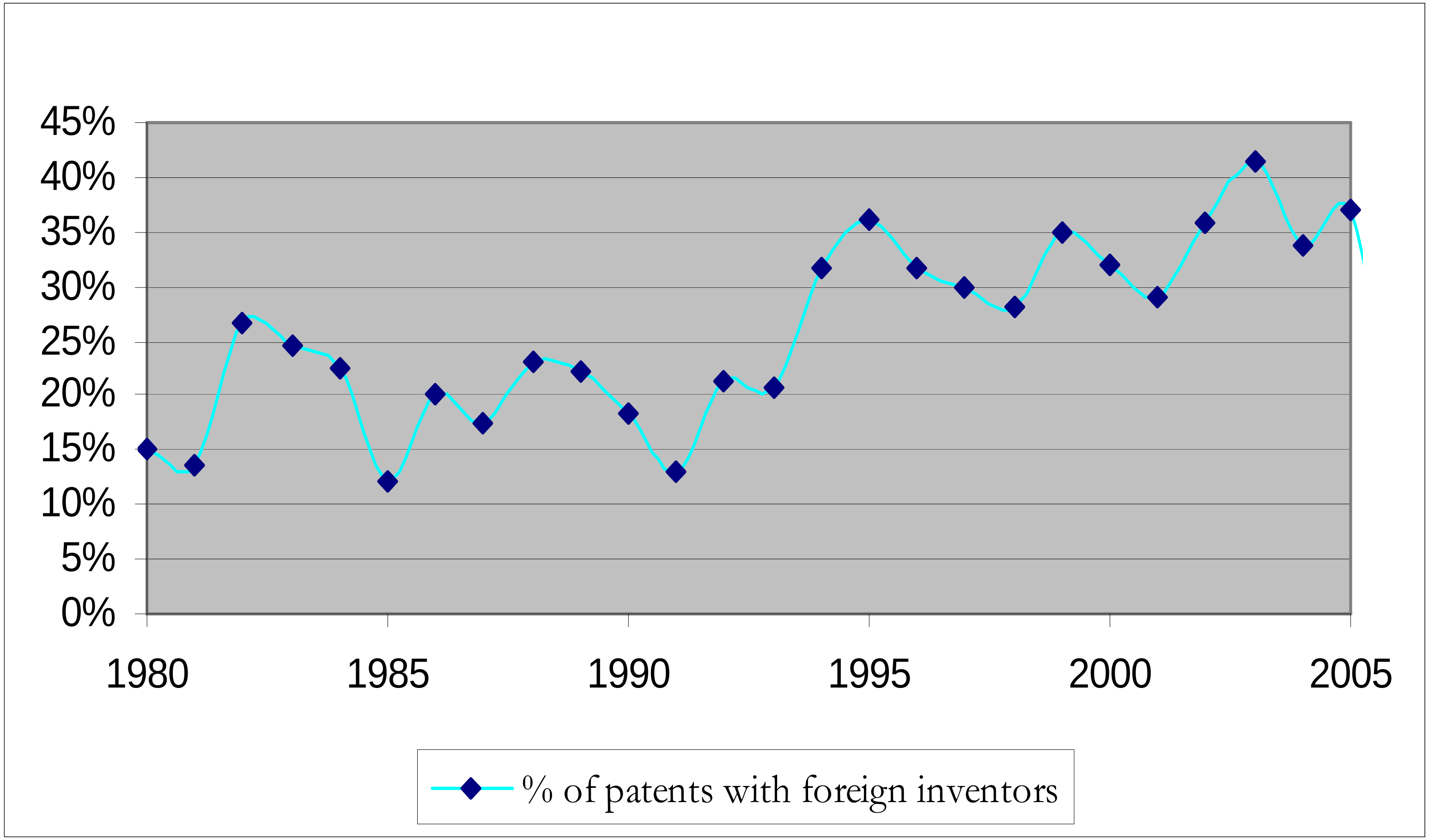
Number of cited patents (%)

Lat_Am	1344	4,29
EU_4	4498	14,34
JP	2849	9,08
US	21234	67,70

 : Latin American patent

Stylized Facts (2) – Pattern of Collaboration Over Time in Latin American Countries



Data

- Patent data: USPTO
  - Years: 1988- 2003
  - Data on tech class (USPC), firms and individuals
- PADI-CEPAL:
  - Value added in real terms, [employment, trade]
- ANBERD Database for external R&D (USA, UK, FR, DE, JP)
  - The R&D capital stocks are estimated using the perpetual inventory method (rate of depreciation δ=0.12)
- MEXICO, BRAZIL, ARGENTINA, CHILE, COLOMBIA.
- Textile and Food - Chemicals and Pharma - Metals

  - Instruments, Electr and non electr. machinery - Transportation

The empirical model

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

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

-We use R&D stocks in the G-5 countries or R&D stocks in the US

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

-*CIT*: relative number of *citations* flowing from country h to a foreign country f in year t

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

-*COINV*: relative number of *co-inventors* from country f for patents of country h in year t

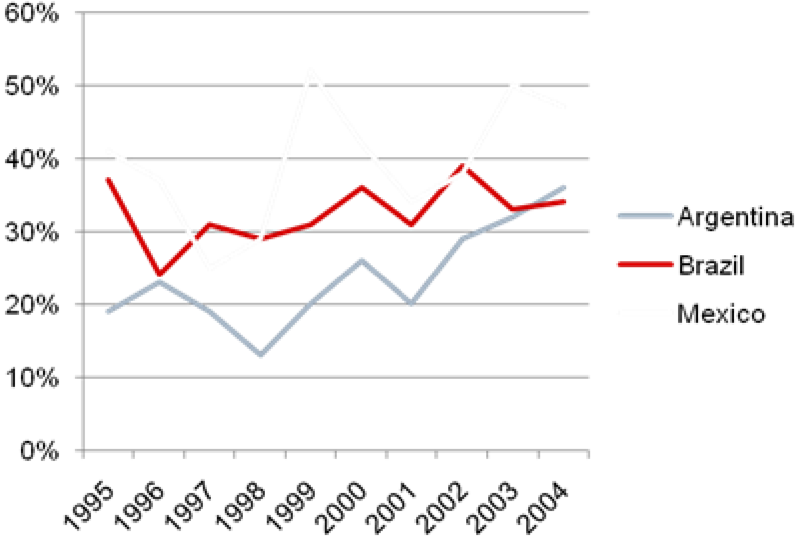
COEFFICIENT	Fixed Effect Log (patents)	Fixed Effect Log (patents)	Fixed Effect Log (patents)	Fixed Effect Log (patents)
Total foreign R&D	*0.095****			
	(0.018)			
US R&D		*0.301****	*0.289****	*0.246****
		(0.065)	*(0.064)*	*(0.065)*
Foreign R&D_cit			*0.034****	*0.032****
			(0.009)	*(0.008)*
Foreign R&D_coinv				*0.027****
				(0.005)
Observations	*400*	*400*	*400*	*400*
Number of i	*25*	*25*	*25*	*25*
Year dummies	*yes*	*yes*	*Yes*	*Yes*
R-squared (total)	*0.8990*	*0.8971*	*0.9014*	*0.9086*
R-squared (within)	*0.5062*	*0.4967*	*0.5177*	*0.5529*

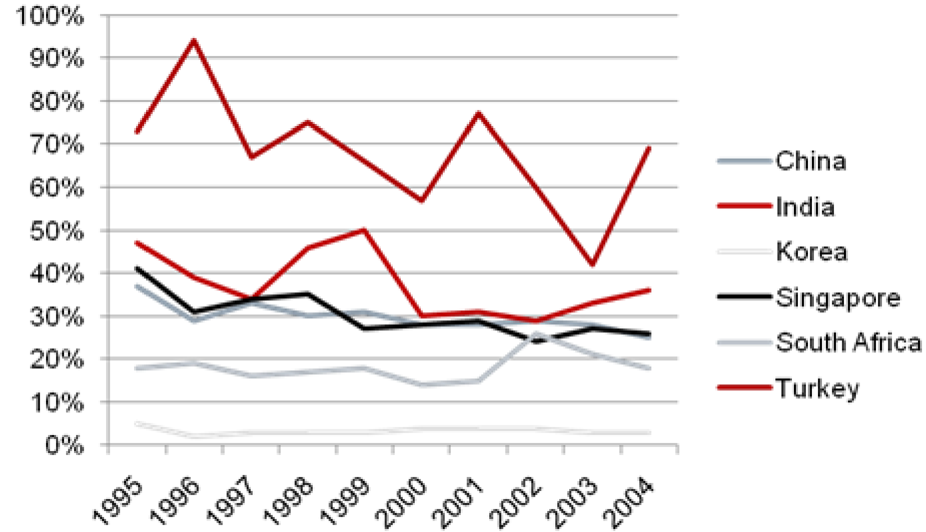
Conclusions II

- International knowledge spillovers from the G-5 countries have a significant impact on inventive activity
- In particular the stock of ideas produced in the US seems to have a strong impact of the international patenting activity of these countries
- 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
- Limitations:
  - extremely tiny portion of the LACs innovative activities
  - FDIs and bilateral trade?

Prospect: The determinants of the different types of knowledge flows

Share of patents with an international team of inventors by country





- Trade openness, FDIs/GDP, share international co-authorships in science grew substantially over the last decade.
- Why less globalisation in technological cooperation ?
- Is there a role for IPRs reinforcements and TRIPs ?
- Is there a role for geographical/technological/cultural distance ?
- Which are the institutional and cultural variables ?

Patenting Activity in Latin American and Caribbean Countries[*]

Report for the project 'Technological Management and Intellectual Property' organized by the World Intellectual Property Organization (WIPO) and Economic Commission for Latin America and The Caribbean (ECLAC)

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1. Introduction

The protection of intellectual property is becoming an increasingly important issue in Latin American countries. Since the adoption of the TRIPs Agreement and a number of bilateral agreements with the US, governments are standardizing their IPRs law. However, most of these policy issues have not been discussed on a sound empirical evidence on the level and relevance of patenting activities in Caribbean and Latin American countries and on a solid evidence on relationship between patenting activity and the main economic variables.

This report tries to assess quantitatively patenting activities in a number of Latin American countries using three databases: the USPTO CESPRI database, the EPO CESPRI database and the PCT- WIPO database. These databases cover the universe of the patent applied for by Latin American individuals or companies or invented by Latin American inventors at the US Patent and Trademark Office (USPTO) and at the European Patent Office (EPO).

In particular this report analyses patenting activity focussing on the actor involved (inventors and applicants) and on the international technological specialisation over time of some Latin American countries and tries to track the connections between some fundamental economic variables like labour productivity and the trade balance and the processes of technological accumulation. The following questions are under scrutiny:

- Which are the actors involved in the patenting activity in Latin America?

- How much growth do we observe in international patenting in different Latin American countries vis à vis other developing and advanced countries?

- Are there differences in the analysis of patenting activity selecting the nationality of the patent on the basis of the inventors' address or the applicants' address?

- What is the average quality of Latin American patenting?

- Where do the knowledge embedded in Latin American countries comes from?

- Which are the technological absolute and relative advantages of a number of Latin American countries? How do they compare with other areas in the world in particular East Asian countries.

- Which are the patterns of technological specialisation ? The important issue here is whether countries become increasingly technologically specialised and whether they are becoming more similar in terms of technological activity.

- Is there any relationship between the technological activity - as measured by patents - and production, value added and productivity?. The final step is therefore adding some economic data to assess the economic impact of patenting activity at the different patent offices.

2. Patents and patent citations databases

Patent data are an extremely useful and rich source of information. Since at least two decades many papers have assessed the use of patents as economic indicators (Pavitt, 1985; Pavitt, 1988, Grupp, 1990 and Griliches 1990). Patents can be used to analyse the technological activities of inventors, firms, regions and countries. They are valuable because they provide the researcher with a coherent set of data across countries and specific technological fields for long time series. Moreover patents show a high level of correlation with R&D at the firm level and this suggests to use patents as an 'input' indicator, that is measuring the technological effort of companies and non-firm organizations to create new products and process.

The use of patents as an indicator of technological output becomes very noisy because the technological and economic value of patents is extremely skewed (e.g. Shankerman, Pakes, 1986), most of the patents have very low economic and technological value while a few of them are extremely valuable. Patent citations are therefore used, to measure the economic and technological value of a patent. 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. As a result counting the number of citations received by patent B can signal its economic and technological importance. A large number of papers show that the number of citations received by a patent is correlated with its economic value. In particular Albert et al., 1991, and Trajtenberg, 1990 are among the first scholars that empirically demonstrated that highly cited patents have higher economic and technological importance. Harhoff et al. (1997) show that the private value of a patent and its subsequent patent citations are correlated. Also Hall et al. (2005) bring solid evidence about the relationship between market value and patent citations.

If a patent is highly cited it also generates many technological spillovers. Therefore citations have also been used to track knowledge flows and spillovers. Again there is a lot of evidence on spillovers within region, international spillovers and spillovers between universities and firms (Jaffe et al., 1993; Jaffe et al., 1993; Jaffe and Trajtenberg, 1996; Jaffe and Trajtenberg, 1999; and in Maurseth and Verspagen, 2002; Malerba, Montobbio, 2003).

The use of patents at the aggregate level to study innovative activity should be based on the awareness of the limits of such an indicator. First of all many inventions are not patented. Surveys of R&D managers keep on showing that - apart from pharmaceuticals - patents are not considered as a major source of appropriability (e.g. Cohen at al. 2000). Secondly, large firms have in many sectors a higher number of patents than small firms given their higher propensity to have R&D expenditures, the fixed costs and scale economies in the patenting activity (Bound et al. 1984, Patel and Pavitt, 1995). So the size distribution of firms may have an important effect on the aggregate count of patent at the national level. Importantly, the propensity to patent varies considerably across different economic sectors. It is not meaningful for example to compare the patent count in different sectors and draw inferences on the innovativity of these sectors because this count reflects simply the propensity to use patents in different technological fields.

In dealing with patent citations the relevant differences between citation practices in the USPTO and EPO have to be taken into account. In the US there is the 'duty of candor' rule which imposes all applicants to disclose all the prior art they are aware of. Therefore many citations at the USPTO come directly from inventors, applicants and attorneys and are subsequently filtered by patent examiners (e.g. Alcàcer and Gittleman, 2004). At the European Patent Office there is no such rule and patent examiners draft their report trying to include all the technically relevant information within a minimum number of citations (Michel and Bettels, 2001; Akers, 2000; Breschi and Lissoni, 2004). Hence, at the EPO, patent citations are, with few exceptions, added by the examiners. As a result, we will observe many more citations in USPTO patents than in EPO ones. Therefore, USPTO citations contain more information but more noisy. On the other hand, less information can be obtained from EPO citations but, exactly because of the rules followed by EPO examiners, these citations are the essential ones.

Patent data contain also lot of informations that can be used as complementary indicators to get closer to the real phenomenon that has to be measured (i.e. the knowledge production and the innovative activity of firms). In particular patents contain citations to non patent literature (e.g. Gittleman Kogut 2001), that can be used to observe the link between technological and scientific activity. The number of claims have been often used to measure the value of patents as number of technological classes and the number of inventors (e.g. Reitzig, 2003).

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 the following section, 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. It should be noted that patents include information on the stated address (and country of residence) of the inventor rather than the 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 .

The study also relies on the Patent Cooperation Treaty (PCT) database of WIPO. The PCT database used contains all patents filed under the PCT since 1979 and those patents with at least one Latin American inventor or applicant were selected for this study. The resulting data set contains 3,199 patents for the period 1980-2004. The analysis concentrates on the following nine countries: Argentina, Brazil, Chile, Colombia, Cuba, Mexico, Panama , Uruguay, Venezuela.

The Appendix contains also an example of local patent activity at a national patent office. In particular it describes the Mexican patents at the Mexican Patent Office applied through the PCT. The data have been provided by WIPO.

3. Inventors and Applicants

There are two ways of assigning a patent to a country. It is possible to look at the country of the inventors or at the country of the applicants (or assignees). In this section we analyse Latina American patents using both criteria. We call the former type of patent 'Latin American invented patent' and the latter type 'Latin American owned patent'. In the first case we observe the inventive activity of individuals declaring that they have their residence in one of the selected Latin American countries. In the second case we observe the patenting activity of companies with the legal address in one of the selected Latin American countries, this includes the subsidiaries of foreign companies. It has to be emphasized that in this report 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.

The applicant is the patentee, the owner of the property right (if the patent is granted), at the date of application. 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. The patent count based on the inventor's address should reflect more directly the inventive activity of laboratories and researchers in a given country. However for developing countries this claim has to be taken with care because inventors active abroad may keep on declaring the original address in the home country. 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.

Unfortunately using USPTO data it is only possible to assign a country to a patent using the inventors' address, however at the EPO it is possible to use both inventors' and applicants' address. Table 1 and 2 show the number of Latin American invented patents applied for at the EPO and granted at the USPTO (the USPTO started publishing applications only in 2001) by year. These numbers are relatively small relative to the overall trend in patenting in other countries as shown in the next sessions. 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 patents, Mexico, Argentina and Venezuela follow with 486, 445 and 160 patents, respectively. At the EPO the relative weights of Mexico and Venezuela are lower. In Table 1 the official USPTO figures have been included for the period 2002-2006 (USPTO, 2007), these observations are not directly comparable with the one provided by the USPTO-CESPRI database and possibly underestimate the patenting activity in a given country because the origin of the patent is determined only by the residence of the first-named inventor at the time of grant. It's however remarkable that 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.

3.1 Latin American owned vs. Latin American invented patents

The comparison between Table 2 and Table 3 shows that 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). This asymmetry reflects partly 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. Counting patents using the applicants' address also shows that Panama is the second largest patenter (313 patents) after Brazil, while if we use the inventor's address Panama turns out to have in the same period just 36 patents. This is because many firms have their legal address in Panama and at the same time there are very few inventors in Panama. Figure 1 shows the average difference between Latin American invented and Latin American owned patents for each Latin American country (excluding Panama). 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 can be determined by national inventors' working for a company active in the country with a foreign legal address or by inventors that work abroad but keep on declaring their Latin American address in the patent documents.

It is worthwhile noting that out of 2636 Latin American invented patents there are only 1520 (56%) Latin American owned patents[1] (i.e. patents in which the applicant's address is in a Latin American country). The rest is owned by foreign companies (1213 – 44%)[2] (i.e. the company's address is not in a Latin American country). In particular Figure 2 shows, by country, the share of Latin American invented patents that have at least one applicant from a non Latin American country. In this case, a part from Cuba and Uruguay there is not such a big difference across countries. Uruguay, Colombia, Mexico and Venezuela show the highest share of non Latin American owned patents to Latin American invented patents.

Table 4 and Table 5 show the number of patents from the WIPO dataset by applicants' and inventors' countries. The overall amount of patent is not dissimilar from the USPTO and EPO data and shows a larger share for Brazil. If we compare these data with the USPTO data we observe that Argentina, Venezuela and Mexico have a considerable lower number of patents in the WIPO data[3]. Again, the number of patents counted by country of the inventors is larger. Table 6 shows the average difference per country. Columbia and Mexico still show the highest difference. For Argentina and Venezuela that are not member of the PCT results are striking: Argentina shows no difference and Venezuela shows a higher number of Latin American owned patents.

In order to conclude this overview it is also worthwhile looking at the total number of patents and inventors in the selected countries relatively to the size of the country. Table 7 gives the overall number of patents at the EPO and USPTO in comparison to the labour force (World Bank) of the same country. Looking at the USPTO patents Brazil is at the top with a considerable growth between the 80s and the 90s (see also Table 1, trends are discussed in the following section) Venezuela and Argentina follow. Mexico had one of the largest patent intensity during the 80s but the growth of patenting relatively to the labour force has not been as high in the other Latin American countries. Concerning EPO patents it is noticeable the similarity across the selected countries with two exceptions: Argentina - that has on average twice the number of patents per million of labour force

[1] 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.
[2] The sum is not 2636 because I counted the patents more than once in case of co-applicants from different countries.

than the other countries - and, at the opposite end, Colombia with only 2 and a half patents per million of labour force.

Table 8 shows the number of inventors over the labour force. Mexico and Brazil have the highest number of inventors both in levels and relatively to the labour force. Cuba has also a considerable number of inventors if compared to the size of the labour force. In particular, regarding patents at the EPO. This is because Cuban patents have on average a larger number of inventors' per patent.

3.2 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, 34.8% of Latin American patents at the EPO are owned by individual inventors (this share jumps to 41.5% if we exclude Panama). 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%[4]. However 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%).

We do not have the applicants' country for the USPTO data and therefore it is difficult to give a detailed country breakdown for the USPTO data. It is interesting though to ask what is the share of individually owned patents when we assign a patent to a country using the inventor's address. In this case 37.3 % of the "Latin American invented" patents granted at the USPTO are 'individually owned'. Argentina (61.7 %), Colombia (55.1 %), Uruguay (52.5%) and Mexico[5] (42.4%) have shares that are higher than the average[6].

It is difficult with our data to give a precise interpretation of this phenomenon. 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 (see footnote 7 in

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[3] Argentina, Chile, Panama, Uruguay and Venezuela are not members of the PCT. This can partly explain why numbers are lower. To file a PCT application, at least one applicant would have to be a national or resident of a PCT member country.

[4] 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.

[5] Note also that 75% of the Mexican owned patents at the Mexican Patent Office belong to individual inventors (WIPO data).

[6] 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%),

the section 3.3) 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 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). However an interesting question for a future research agenda is where these inventors get the fund to apply for the quite expensive EPO and USPTO patents and which is the network of relationships they are involved in.

There might be some exceptions to this negative interpretation, though. Some inventors, active abroad, might want to keep the address of their home country (e.g. some Argentinean patents are highly cited and come from the activity of a professor active at the Washington School of Medicine in St. Louis, US, see footnote 7 in section 3.3 and footnote 10 in section 5). Even if this inventive activity is valuable, these individual patents can be hardly related to innovation occurring in Latin America.

In this respect if we consider Latin American invented patents at the USPTO after 1977, there are 871 patents (out of 4962 – excluding Panama) that have also an inventor with a US address. Therefore a considerable share (17%) of the total Latin American invented patents filed in the US are the result of a collaborative activity with US laboratories, companies and inventors. It is worthwhile noting that these patents are mainly owned by US companies (like Syntex USA (34 patents), Delphi Technologies (32), Procter & Gamble (20), IBM (21), Hewlett-Packard (13), General Electric(13)) and there is a non negligible number of patents owned by US universities and research laboratories (e.g. University of Pennsylvania (7 patents), California (7) and Texas (5)).

3.3 Applicants.

The top 10 applicants at the EPO of the Latin American invented patents[7] (for the period 1978-2001; in parenthesis company's country address) are: EMPRESA BRASILEIRA DE COMPRESSORES S/A (Brazil), PETROLEO BRASILEIRO S.A. – PETROBRAS (Brazil), CENTRO DE INGENIERIA GENETICA Y BIOTECNOLOGIA (Cuba), BAYER (German), 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 9 shows the top 21 applicants and their number of patents. Patents filed by Latin American applicants (i.e. companies with a Latin American address) have been highlighted in italics.

Colombia (37.7%) and Uruguay (33.3%). This means that very few foreign assignees of Latin American invented patents are individual inventors.

[7] 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 9 shows a quite heterogeneous group of applicants. These companies are either big multinational companies or national oil based companies or companies with a technological specialization that needs to be protected in Europe. The firm with the highest number of patents is Unilever. There are six US multinational companies heavily diversified active mainly in Electronics but also in Pharmaceutical (like Johnson&Johnson or Syntex). There is a group of five big German firms active in Chemicals, Pharmaceuticals and Electronics that for historical and geographical reasons are very active patenters at the EPO. Among the companies with a Latin American address there are two firms linked to big oil producers (Petrobras and Intevep), other companies in the Metal, Machinery and House Appliances sectors and two research centres on molecular biology in Cuba. It is interesting to note that the patenting activity of Petrobras and Intevep is not concentrated in the Oil sector. In particular the 80% of Petrobras' patents are in Metals, (Non Electrical) Machinery and Transports. Intevep has 17 patents in the Oil sectors, 14 in Non Electrical Machinery and 11 in Chemicals and Pharmaceuticals.

There are no Latin American companies active in high tech and high growth sectors like Electronics, Telecommunications or Pharmaceuticals. If we consider the most important industrial groups that patent at the EPO it is remarkable that some big companies active in Electronic and Telecommunications like Siemens, Phillips, and companies from Japan like Canon and Sony are left out from the picture (presumably this is because they do not do any R&D in Latin America or their patents do not have Latin American residents as inventors).

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 (VE), PETROLEO BRASILEIRO S.A. PETROBRAS (BR) EMPRESA BRAZILEIRA DE COMPRESSORES S/A EMBRACO (BR), HYLSA (MX), CARRIER (BR), SYNTEX U.S.A (MX), VITRO TEC FIDEICOMISO (MX), HEWLETT-PACKARD (MX), BAYER (BR, MX and few from CO and AR), DELPHI TECHNOLOGIES (MX). Table 10 shows the top 23 companies and their number of patents by applicant. 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. Latin American companies are, as in the EPO list, involved in a set of heterogeneous activities that do not appear to be particularly R&D intensive (e.g. Oil, Glass, Electric, Metals and Machinery).

3.4 Summing up

This section has shown the number of Latin American invented and owned patents at the EPO, USPTO and WIPO. In terms of absolute numbers, looking at the inventor's addresses, Brazil and

Mexico are the top patenters. Looking at the applicants' address Panama also gives the legal address to many companies with patenting activity. Controlling for the size (labour force) of the country, Brazil, Venezuela and Argentina have the highest patenting intensity at the USPTO. At the EPO Argentina has the highest propensity to patent and there are no significant differences between the other countries (with some exceptions). Overall the sheer numbers are quite small. Brazilian and Mexican inventors over 33 years have respectively 1715 and 1783 patents at the USPTO. These numbers are smaller than the number of the patents applied for every year by big companies like IBM in US[8] or Philips and Siemens in EU.

We have shown that there is some heterogeneity across countries. However, trying to draw a unifying picture, the Latin American weakness in terms of patenting activity can be substantiated with the following characteristics:

- Latin American owned patents are considerably less than the Latin American invented ones,
- a big 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,
- approximately one third of Latin American invented and owned patents belong to individual inventors,
- 17% of the total (Latin American invented) patents granted at the USPTO have also an inventor with a US address,
- top applicants at the USPTO and EPO are mainly US and German multinationals. 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). Almost no Latin American companies are active in high tech and high growth sectors like Electronics, Telecommunications or Pharmaceuticals.

Together with this broad picture some more specific results can be underlined. Different patterns emerge according to the different patent offices we consider. At the EPO there is a higher propensity to patent by German firms, at the USPTO by US firms. Related to this we observe that at the USPTO there are relatively more Mexican patents. At the EPO Argentina and Cuba rank higher relatively to the other Latin American countries.

Finally Colombia, Mexico and Venezuela are not only the countries with the highest difference between Latin American invented and Latin American owned patents. For these countries we observe also that a substantial share of 'invented' patents are assigned to applicants that have an address outside

[8] See for example the Science and Technology Indicators of the National Science Foundation at

Latin America. Colombia (together with Argentina) is also a country with a very high share of patents belonging to individual inventors.

4. Patenting Trends vis à vis Other Geographical Areas.

This section compares the patterns (absolute numbers and trends) of patenting activity of the selected Latin American countries relatively to other geographical areas. In particular, we have chosen a set of developing and developed areas that at the beginning of the eighties had comparable patenting activities and kept US and Japan in the picture for comparison. If we look at the absolute numbers (Table 11, 12) at the beginning of the eighties the Latin American group of countries had about half the number of patents of Eastern European countries, one third of the number of patents of Australia and New Zealand and two thirds of the number of patents of the Four Asian Tiger Economies (Taiwan, Hong Kong, Singapore, and South Korea). At the same time, the number of patents of Latin American countries is about five times larger than the sum of China, India, Malaysia and Thailand.

At the end of the 90s Latin American countries have a larger number of patents than East European countries and maintain one third of the New Zealand and Australian patents. Impressively, Taiwan, Hong Kong, Singapore and Korea increase their patenting activity by a factor close to 30. China, India, Malaysia and Thailand are rapidly catching up but their absolute numbers in 2000 are still lower than the total Latin American countries[9]. Also in Table 11 the official USPTO figures have been included for the period 2002-2006 (USPTO, 2007). Even if these observations are not directly comparable with the one provided by the USPTO-CESPRI database for the previous years, for the reasons mentioned above, they confirm in very recent year the massive growth of patenting from the Asian countries and conversely the stable trend for the Latin American countries.

Table 12 shows the growth rate of patents at the USPTO of the selected Latin American countries between the sub-periods 85-89 and 95-99. The growth rate is 81.65%, it is higher than Eastern Europe that in the same period is incurring deep economic and political transformations and it is also higher than Australia and New Zealand's one. This is a period of massive upsurge of patenting worldwide and Latin American countries score a growth rate that is also higher than countries like the US and Japan that however in the initial sub-period had a number of patents 200 and 80 times larger,

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http://www.nsf.gov/statistics/seind06/c6/tt06-04.htm

[9] We are comparing a whole continent with individual countries and with Malaysia and Thailand taken together. If we consider the single largest country in Latin America (Brazil) it has less patents than China (since 1987) and India (since 1996).

respectively. At the same time, Asian countries show a much higher rate of growth of patents in the same period.

Table 13 and Figure 3 break down the figure by Latin American countries and show that Cuba, Chile, Argentina and Brazil grow above the average (looking at the USPTO data). Results for Chile and Cuba are affected by the low numbers in the first sub-period. Results for the EPO data are similar with the exception of Mexico that displays a higher growth rate of patents in Europe.

5. Patent Quality and Knowledge Flows through Patent Citations

This section is devoted to analysis of patent citations. Table 14 shows the number of citations per patent over time by geographical areas at the USPTO. The common decreasing trend is due to the truncation bias: more recent patents have a lower likelihood to be cited.

5.1 Citations received by Latin American Patents

On average Latin American countries get 4.26 citations per patent. So in terms of citations received Latin American countries perform better than Eastern Europe, China, India and Malaysia and Thailand (the latter two are considered together). These results, however, might be affected by the truncation bias because the Asian patents are more recent. At the same time, Australia and New Zealand and the Four Tigers show a slightly better score (for the US-invented patents the average number for same period is 20.2). It has to be noted that these are average values over extremely skewed distributions. Typically the median value is smaller due to the presence of few patents with a high number of citations.

If we look at the data considering the different Latin American countries (Table 15, 16 and Figure 4) we observe that Argentina, Colombia and Mexico show above average citations per patents. Again because of the skewed character of the distribution these results have to be interpreted with caution. For example a careful scrutiny of the 4958 citations received by the Argentinean patents shows that these results are influenced by few patents with many citations. Looking at these highly cited patents it can be noted that some of them are important patents granted to Argentinean scientists working in the US but declaring an Argentinean address[10].

[10] 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 [...]".

In Table 16 we show also the number of citations at the EPO. The number of citations per patent is on average lower because of the specific citation practices of the EPO examiners mentioned in the introduction. However it is noteworthy the similarity of the ranking with the US citations with the exception of Cuba which has the highest level of citations per patent in Europe. Overall for Latin American patents the citation rate is not very high, and accordingly we suspect that the same occurs with their quality (with the exclusion of some possible outliers).

5.2 Knowledge flows

Knowledge flows are inherently difficult to measure. 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 are 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.

Accordingly for both USPTO and EPO data, we use patent citations from the period 1975-2000 for USPTO and 1978-2000 for EPO. We use citations to build a matrix CIT. Each element of the 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 17 and Table 19 illustrate the two matrices from the two datasets. We simplify the data and show the aggregation for geographical areas. Each column represents the citing country and the rows are the cited countries[11] (e.g. Latin American patents cite ten times Chinese patents at the USPTO). Table 18 and Table 20 show the specific share (for each receiving country) of the total number of citations contained in the patents of each citing country (e.g. the ten citations to Chinese patents corresponds to the 0.03% of the citations done by Latin American patents, that, in turn, can be interpreted as a 0.03% of knowledge flows received by Latin American countries comes from China). Figure 5 summarizes the relevant knowledge flows (outflows and inflows) for the selected Latin American countries.

The main evidence that can be noted can be listed as follows. There is a very low share of citations among Latin American countries both at the USPTO (4.29% of citations) and EPO (6.21%).

This is similar to other countries like China and India. If we look at the USPTO data we observe that approximately 70% of the citations done and received are from US patents. 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.

The evidence suggests that when firms based in Latin America patent in US there is a higher likelihood to cite a patent with an American inventor. At the same time when firms based in Latin America patent in Europe there is a relatively higher likelihood to cite a patent with an European inventor. Four types of explanations can be put forward: first there is a sectoral effect. The sectoral composition of patenting activity of the two Patent Offices is different reflecting the sectoral composition of the US and European economies (firms want to patent where the important production activity is), as a consequence firms based in Latin America will patent relatively more in Europe in those technological fields that are particularly important there and therefore there is also a higher likelihood to get knowledge flows from there.

The second possible explanation is a market effect. Firms may want to patent at the EPO (USPTO) because Europe (US) is the most important export market. If the strong competitors are European (US) based firms there is also a relatively higher likelihood to cite European (US) patents. Third, but not less important, there can be a firm effect. We have seen that many Latin American patents at the EPO (USPTO) are from European (US) multinationals. A Latin American subsidiary may want to patent where the headquarters are because it is the most important market for the firm. At the same time the probability to cite a European patent is higher because in many cases patents cite other previous patents from the same company. Finally, for example in Europe the set of potentially citable US patents is smaller. In addition we use only EPO to EPO citations (and USPTO to USPTO citations) and informations about EPO patents citing USPTO patents or USPTO patents citing EPO patents are not available. This might create a downward bias in the spillovers to and from the US in the EPO patents (and similarly a downward bias in the spillovers to and from Europe in the USPTO patents).

Finally it can also be noted that (see Table 18 and 20) 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.

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[11] When patents have co-inventorships from different countries, patents have been assigned to all countries in the list of inventors' addresses.

6. Technological Disadvantage, Specialisation and its Dynamics

This section examines the patenting activity of Latin American countries in different economic sectors. First we look at their absolute technological performance focussing on their patent world shares in different fields and how these shares change over time. Secondly we look at the international technological specialisation of Latin America. We define *international technological specialisation* (ITS) as the international technological performance of a country in a specific technology relative to its overall international technological performance. Thus, a country is specialized in Chemicals or Mechanics if its technological performance in these classes at the international level is higher than its overall international technological performance. Technological specialization is related to relative (dis)advantages and not absolute ones. In fact Latin American countries have absolute disadvantages (and are less innovative) in all technologies relative to the other industrialized and developing countries analyzed here. However, even in this case, they have relative advantages in some technologies compared to others.

Patents are classified according to very specific technological classes and therefore can be used to measure innovative activities in specific sectors of economic activity. The technological strength of a country is approximated by the share of that country's patents to total world patents. Similarly, the technological strength of a country in a specific sector can be measured by the share of that country's patents to total world patents in that sector. This is an indicator reflecting absolute (dis)advantages. In fact, a country may have a very low share in all sectors, as a consequence of its low R&D expenditures in all sectors or its overall small size and limited number of firms. For example, in the period 1995-1999 the selected Latin American countries have a very low world share of patents in all the sectors considered ranging from 0.06% in Computer&Communications to 0.37% in Drugs& Medical. While a country's share in a specific technology is a good indicator of absolute disadvantage, it does not indicate how that country is performing in a specific technological class relatively to other technological classes. For example, the selected Latin American countries, despite their low world patent shares, are relatively specialised in the Chemical fields, because their international performance in other classes is lower (see below the details).

As a result, many authors have adopted the so-called Revealed Technological Comparative Advantage index (RTA) in order to measure the ITS in a technological field[12]. RTA is the traditional Balassa indicator of revealed comparative advantage applied to innovation analysis (Balassa, 1965). It measures the share of patents granted to (or applied for by) firms and other organisations in country *c*

[12] For example, the Technological Revealed Comparative Advantage index has been used by Soete (1981); Patel and Pavitt (1994), Archibugi and Pianta (1992) and recently Malerba, Montobbio (2003).

in technology *j* on total world patent in technology *j*, divided by the share of total patents granted to (or applied for by) firms and other organisations in country *c* to total world patents.

$$RTA_{cj} = \frac{p_{cj}}{\sum_c p_{cj}} \Bigg/ \frac{\sum_j p_{cj}}{\sum_j \sum_c p_{cj}},$$

where p_{cj} denotes the total amount of patent applications (granted) in technological class *j* by country *c*. This index has a weighted average equal to 1 and a skewed distribution, taking values between zero and infinity. A modified and symmetric version of this index[13] have nicer properties in order to perform statistical analyses:

$$RTAN_{cj}=(RTA_{cj}-1)/(RTA_{cj}+1). \qquad (1)$$

RTAN is a monotonic transformation of RTA that is better suited to the statistical analysis of ITS because it is symmetric and reduces the value of extreme observations; it has values that belong to the [–1,1] set. $RTAN_{cj}>0$ ($RTAN_{cj}<0$) means that country *c* is relatively specialised (de-specialised) in class *j*.

In the analysis we considered only USPTO data (results for the EPO data are not substantially different[14]) for two sub periods. The first period considered is 1985-1989 and the second period is 1995-1999. We have grouped five years to avoid the noise of yearly data and catch only the robust patterns of change over 10 years. We used macro sectors as provided by the re-aggregation of SIC codes by the USPTO. In particular the six sectors are: Chemicals, Drugs&Medical, Computer&Communications, Mechanicals and Others. The residual sector 'Others' is not irrelevant for our analysis because it includes a set of relatively less technological intensive sectors like, for example, Agriculture, Food, Amusement Devices, Apparel & Textile, Furniture, Fixtures, Heating and Pipes & Joints. Tab. A6 in the Appendix shows all the technological classes and the related number of (Latin American invented) patents for the sector "Others". It can be noted that potentially high tech (biotech) agricultural patents are very few and do not affect substantially the count of patents in this sector.

[13] See Grupp, (1994) and Laursen (2000) and Malerba, Montobbio (2003) for a discussion.
[14] Table 25 shows the revealed technological advantages also for the EPO data. The broad picture outlined using USPTO and EPO data is substantially the same. It is interesting to note the case of Cuba that also at the EPO has a relative advantage in the drugs and medical sector as it is often claimed. In this case the advantage is declining.

6.1 World Patent Shares

Table 21 and Panel 1 show the world patent shares of the selected group of Latin American countries in the six sectors and in the two sub-periods. In the period 95-99 the highest share of world patents by Latin American countries are in Chemicals, Drugs&Medical and Others with respectively, 0.37%, 0.34% and 0.31% of world patenting activity. The lowest shares are in Computer & Communications and Electrical and Electronics with values equal to 0.06% and 0.08% respectively. These shares are weakly increasing in all sectors. In particular for Electronics and Computer&Communications these increases are negligible. It is worth noting that these two sectors, together with Drugs&Medical, are the ones that had the largest rate of growth at the USPTO if we consider all the patents granted by the USPTO. Latin American countries therefore have a low share of world patents in particular in the technologies that seem to have the highest level of technological opportunities (a part from Drugs&Medical).

Patent shares in China, India, and, Malaysia and Thailand taken together, grow more in particular in these high growth sectors. It is impressive during the same years the growth of the world patent shares of the Four Asian Tiger Economies. In 85-89 in Chemicals and Drugs&Medical Latin American countries and the Four Tigers had the same world share. After ten years, the overall share of Singapore, Taiwan, South Korea and Hong Kong has increased more than ten fold in Chemicals and three folds in Drugs&Medical. These countries display an impressive growth also in Electrical and Electronics and Computer&Communications having in these sectors also a higher starting point in the period 85-89.

China and India also display a considerably higher percentage growth of their world shares between the two sub-periods, in particular in high opportunity sectors like Electrical and Electronics and Computer&Communications. For example, comparing China and the Latin American countries in these two sectors (Table 21) we observe that China is ahead in both sectors even if ten years earlier its absolute technological performance was far behind.

Table 22 and Panel 2 show the world patent shares for each Latin American country considered. Most of the patterns highlighted above are guided by the highest shares that belong to Argentina, Brazil, Mexico, and, to a minor extent, Venezuela. All Latin American countries increased their shares in Chemicals (apart from Colombia). The observed improvement in Drugs&Medical is mainly driven by Argentina and Brazil. On the contrary, Mexico is mainly responsible for the improvement in patent shares in Electrical and Electronics and Computer&Communications. In the latter sector there is improvement also from Brazil's share and a remarkable decline in Argentina and, in particular, in Venezuela. All countries improved (with the exception of Uruguay) their shares in the residual sectors 'Others' that includes most of the traditional activities. In smaller countries we observe that Chile's share has improved in all sectors but one (Mechanical) and Colombia experienced a decline in Computer&Communications, Chemicals and Mechanical and gained shares in the other sectors. Finally, Venezuela has a negative performance in all sectors except from Chemicals and Mechanicals.

6.2 International Technological Specialization

Panel 4 and Table 20 show the ITS of Latin American countries as measured by equation (1). In the period 95_99 Latin American countries are specialised in Chemicals, Drugs&Medical and 'Others' with values of the RTAN index ranging from 0.19 in Others to 0.27 in Chemicals. At the same time they are heavily de-specialised in Electrical and Electronics and Computer&Communications with values respectively equal to -0.45 and -0.53. It is noteworthy that, if we consider all the Latin American countries together, the Latin American area seems to deepen its specialisation pattern over the ten years considered. Apart from the Mechanical sector, the RTAN grows in the sectors where in the first period it is positive and declines in the sectors where in the first period it is negative (as we show in the next section).

China and India are also becoming more specialized in Chemicals. However, they are massively counteracting the initial de-specialization in Computers&Communication and in particular India also in Electrical and Electronics. Conversely, the Latin American area is the only one that increases its relative specialization in the less technological intensive sectors grouped in 'Others'.

The analysis of the standard deviations and their change over time (Table 20) suggests that the Latin American countries are together with India the countries with the highest standard deviation and therefore they display the higher degree of specialization. Moreover India and Latin American areas' standard deviation have the highest growth (with the US that has, however, a relatively much lower specialization). Despite these similarities the nature of patterns of specialization in India and Latin America differs substantially because India is heavily reducing its degree of de-specialization in Electrical and Electronics and Computers&Communication and at the same time exiting technological activities in lower growth technological fields like Mechanicals and Others. Latin American countries become more specialized in 'Others' and seem to increasingly have a relatively slower pace of innovation in Electrical and Electronics and Computers&Communication.

Looking more specifically at each Latin American country (Table 24 and Panel 5) we notice that, in the most recent period 95-99, all countries have a revealed technological advantage in Chemicals (except from Argentina and Uruguay), in Drugs&Medical (except from Venezuela) and 'Others'. In parallel all countries are de-specialized in Electrical and Electronics (except for Uruguay) and Computers&Communication. In parallel, some heterogeneity in the patterns of structural change emerges: over ten years some countries are becoming more specialized and other countries are becoming less specialized. In particular, in Argentina, Brazil, Chile and Venezuela the standard deviation of the RTAN increases substantially (Tab. 24 – last three rows). For all these countries we have a large decline in the RTAN in Electrical and Electronics and Computers&Communication (excluding Brazil in this latter case). At the same time, for these four countries RTAN values increase in Chemicals and also show a positive trend in Drugs&Medical (excluding Chile and Venezuela).

Mexico shows a quite different process of structural change and reduce its technological specialization over the ten years considered (Tab. 24 – last row). Apart from the Mechanical and Others sectors where changes in the RTAN are very small, the RTAN declines in the sectors where in the first period it is positive (Chemicals and Drugs&Medical) and grows in the sectors where in the first period it's negative (Electrical and Electronics and Computers&Communication). This is consistent with the evidence provided in the previous section with Mexico being the only Latin American country which improves its patent shares in both Electrical and Electronics and Computer&Communications.

6.3 Stability and Convergence of Specialization Patterns.

This section analyses the dynamics of technological specialization patterns in Latin America. Specialization is defined as a process that occurs within a country *across sectors*. First this section provides some quantitative assessment on the stability of Latin American technological specialization patterns i.e. whether Latin American countries specialization becomes more dispersed or, alternatively, more concentrated in specific activities. Secondly this section evaluates whether Latin American countries are converging or becoming more similar in terms of technological specialization.

6.3.1 Stability of specialization patterns.

The stability of technological specialization is typically assessed in two ways. First it is used a simple regression analysis of the following equation:

$$RTAN_{ij}^{\,t2} = \alpha_j + \beta RTAN_{ij}^{\,t1} + \varepsilon_{ij} \qquad (2)$$

$RTAN_{ij}$ refers to the normalized index of revealed technological advantage in country *j* and sector *i*, *t1* and *t2* refer to the first and second sub-periods (85-89 and 95-99 respectively). If $\beta=1$ there is no structural change between *t1* and *t2*. If $\beta>1$ countries are becoming more specialized (de-specialized) in sectors where they are already specialised (de-specialized). Finally if $0<\beta<1$ we observe that specialization levels of each sector tend to converge to the mean value. If $\beta=0$ patterns of specialization are randomly distributed. The value of $(1-\beta)$ measures the so called 'regression effect' or β-de-specialisation. If $\beta=1$ of course there is no regression effect and the patterns of specialization are stable.

However the overall level of technological specialization can be measured by the standard deviation (σ) of the specialization indexes across sectors. This is determined in equation 2 partly by past specialization and partly by something unexplained that falls into the error terms. Therefore to evaluate the overall level of specialization, the standard deviations of the two periods have to be compared. This is often defined σ-specialization.

Due to the low number of observations we pool the data for different countries and include a different intercept for each country. The basic idea should be to compare the sectoral cross-sections in the two sub-periods within each country. However since we use 48 observations (8 countries and 6 sectors) we impose the restriction of having the same β for all countries and therefore we find an average effect.

The estimation of equation (2) using Ordinary Least Squares shows that the estimated β is 0.87. This might suggest a pattern of slow β–de-specialization. However the F test (F= 1.13; p-value=0.29) suggests that the estimated parameter β cannot be considered different from one. The first evidence therefore show stability and no major structural changes in Latin American countries in the period considered. We do not observe big shifts in the technological activity of Latin American countries.

The overall level of specialization of countries is analysed looking at the standard deviation of the RTAN indexes across sectors for each country. Table 24 shows that σ-specialization increases in all countries except Colombia, Cuba and Mexico. An increase in the dispersion can be interpreted as a movement towards a more narrow specialization pattern (Cantwell, 1989). In sum in a context of a broad stability of technological specialization patterns we observe an increased level of overall specialization in particular for Chile and Venezuela but also for Argentina, Brazil and Uruguay.

6.3.2. Convergence of specialization patterns.

The issue of convergence can be dealt with looking at the dispersion *across countries* of the specialization indexes within each sectors. If the dispersion increases in the two sub periods countries are becoming more different because they display different values of the RTAN within that sector.

The issue can be considered sector by sector looking at the last two columns of Table 24. In three sectors (Computers&Communications, Mechanicals and Others) we observe a decrease in the standard deviation and therefore a process of convergence between countries. In the three other sectors (Chemical, Electrical and Electronics and Drugs & Medical) we observe an increase in the standard deviation (divergence). The sector with the highest degree of convergence and with the lowest value of the standard deviation is the residual sectors (Others). The decrease in the dispersion is mostly due to Colombia and Chile that were de-specialized in this sector in the first period and display a positive sign of the index in the second period. Almost all the Latin American countries considered have a moderate specialization in this sector.

In the Mechanical sector the decrease in the dispersion of the RTAN is explained mostly by Chile and Brazil that were specialized in the first period and in the second period have a value of the index close to zero. Countries are becoming more similar also because Venezuela which was not specialized in the Mechanical activities in the second period has a small positive value of the RTAN like Chile and Brazil. Finally, in Computers & Communications there is also a process of convergence. Countries are becoming more similar because they are de-specializing in this sectors. In particular in Chile, Argentina, Cuba and Venezuela the RTAN values are decreasing.

7. Patents, Trade, Value Added and Productivity

This report shows that, even in big Latin American countries, patenting at the EPO and at the USPTO is not a pervasive activity. It reflects mainly the activity of some big companies with strong economic linkages in Europe and US and the activity of many (dispersed) inventors. In general we show that patenting at the EPO and USPTO does not reflect the overall amount of R&D or innovation activity in Latin American countries rather it witnesses some specific projects or a number of occasional activities[15].

This section enquires whether some economic variables like value added, productivity, export and import may affect, at the sectoral level, international patenting activity. In particular we are interested in studying whether the international patenting activity responds to the dynamics of productivity and trade. This is relevant for at least two reasons: if productivity and export gains are associated with the growth of patenting activity, specialization in production and trade may be expected to drive innovation and the accumulation of technological capabilities. Secondly it has been emphasised that trade openness is more conducive to economic growth and convergence with advanced countries if complemented by R&D efforts and technological learning (Cimoli et al. 2006; Cimoli and Correa, 2005). A positive association, at a sectoral level, between productivity growth, trade openness and international patenting would suggest that some capabilities of adopting and adapting technologies are accumulated and, in turn, influenced by the specific economic trajectories of each economy.

[15] Given the extent of these activities, in particular for small countries, it is difficult to ask, at the sectoral level, whether patents at the USPTO and at the EPO affects value added and productivity and trade. This is a typical question in the technological gap tradition for the OECD countries, for a discussion in relationship to developing countries see Montobbio, Rampa (2005). In particular Montobbio and Rampa focus on nine large developing countries and suggest that technological activity is related to export gains, in high technology sectors if a country expands in industries with increasing technological opportunities; in medium technology sectors if it moves away from low opportunity sectors; in low technology sectors if it is initially specialized in growing sectors.

The issue is addressed for eight manufacturing sectors (Chemicals and Pharmaceuticals, Oil, Metals and Metal Products, Non Electrical Machinery, Electrical Machinery, Transports and Instruments) and six countries (Argentina, Brazil, Chile, Colombia, Mexico and Uruguay) in the period 1980-2000. 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 value added, employment, exports and imports. Manufacturing sectors are defined following the International Standard Industrial Classification (ISIC – Rev. 2). We use patent data at the EPO because the IPC classes (only available at the EPO for such a long time series) are needed in order to have a concordance with the ISIC sectors. To convert IPC classes into industrial sectors we have updated and elaborated upon Verspagen et al. (1994). We have considered the patents with at least one Latin American inventor by priority dates.

In particular we have considered the following variables (*i* refers to countries, *j* refers to sectors and *t* is time):

VA_{ijt} = the value added in real terms (millions of 1985 \$),

L_{ijt} = employment

EXP_{ijt} = export at current prices (\$)

IMP_{ijt} = import at current prices (\$)

P_{ijt} = number of patents applied for at the EPO

Since these variables mainly reflect the size of the sector in each country, we have calculated normalized indexes in each year, sector and country: the propensity to patent (or patent intensity i.e. patents per employee), a labour productivity index (i.e. valued added per employee) and an index of trade balance relative to the total trade activity:

$Pat\_int_{ijt}=P_{ijt}/L_{ijt}$ (to avoid small numbers L is millions of employees)

$Lab\_prod_{ijt}=VA_{ijt}/L_{ijt}$

$Trade_{ijt}= (EXP_{ijt} - IMP_{ijt})/(EXP_{ijt} + IMP_{ijt})$

Due to the scarcity of observations and missing values the analysis has been restricted to the period 1991-2000. Moreover this exercise is meaningful only if we have a sufficient number of patents. Therefore we decide to drop the observations for each sector in Uruguay and for the Oil sector in each country because the number of patents is never above 10[16].

[16] Note that only 4 Petrobras's patents (out of 68, see Table 9) can be assigned to the oil sector. Even if Venezuela is not in the sample it's worth noting that Intevep has 17 patents (out of 48) in the oil sector.

Table 26 shows the total number of patents considered by country and sector[17]. The total number of patents by country corresponds broadly to the numbers in Table 2, in particular, due to the focus in this section upon a selected number of manufacturing sectors, we use a percentage between the 80% and the 85% (depending on the country) of the numbers of patents displayed in Table 2 (for the same time span). The sectors with the highest number of patents are Chemical and Pharma, Non Electrical Machinery and Instruments. Table 27 displays the patent per unit of employment. In this case there is a much higher heterogeneity. It's particularly noticeable the relative higher value of Pat_int_{ijt} for Instruments (due to the relatively low number of employees in this sector) and for Argentina, consistently with the evidence displayed in Table 7.

In Table 28 we display the labour productivity defined as value added in real terms per unit of the employed labour force (the unit of measurement is millions of 1985 US$). Argentina has the highest average value and Mexico the lowest. In terms of sectoral averages the highest productivity is in Chemicals and Pharmaceuticals and Metals and Metal Products. Looking at the trade balance the picture is more articulated (Table 29). Brazil and Mexico have the highest value of the trade index because of their export activity in the transport sector. Brazil has a positive sign also in the Metals and Metal product sector and Mexico has relatively better trade performance in Electrical Machinery. Looking at the sectors the only positive sign is observed for Metals and Metal Products (also because of Chile) and the worst sectoral trade performance for these Latin American countries is Electrical and non Electrical Machinery and Instruments.

Figure 6 shows the average growth of patenting, patenting per employee, labour productivity and the trade balance. Patents and patents per employee show a considerable growth. In the case of the number of patents per employee the graph has to be considered with care because these are averages across very heterogeneous sectors and, for example, the sudden drop in 1997 of the patent intensity is almost entirely due to a drop in Argentina's patenting in the Instruments sectors. Value added per employee grows moderately and the normalized trade balance tends to decline in the ten years considered.

Table 30 shows the correlation coefficient between the variables, with the p-values and the number of observations. These coefficients are clearly confounded by common trends and by time invariant unobserved characteristics of the observational unit. In order to estimate more correctly a possible association between the economic variables and patenting activity it is possible to exploit explicitly both the cross sectional and the time series dimension, using the panel structure of the data. Therefore we estimate the following logarithmic specification:

[17] Numbers are not integers because the concordance between IPC classes and ISIC sectors uses weights to assign patents to the specific industrial sectors.

$$\text{Log(Pat\_Int)}_{kt} = \alpha_k + \tau_t + \beta \text{Log(Lab\_Prod)}_{kt} + \gamma \text{Trade}_{kt} + e_{kt} \qquad [1]$$

With k=1,….,22; and t=1,…., 10 for the period 1991-2000. *k* indexes each country-sector group. In particular we have eliminated the couples sector-country with less than 10 patents (see table 26). Therefore the remaining observational units are: all sectors for Argentina, Brazil and Mexico (18 units - 180 observations) and two sectors for Colombia (Chemicals&Pharmaceuticals and Instruments) and Chile (Chemicals&Pharmaceuticals and Non Electrical Machinery) (4 units - 40 observations). α_k is the individual fixed effect that controls for all time invariant characteristics of each couple country-sector and τ_t are time dummies to control for common time effects across observational units.

We take the log to have the variables more closely distributed to normality and estimated coefficients closer to the value of an elasticity. In some cases the amount of patent applications 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).

We also assume that there could be some time lag between the economic gains from the trade balance improvements and from increases in labour productivity and patenting activity. We estimate the different lags separately because Lab_Prod and Trade variables are highly persistent and, due to heavy multi-collinearity, the different lag structures cannot be estimated simultaneously.

Results are displayed in Table 31. Results are quite robust to different specifications. Increases in labour productivity and in the trade balance have no positive effects on patenting activity. As a result we do not find that growth of the value added per employee and trade drive innovation and technological accumulation at the sectoral level. Moreover we find a significant negative relationship between trade balance movements and international patenting activity per employee. This relationship is particularly strong with a two years lag and in high and medium tech industries like Chemicals & Pharmaceuticals, Electrical Machinery and Instruments. Moreover the coefficient linking Trade and Patent Intensity is particularly negative for relatively smaller countries like Columbia and Chile.

These results confirm the idea that patenting abroad have an occasional and episodic nature not strictly linked to the main trends of the economic variables. The patenting intensity does not improve in those sectors where value added pro capita and trade grows. If the growth of patenting intensity can be interpreted as an improvement in technological opportunities, this does not occur in the most economically lively sectors. Economic gains emerge in sectors where there is no growth in patents per employee, at the same time, in those fields where patenting grows, trade gains seem to be weaker.

Another way to interpret the statistically significant negative effect of Trade on Pat_int is to underline that improvements in the trade balance have a positive impact on employment. The negative effect on patent intensity is then related to this increase in the employed labour force. As a result our evidence suggests that positive variations of the trade balance increase employment in sectors where innovative activities, in terms of patenting, do not grow at the same speed and therefore we observe a decrease in patents relative to the number of employees.

This negative association between trade and patenting can be interpreted in different ways. First there could be a crowding out effect, if exports and employment expand in relatively low tech activities, the weight of more high tech activities (where patenting is more likely) may decline. However it has to be pointed out that the analysis is performed in sectors that are very broad. As a result (and this is the second point) the lack of relationship between productivity gains and the negative link with trade could be the result of aggregating many different types of activities. Trade and patents could describe the reality of different and possibly unrelated classes of products, within the broad classification used here.

8. Conclusions

This report analyses empirically the nature of patenting activity in a selected number of Latin American countries using three databases: the USPTO-CESPRI database, the EPO-CESPRI database and the PCT-WIPO database. It shows that international patenting in Latin America is growing but it's not a pervasive and diffused activity across Latin American firms. This report considers two types of Latin American patents: Latin American invented patents and Latin American owned patents. In the former case the country is assigned on the basis of the inventors' address. In the latter case the applicants' addresses are considered.

In absolute numbers, looking at the inventor's addresses, Brazil and Mexico are the top patenters. Looking at the applicants' address also Panama ranks at the top. Controlling for the size (labour force) of the country Brazil, Venezuela and Argentina have the highest patenting intensity at the USPTO. At the EPO Argentina has the highest propensity to patent and there are no major differences between the other countries.

The important actors involved in Latin American patenting are mainly US and German companies with a foreign address or their foreign subsidiaries with a Latin American address. Moreover we show that approx. 16% of the total (Latin American invented) patents granted at the USPTO have also an inventor with a US address. There are also some Latin American companies (e.g. Intevep, Petrobras, Embraco, Vitro Tec) active in a set of heterogeneous sectors of activity (e.g. Oil, Glass, Electric, Metals and Machinery). Finally, at least one third of Latin American invented and owned patents belong to individual inventors. These patents are dispersed across a large number of individuals with few patents. Latin American owned patents are considerably less than the Latin American invented ones, this reflects the geographical activity of multinationals corporations. In some cases, like Colombia, Mexico and Venezuela, the difference is substantial.

These evidences taken together witness the weakness of the Latin American international patenting activity. This is characterized by a growing but still small number of patents, with a big role of foreign companies and foreign collaborations and a big share of the patents from individuals that - possibly - are the result of occasional activities.

Looking at the patent citations as a possible indicator of patent quality on average Latin American countries get 4.26 citations per patent. The US we have 20.2 average citations per patent and also Australia and New Zealand and the Four Tigers show a higher score. However Latin American countries perform better than Eastern Europe, China and India. These results, however, might be affected by the truncation bias because the Asian patents are more recent and consequently may have less citations. Consistently EPO and USPTO citations suggest that on average patents from Argentina, Colombia, Mexico and Venezuela get more citations. However the value distribution of these patents is extremely skewed and therefore these average values are importantly affected by few highly cited patents.

The analysis of knowledge flows uses patent citations and shows that there are very few citations among Latin American patents. The evidence suggests that when firms based in Latin America patent in US there is a very high likelihood to cite a patent with an American inventor. At the same time when firms based in Latin America patent in Europe there is a relatively higher likelihood to cite a patent with an European inventor. Finally, the evidence of knowledge flows from Latin America to other regions appear to be extremely low.

This report analyses also the technological position of Latin American countries vis à vis other countries in the world. It shows that the Latin American shares of world patent is extremely low. The highest share of world patents are in Chemicals, Drugs&Medical and Others with respectively, 0.37%, 0.34% and 0.31% of world patenting activity (USPTO data). The lowest shares are in Computer & Communications and Electrical and Electronics with values equal to 0.06% and 0.08% respectively. A part from Drugs&Medical, Latin American countries display a low share of world patents in particular in the technologies with a high level of technological opportunities. Moreover these shares are not increasing at the same rate as other developing countries in Asia. In particular for Electronics and Computer&Communications these increases are negligible, contrary to what it's occurring in the Four Asian Tigers or in China.

In the nineties Latin American countries are specialised in Chemicals, Drugs&Medical and the 'Others' sector (that contains a set of less technological intensive activities) and are de-specialised in Electrical and Electronics and Computer&Communications. This evidence is complemented by the fact that almost no Latin American companies are active in high tech and high growth sectors like Electronics, Telecommunications or Pharmaceuticals. At the same time, contrary to what is happening in most Asian countries Latin American countries are not reducing their de-specialization in high opportunity sectors like Computers and Communications or Electronics. In general over the nineties the technological specialization of the Latin American countries is quite stable and no major structural changes occur.

Since international patenting at the EPO and USPTO appear to be related to some specific projects by some (often foreign owned) big firms and to a number of occasional activities by individual inventors there is no a strong relationship, at the sectoral level, with economic variables like value added per employee. Increases in labour productivity and in the trade balance do not turn into innovation and technological accumulation at the sectoral level. This report shows that patenting intensity does not increase in the sectors where value added per employee and trade grows. If international patents may reflect technological opportunities at the sectoral level, these do not seem to emerge in the most economically lively sectors.

Moreover in the technological fields where patenting declines, trade gains seem to be stronger. The analysis is performed at a very high level of sectoral aggregation and therefore it is difficult to lay down a precise interpretative framework in this respect. However the negative relationship between the sectoral trade balance and patenting intensity is not un-compatible with a *crowding out* effect according to which the expansion of export-led activities are relatively less technological intensive and, in turn, the weight of more high tech (patent intensive) activities turns out to be reduced.

Summing up different reasons can be considered for the weak international patenting activity in many Latin American countries. First the productive and trade specialization of these countries may cover sectors in which the use of intellectual property rights is relatively less important. Secondly even in those sectors where the intellectual property is important Latin American countries do not generate many international patents. This may depend on the type and number of inventions that are generated in the countries or on the appropriability strategies of the firms. Probably different countries face different problems and constraints and a precise distinction between these possible different reasons is mainly outside the realm of the patent data analysis. However, given the significant heterogeneity across countries, the large number of patents owned by individuals, the lack of continuity in patenting activity, the important role of foreign firms, the weak contribution of domestic companies and, finally, the lack of a significant relationship between productivity growth, trade gains and patenting intensity, are all common traits that point in the direction of an underdeveloped innovation system in Latin America.

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Appendix. An overview of the patenting activity in some national patent offices in Latin America

In this Appendix we give an overview of the patenting activity at the National Patent Offices of a number of Latin American countries. Patents at domestic patent offices provide important additional information on the nature of patenting activity in a developing country because international patenting is expensive and, as we have seen in this report, the numbers of patent applications are very low relative to the dimension of the Latin American economy. Moreover the analysis at the level of national patent offices allows investigating the patenting activity of foreign companies and the impact of changes in legislation like the adoption and implementation of the TRIPs agreement.

The drawback of the analysis of data from national patent offices is that they heavily depend upon the administrative and organizational rules at the level of the patent office, in particular for small countries, and therefore numbers are hardly comparable over time and across countries. Moreover these data are very hard to obtain, coverage is partial and not all the information contained in a patent is available. We provide here a stylized picture of the patenting activity at the domestic patent office in Brazil, Cuba, Dominican Republic, El Salvador, Panama and Peru. The idea is to give a cornerstone to be compared with the analysis on international patenting given in this report. We have received directly the data from the national patent offices except for Brazil. For this country we use the PATSTAT database[18] (Laforgia et al. 2007).

Table A1 shows the total number of patent applications in the different national patent offices. In ten years between 1995 and 2005 this number is doubled or more for all countries with the exception of Chile where the growth rate has been 68%. With the exception of Cuba most of the patents are from foreign applicants, as shown in table A2. Cuba has the biggest share of residents' patent applications (36,58% in 2006), the Brazil's share of resident patents was 21% in 2004 and in Chile 16% in 2005. It's noticeable that in Peru and in smaller countries like El Salvador, Dominican Republic and Panama the residents' share is below 4%. Moreover the share of patents applied for by residents declined steadily during the second half of the nineties. This decline is interrupted or less pronounced after 2000.

The number of patents granted is particularly affected by the administrative procedures at the local patent offices. Accordingly Table A3 shows that there is a very high variation across countries and over time in the amount of granted patents relative to the number of applications. In recent years the share of granted patents is approx 10% in Chile, 30% in Cuba, always above 50% in Panama. It varies a lot but the numbers are very low in El Salvador and Dominican Republic.

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[18] PATSTAT is the OECD and EPO Worldwide Patent Statistical Database. The dataset contain also utility model applications.

It is difficult to give a unified picture in terms of the technological composition of these patents. The technological composition itself depends upon the specific regulation reagarding the intellectual property rights in each country. An interesting example comes from the pharmaceutical sector. We have been able to calculate the share of pharmaceuticals patents (limited to the ipc class A61K) only for some countries as shown in Table A4. With the exception of Chile, the share of pharmaceutical patents increased a lot in recent years in all the countries considered: Cuba (where the pharmaceuticals patents are more than 40% of the total), Brazil and Peru. In particular in Brazil in the period 2002 – 2004 there is a sharp increase in patenting activity in the pharmaceutical sectors. All along the 90s, when pharmaceutical patents were not allowed, there are very few patents in pharmaceuticals with the minimum number in 1994. The substantial take off of pharmaceutical patents takes place after 2000. The increase in the number of patent applications in the pharmaceutical sector appears therefore delayed of at least three years with respect to the adoption of the TRIPs agreement in this country. It's worthwhile emphasizing that these numbers refer to patent applications and not to patent granted. The number of patent granted is still very low, in the pharmaceutical industry. However these data shows that a precise understanding of these trends depend on the national specific implementation of the TRIPs (Laforgia et al. 2007).

Finally the increased role of pharmaceutical patents in particular for small countries is reinforced by the analysis of the 5 top applicants in the period 2000-2006. Table A5 shows that in all countries the top 5 applicants are mainly multinational pharmaceutical companies. Moreover in small countries like El Salvador and Panama the top five companies account for almost half of the total patenting activity at the national patent office. In Peru for the 15%. In Brazil, given the size of the economy, the patenting activity is much more dispersed and the top five companies account only for 1.40% of the patents. Finally Cuba is the only country where we find domestic institutions among the 5 top applicants (Centro de Ingeniería Genética y Biotecnología, Universidad Central De Las Villas).

Tables

Table 1. Patents at the USPTO by inventor's country

YEARS	*AR*	*BR*	*CL*	*CO*	*CU*	*MX*	*UY*	*VE*	*Total*
1968	0	0	0	0	0	1	0	0	1
1970	0	0	0	0	0	2	0	0	2
1971	0	2	1	0	0	3	1	0	7
1972	7	5	0	0	0	10	0	0	22
1973	11	12	4	1	0	38	1	5	72
1974	27	21	6	7	0	72	0	3	136
1975	24	30	2	2	2	70	1	10	141
1976	23	25	3	9	1	45	1	9	116
1977	26	30	2	10	1	42	0	12	123
1978	22	32	5	4	1	46	0	13	123
1979	22	27	4	2	1	47	0	15	118
1980	25	31	2	6	0	43	1	14	122
1981	19	22	3	4	1	48	0	6	103
1982	16	27	2	7	1	49	0	10	112
1983	12	27	2	9	1	31	1	15	98
1984	15	34	4	3	0	42	0	17	115
1985	15	36	3	3	2	41	1	19	120
1986	21	38	9	5	0	52	0	29	154
1987	30	41	1	4	1	35	2	26	140
1988	14	38	3	9	0	42	2	17	125
1989	13	73	9	2	1	47	3	19	167
1990	29	46	7	9	0	45	1	30	167
1991	25	63	8	5	3	46	2	34	186
1992	27	66	13	13	3	55	2	34	213
1993	39	71	10	3	1	50	2	31	207
1994	49	115	5	13	6	70	2	28	288
1995	42	92	12	12	2	93	2	30	285
1996	53	90	24	5	4	91	2	34	303
1997	56	125	19	7	4	89	6	42	348
1998	63	122	12	9	4	110	0	42	362
1999	45	143	18	12	6	123	4	34	385
2000	63	128	11	14	6	115	2	38	377
2001	48	103	7	6	2	90	1	24	281
2002*	54	96	11	6	9	94	3	30	303
2003*	63	130	11	10	7	85	2	19	327
2004*	46	106	15	10	2	86	0	18	283
2005*	24	77	9	7	3	80	2	8	210
2006*	38	121	14	5	2	66	2	13	261
Total	1106	2245	271	233	77	2194	49	728	

Note: when the patent is a co-invention by inventors from different countries it is counted more than once
Source: USPTO-CESPRI
* Source: USPTO (2007); residence in this case is determined by the residence of the first-named inventor at the time of grant. Data for the period 2001-2006 are therefore not directly comparable with data 1980-2000

Table 2. Patents at the EPO by inventor's country

YEARS	*AR*	*BR*	*CL*	*CO*	*CU*	*MX*	*UY*	*VE*	*Total*
1977	0	6	0	1	0	0	0	1	8
1978	0	15	0	0	0	1	1	1	18
1979	1	18	0	0	0	1	0	2	22
1980	14	16	1	1	0	8	0	2	42
1981	5	22	1	2	0	7	0	1	38
1982	6	23	0	7	0	4	0	1	41
1983	6	21	1	9	0	14	2	2	55
1984	6	24	4	0	0	4	0	4	42
1985	7	36	2	1	0	4	1	2	53
1986	7	18	1	1	0	13	1	5	46
1987	6	27	3	2	1	9	0	2	50
1988	10	26	2	0	0	17	1	6	62
1989	14	27	5	4	1	18	1	6	76
1990	19	51	6	3	9	18	1	3	110
1991	15	35	5	1	3	14	0	11	84
1992	17	58	2	5	3	16	0	4	105
1993	24	61	2	4	8	24	1	5	129
1994	16	46	6	6	6	21	0	9	110
1995	21	76	9	5	5	36	1	8	161
1996	39	70	11	2	5	32	1	10	170
1997	36	106	13	6	10	54	3	19	247
1998	47	112	6	5	6	45	4	17	242
1999	48	140	5	9	4	55	4	18	283
2000*	59	136	12	9	14	39	5	14	288
2001*	38	171	18	11	11	58	4	12	323
2002*	53	152	17	6	20	69	7	2	326
2003*	55	191	17	11	15	78	7	7	381
Total	569	1684	149	111	121	659	45	174	

Note: when the patent is a co-invention by inventors from different countries it is counted more than once
Source: EPO-CESPRI
* update with the 2007 version of the EP-CESPRI database

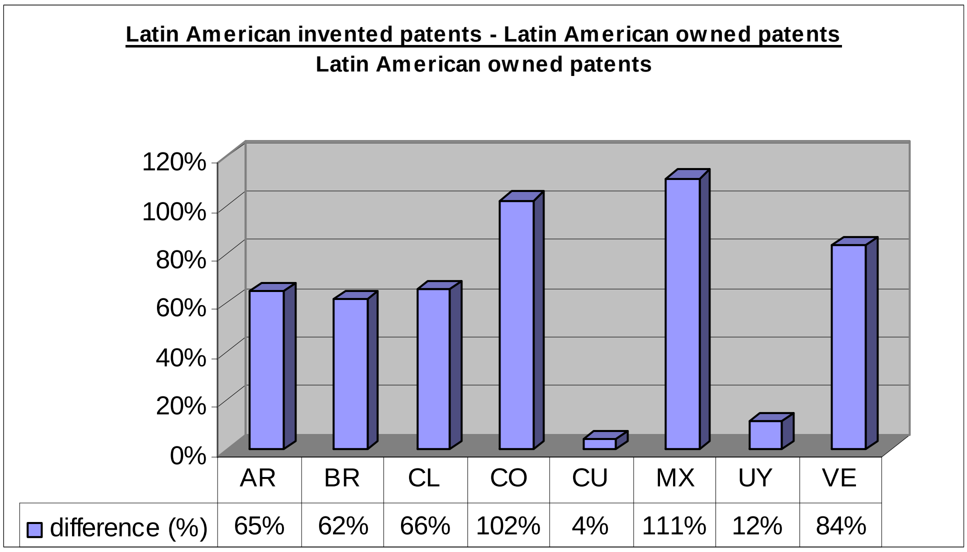
Table 3. Patents at the EPO by applicant's country

YEARS	*AR*	*BR*	*CL*	*CO*	*CU*	*MX*	*PA*	*UY*	*VE*	*Total*
1977	0	4	0	0	0	0	3	0	0	7
1978	0	12	0	0	0	1	8	0	0	21
1979	0	12	0	0	0	0	10	0	1	23
1980	9	7	1	1	0	4	7	0	0	29
1981	3	24	0	1	0	1	15	0	1	45
1982	0	12	0	3	0	2	31	1	0	49
1983	1	8	1	7	0	7	25	1	2	52
1984	4	14	4	0	0	2	24	0	4	52
1985	2	28	2	0	0	0	18	1	3	54
1986	7	7	1	0	0	5	14	0	3	37
1987	5	9	1	1	1	4	8	0	2	31
1988	6	13	2	0	0	8	18	0	2	49
1989	8	12	1	1	1	11	15	2	3	54
1990	12	35	2	1	9	14	8	2	3	86
1991	10	20	2	1	3	10	11	3	5	65
1992	12	41	1	1	3	8	13	2	1	82
1993	18	36	1	2	7	7	9	0	3	83
1994	9	25	2	3	6	9	13	1	1	69
1995	15	41	6	3	5	15	8	0	6	99
1996	27	40	7	2	5	10	18	2	5	116
1997	21	70	7	3	10	30	10	4	9	164
1998	30	56	3	2	5	25	6	1	7	135
1999	29	105	5	6	3	26	10	2	10	196
2000*	28	95	7	2	14	20	6	4	11	187
2001*	16	107	12	6	11	21	8	2	7	190
2002*	30	106	10	5	20	25	17	7	0	220
2003*	23	133	14	6	15	45	6	4	3	249
Total	325	1072	92	57	118	310	339	39	92	

Source: EPO-CESPRI

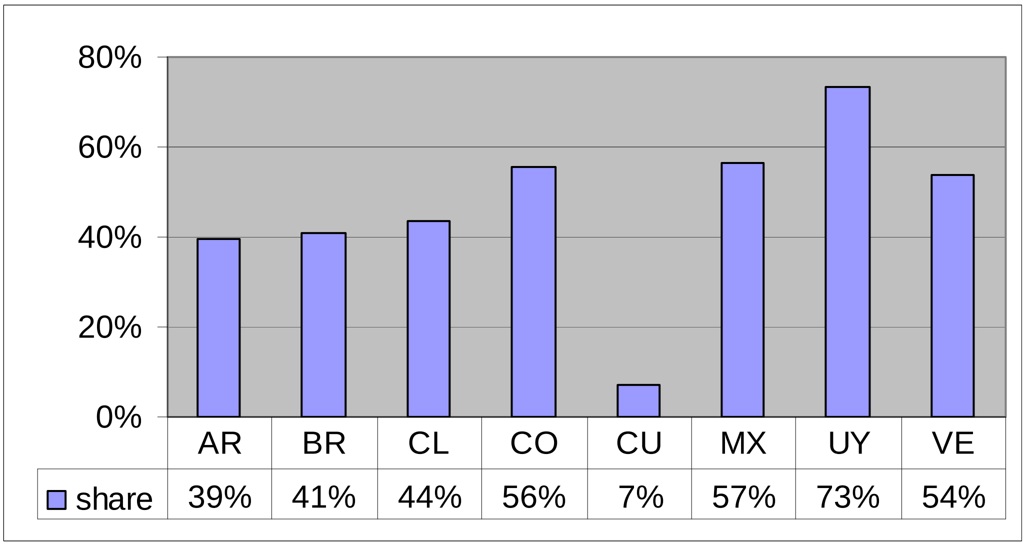
* update with the 2007 version of the EP-CESPRI database

Figure 1. Latin American invented patents and Latin American owned patents, by country (EPO data)



Source: EPO-CESPRI (1978-2001)

Figure 2. Non Latin American owned patents to Latina American invented patents, by country (EPO data)



Source: EPO-CESPRI (1978-2001)

Table 4. Patents at the PCT - WIPO by inventor's country

YEARS	*AR*	*BR*	*CL*	*CO*	*CU*	*MX*	*PA*	*UY*	*VE*
1981	0	4	0	0	0	0	0	0	1
1982	0	23	0	0	0	0	0	0	0
1983	0	6	0	1	0	0	0	0	0
1984	0	5	0	0	0	0	0	0	0
1985	0	15	0	0	0	1	0	0	1
1986	0	27	0	0	0	0	0	0	0
1987	1	12	0	0	0	1	0	0	0
1988	0	14	1	0	0	1	0	0	0
1989	1	17	0	0	0	0	0	0	1
1990	1	23	1	0	0	3	0	0	0
1991	2	38	1	1	0	3	1	1	1
1992	1	28	1	0	0	1	0	0	3
1993	3	53	0	2	1	5	1	0	0
1994	5	59	2	2	1	7	0	1	3
1995	8	71	4	5	3	15	0	0	4
1996	5	95	5	6	5	37	0	0	3
1997	9	111	5	4	8	64	0	3	7
1998	10	139	9	2	9	80	3	1	7
1999	27	176	4	3	7	75	0	4	5
2000	31	215	4	7	4	84	2	4	8
2001	40	192	15	20	14	114	1	9	3
2002	26	247	14	40	11	141	0	8	4
2003	38	276	15	27	24	145	5	9	4
2004	65	351	17	27	18	162	0	10	5
Total	273	2197	98	147	105	939	13	50	60

Source: WIPO

Table 5. Patents at the PCT - WIPO by applicant's country

YEARS	*AR*	*BR*	*CL*	*CO*	*CU*	*MX*	*PA*	*UY*	*VE*
1981	0	0	0	0	0	0	1	0	0
1982	0	6	0	0	0	0	0	0	0
1983	0	2	0	0	0	0	0	1	0
1984	0	2	0	0	0	0	0	0	0
1985	0	3	0	0	0	0	5	0	1
1986	0	14	0	0	0	0	2	0	0
1987	0	3	0	0	0	0	1	0	0
1988	0	4	0	0	0	0	0	0	0
1989	0	13	0	0	0	0	2	0	0
1990	0	8	0	0	0	1	2	0	0
1991	0	19	0	0	0	2	1	0	1
1992	0	11	0	0	0	0	0	0	1
1993	0	25	0	0	1	0	5	0	0
1994	1	34	0	1	0	2	4	1	1
1995	1	43	0	2	3	6	3	0	0
1996	2	46	3	2	3	13	3	0	0
1997	4	64	1	3	9	14	9	0	1
1998	1	72	2	1	9	28	16	2	3
1999	3	63	1	0	7	24	12	0	4
2000	6	101	3	1	4	32	28	3	17
2001	8	122	3	4	14	22	54	5	9
2002	3	137	4	5	11	29	37	6	0
2003	8	140	7	4	24	43	57	9	1
2004	6	199	6	4	17	37	43	6	0
Total	43	1131	30	27	102	253	285	33	39

Source: WIPO

Table 6. Percentage difference by country between Latin American invented and Latin American owned patent using the PCT - WIPO data.

Patents	*AR*	*BR*	*CL*	*CO*	*CU*	*MX*	*UY*	*VE*
By applicant	270	769	64	43	76	230	26	87
By inventor	273	2197	98	147	105	939	50	60
	1%	186%	53%	242%	38%	308%	92%	-31%

Source: WIPO

Table 7. Patent per million labour force (Labour force refers to 1989 and 1999)

	USPO		*EPO*	
	1980-1989	*1990-1999*	*1980-1989*	*1990-1999*
Argentina	15,00	29,99	6,75	19,76
Brazil	5,76	65,37	3,77	9,71
Chile	7,82	21,00	4,12	10,67
Colombia	3,89	4,93	2,02	2,58
Cuba	1,50	6,00	0,43	10,73
Mexico	14,45	19,60	3,29	8,00
Uruguay	7,51	15,52	4,50	10,12
Venezuela	24,11	35,07	4,35	10,76

Source: EPO-CESPRI (1978-2001), USPTO-CESPRI, World-Bank

Table 8. Inventors and the labour force.

COUNTRY	*Number of inventors*		*Labour Force 1999*	*Inventors per million LF*	
	USPTO	*EPO*		*USPTO*	*EPO*
Argentina	1008	564	14,273,480	70,62	39,51
Brazil	2098	1784	77,782,840	146,99	124,99
Chile	276	142	6,093,923	19,34	9,95
Colombia	212	93	17,842,510	14,85	6,52
Cuba	295	543	5,498,755	20,67	38,04
Mexico	2214	739	39,387,160	155,11	51,77
Uruguay	40	33	1,482,429	2,80	2,31
Venezuela	945	288	9,665,180	66,21	20,18

Source: EPO-CESPRI (1978-2001), USPTO-CESPRI, World Bank

Table 9. Top 21 applicants at the Epo (1978-2001) and relative patents (in *ITALICS* the applicant with a Latin American address)

Company	Country (a)	# of patents
UNILEVER	NL and GB	79
EMPRESA BRASILEIRA DE COMPRESSORES S/A – EMBRACO +	*BR*	*69*
PETROLEO BRASILEIRO S.A. - PETROBRAS	*BR*	*69*
INTEVEP	*VE*	*48*
BAYER*	DE	39
PROCTER & GAMBLE	US	37
CENTRO DE INGENIERIA GENETICA Y BIOTECNOLOGIA	*CU*	*32*
JOHNSON & JOHNSON **	*BR and US*	*27*
VOITH ***	DE	23
HYLSA	*MX*	*21*
PRAXAIR TECHNOLOGY	US	21
BASF	DE	20
MULTIBRAS S.A. ELETRODOMESTICOS	*BR*	*16*
METAGAL INDUSTRIA E COMERCIO	*BR*	*15*
CENTRO DE INMUNOLOGIA MOLECULAR	*CU*	*14*
ROBERT BOSCH	DE	14
HOECHST	DE	13
DELPHI TECHNOLOGIES	US	12
GENERAL ELECTRIC	US	12
SYNTEX	US	10
SERVICIOS CONDUMEX	*MX*	*10*

(a) This is the address of the applicant
* It includes also BAYER CROPSCIENCE
** It includes JOHNSON & JOHNSON INDUSTRIA E COMERCIO (BR), JOHNSON & JOHNSON CONSUMER PRODUCTS (US), JOHNSON & JOHNSON INDUSTRIAL (BR)
*** It includes VOITH PAPER PATENT and VOITH SULZER PAPIERMASCHINEN
+ Owned by Whirlpool S.A.
Source: EPO-CESPRI (1978-2001)

Table 10. Top 23 applicants at the Uspto (1978-2001) and relative 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
CENTRO DE INVESTIGACION Y DE ESTUDIOS AVANZADOS DEL INSTITUTO POLITECNICO NACION	17
CARDIOTHORACIC SYSTEMS	17
COLGATE-PALMOLIVE	15
INDUSTRIAS ROMI	15
T & R CHEMICALS	15
VIDRIO PLANO DE MEXICO	15
SERVICIOS CONDUMEX	15

Source: USPTO-CESPRI

Table 11. Latin American patents at the USPTO vis à vis other geographical areas (by inventor's country)

YEAR	*Latin America (a)*	*East Europe (b)*	*Australia New Z.*	*Four Tigers (c)*	*China*	*India*	*Malaysia Thailand*	*US*	*Japan*
1980	122	280	345	144	2	12	6	38994	9609
1981	103	265	351	95	2	22	5	36935	10051
1982	112	241	338	162	4	16	4	36777	11350
1983	98	209	344	156	4	14	3	34715	10858
1984	115	207	393	201	9	18	5	36494	12505
1985	120	213	432	296	24	21	8	38026	14399
1986	153	198	498	414	54	24	2	39229	15463
1987	140	194	505	592	47	29	10	42754	17071
1988	124	223	515	640	63	40	7	47357	19998
1989	166	181	512	832	61	48	15	50693	21776
1990	166	165	526	1037	51	42	13	53842	22264
1991	185	117	488	1260	65	37	28	54660	23054
1992	213	106	541	1449	65	49	15	58056	23131
1993	206	125	606	1791	100	62	29	61503	22767
1994	288	146	667	2229	79	70	33	69150	26544
1995	285	191	825	2602	91	85	56	82973	29473
1996	299	150	933	3367	100	117	60	78927	31202
1997	344	194	947	4082	156	170	84	92698	36025
1998	361	215	1097	5138	172	197	81	90337	32859
1999	384	221	1026	6428	270	261	102	89632	31627
2000	371	221	982	5587	322	281	159	78565	30513
2001*	297	146	1000	9422	195	178	63	87600	33223
2002*	303	133	999	9860	289	249	99	86971	34858
2003*	327	175	1037	9945	297	342	75	87893	35515
2004*	283	138	1095	11126	404	363	98	84271	35348
2005*	210	136	1032	10099	402	384	104	74637	30341
2006*	261	168	1461	12988	661	481	144	89823	36807

Note: when the patent is a co-invention by inventors from different countries it is counted more than once
Source: USPTO-CESPRI
* Source: USPTO (2007); residence in this case is determined by the residence of the first-named inventor at the time of grant. Data for the period 2001-2006 are therefore not directly comparable with data 1980-2000

(a) includes Argentina, Brazil, Chile, Colombia, Cuba, Mexico, Uruguay, Venezuela (Panama is excluded).
(b) includes: Latvia, Estonia, Lithuania, Byelorussia, Ukraine, Poland, Czech Republic, Hungary, Romania and Bulgaria.
(c) South Korea, Hong Kong, Singapore and Taiwan

Table 12. Latin American patents at the USPTO vis à vis other geographical areas (by inventor's country)

Geographical Area	*_80_84*	*_85_89*	*_90_94*	*_95_99*	*Growth rates between the period 85-89 and 95-99*[a].
Latin America	550	703	1058	1673	81,65
East Europe	1202	1009	659	971	-3,84
Malaysia & Thailand	23	42	118	383	160,47
Four Tigers	758	2774	7766	21617	154,51
Australia & NZ	1771	2462	2828	4828	64,91
China	21	249	360	789	104,05
India	82	162	260	830	134,68
US	183915	218059	297211	434567	66,35
Japan	54373	88707	117760	161186	58,01

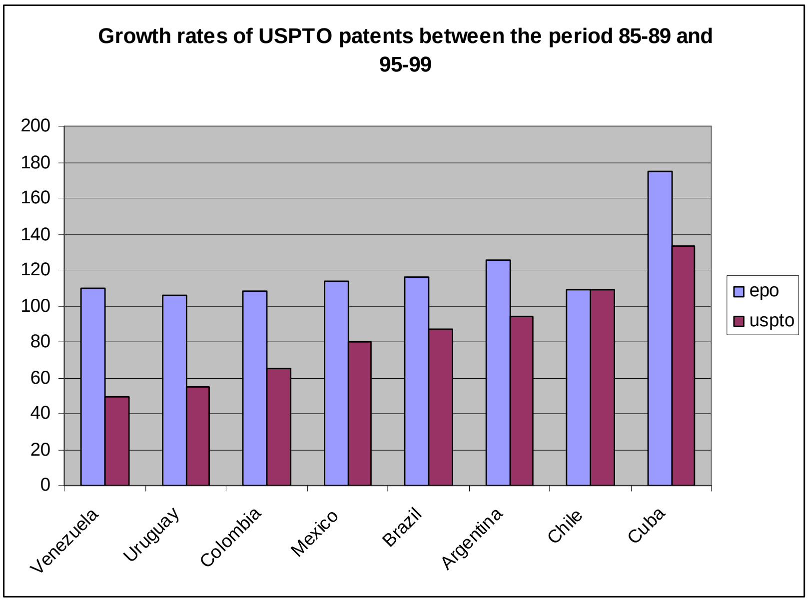
[a] the denominator is the average between the two periods.
Source: USPTO-CESPRI (1978-2001)

Table 13. Rate of growth of patents by inventors' and applicants' country

COUNTRY	*Growth rates between the period 85-89 and 95-99.* *epo*	*uspto*	*Epo (applicants' country)*
Argentina	125,11	94,32	125,33
Brazil	115,99	86,72	127,56
Chile	108,77	109,09	120,00
Colombia	108,57	64,71	155,56
Cuba	175,00	133,33	173,33
Mexico	113,78	79,94	116,42
Uruguay	105,88	54,55	100,00
Venezuela	109,68	49,32	96,00

Source: EPO-CESPRI (1978-2001), USPTO-CESPRI

Figure 3:



Source: USPTO-CESPRI (1978-2001)

Table 14: Citations per patent (USPTO) over time by geographical area

YEAR	*Latin_America*	*East_Europe*	*Australia_NZ*	*Four_Tigers*	*China*	*India*	*Malaysia_Thai*
1980	7,01	4,27	7,38	6,76	7,00	4,67	4,50
1981	6,11	4,99	7,98	9,72	16,00	4,86	4,40
1982	6,98	4,70	7,16	8,48	11,00	6,50	10,25
1983	8,03	4,92	7,78	7,17	19,50	7,93	12,00
1984	6,70	5,61	7,46	8,02	7,56	4,83	16,60
1985	6,63	4,02	8,07	8,27	7,38	13,71	10,38
1986	6,55	5,25	7,80	7,74	8,19	4,50	6,50
1987	5,75	4,48	6,83	8,68	7,55	14,10	7,70
1988	6,27	3,86	7,87	7,92	10,76	8,25	6,71
1989	6,20	4,19	7,35	7,81	6,57	7,63	10,93
1990	6,84	4,96	7,63	7,72	7,00	5,76	10,38
1991	6,73	3,46	7,23	7,70	8,09	6,35	8,93
1992	5,19	5,48	6,95	8,06	5,63	6,16	7,93
1993	5,67	6,02	6,70	7,06	3,94	6,89	5,79
1994	5,24	3,98	5,27	7,28	3,39	7,39	7,55
1995	5,00	3,70	4,30	6,19	2,96	3,74	5,29
1996	3,44	3,34	3,37	5,59	3,15	4,21	4,05
1997	1,81	2,11	2,69	4,39	2,29	2,54	3,40
1998	1,77	1,56	1,50	2,95	1,54	1,66	1,80
1999	0,79	0,66	0,75	1,89	1,00	0,74	1,65
2000	0,37	0,33	0,34	0,93	0,58	0,25	0,45
Total	*4,26*	*3,82*	*4,88*	*4,47*	*3,37*	*3,42*	*3,76*

Source: USPTO-CESPRI (1978-2001)

Table 15: Citations per patent (USPTO) over time

YEARS	*AR*	*BR*	*CL*	*CO*	*CU*	*MX*	*UY*	*VE*
1975	6,79	6,60	3,50	8,50	4,00	5,86	3,00	4,50
1976	7,61	9,68	0,67	7,11	2,00	6,73	12,00	15,56
1977	6,38	5,27	2,00	7,50	5,00	8,71	0,00	6,08
1978	4,73	4,63	8,40	11,50	0,00	6,59	0,00	4,00
1979	6,59	6,78	5,00	7,00	0,00	5,17	0,00	5,73
1980	7,28	5,00	5,00	8,83	0,00	9,02	0,00	4,79
1981	7,89	7,32	7,00	9,50	3,00	4,65	0,00	5,50
1982	6,13	9,11	9,50	9,43	3,00	6,47	0,00	3,30
1983	7,50	6,96	4,00	10,11	3,00	8,35	0,00	9,87
1984	5,40	5,53	4,25	8,00	0,00	7,00	0,00	9,82
1985	7,27	8,00	2,67	6,33	16,50	5,61	1,00	5,63
1986	11,00	6,97	3,33	3,60	0,00	6,94	0,00	3,79
1987	4,13	7,63	12,00	4,25	13,00	5,46	5,50	4,77
1988	5,50	4,47	3,00	7,33	0,00	8,31	1,50	6,12
1989	4,62	5,49	3,44	7,00	0,00	8,74	3,67	5,68
1990	13,41	5,52	3,14	9,00	0,00	5,91	13,00	3,80
1991	17,56	5,38	4,13	2,40	3,67	5,00	15,00	4,68
1992	3,33	4,73	6,08	3,00	7,00	7,05	1,00	5,12
1993	10,95	4,14	4,00	8,00	0,00	5,66	0,00	3,26
1994	8,22	5,29	4,40	3,62	1,67	4,14	2,00	4,43
1995	10,31	4,15	2,08	3,33	0,50	4,41	1,00	4,40
1996	7,92	1,70	2,83	3,00	2,75	3,13	2,50	2,35
1997	2,77	1,57	1,26	1,71	0,25	1,65	0,67	2,00
1998	2,59	1,41	1,25	2,56	0,00	1,76	0,00	1,74
1999	1,49	0,85	0,39	1,50	0,00	0,59	0,25	0,47
2000	0,27	0,48	0,09	0,50	0,00	0,45	0,50	0,11
Total	*6,29*	*3,94*	*2,98*	*5,19*	*2,40*	*4,64*	*2,78*	*4,04*

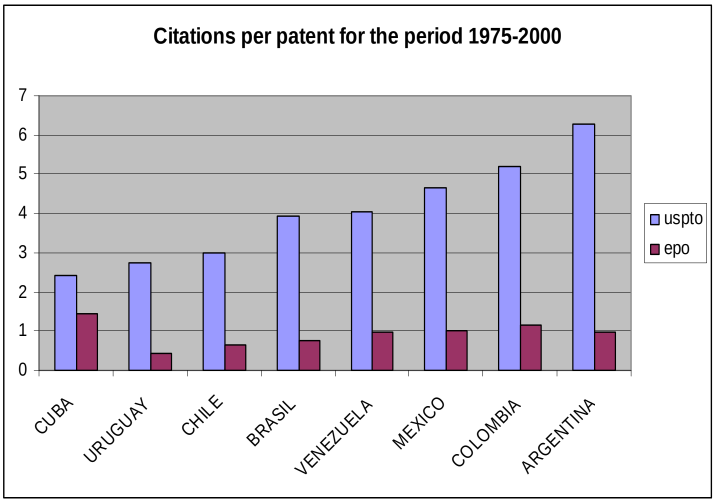
Source: USPTO-CESPRI (1978-2001)

Table 16: Citations per patent for the period 1975-2000 at USPTO and EPO

	USPTO: 1975-2000			EPO: 1978-2000		
	Patents	Citations		Patents	Citations	
	(a)	(b)	(b)/(a)	(a)	(b)	(b)/(a)
ARGENTINA	788	4958	*6,29*	420,00	403,00	*0,96*
BRASIL	1572	6198	*3,94*	1124,00	837,00	*0,74*
CHILE	193	576	*2,98*	96,00	62,00	*0,65*
COLOMBIA	181	940	*5,19*	82,00	96,00	*1,17*
CUBA	52	125	*2,40*	75,00	109,00	*1,45*
MEXICO	1567	7266	*4,64*	449,00	452,00	*1,01*
URUGUAY	37	101	*2,73*	26,00	11,00	*0,42*
VENEZUELA	608	2458	*4,04*	148,00	144,00	*0,97*
Total	*4998*	*22622*	*4,53*	*2420,00*	*2114,00*	*0,87*

Source: EPO-CESPRI (1978-2001), USPTO-CESPRI

Figure 4: Citations per patent.



Source: EPO-CESPRI (1978-2001), USPTO-CESPRI

Table 17:Citations matrix (USPTO data)

	Citing Country											
Cited Country_	**Latin_America**	CA	EU_4	JP	US	Australia_N	East_Europe	Four_Tigers	India	Malaysia_Th	China	**Total**
Latin_America	**1344**	**689**	**2620**	**1572**	**18090**	**270**	**39**	**405**	**31**	**26**	**46**	**25132**
CA	**793**	44885	30755	25734	264214	3180	358	5687	249	128	358	376341
EU_4	**4498**	46557	553547	259285	1267036	12757	3100	23817	2317	704	2040	2175658
JP	**2849**	39697	267855	1338757	1426383	9406	2465	51483	1863	1098	2652	3144508
US	**21234**	273847	947388	1021360	9647665	64551	10390	173412	8756	4538	11028	12184169
Australia_N	**273**	3216	8118	5384	60119	6023	89	1331	71	30	81	84735
East_Europe	**49**	608	3542	2542	15628	157	1581	161	41	4	42	24355
Four_Tigers	**280**	3626	11622	20828	117476	925	65	57853	105	345	1459	214584
India	**23**	156	648	622	4609	37	19	92	411	4	9	6630
Malaysia_Th	**12**	82	285	374	2371	24	2	272	2	128	24	3576
China	**10**	154	583	704	4100	23	13	464	18	8	476	6553
Total	**31365**	413517	1826963	2677162	12827691	97353	18121	314977	13864	7013	18215	18246241

Source: own elaboration on USPTO-CESPRI

Table 18: 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 19: Citations matrix (EPO data)

Cited Country	Citing Country ***Latin_America***	CA	EU_4	JP	US	Australia_N	East_Europe	Four_Tigers	India	Malaysia_Th	China	**Total**
Latin_America	***98***	**16**	**466**	**94**	**401**	**10**	**4**	**1**	**5**	**0**	**0**	**1095**
CA	***24***	2417	3939	1247	3943	178	30	42	10	0	13	11843
EU_4	***664***	3531	241199	37773	73549	2813	994	773	279	96	243	361914
JP	***181***	1541	52634	112031	45001	920	378	558	134	30	166	213574
US	***574***	4822	100079	45316	180987	3043	754	818	311	83	258	337045
Australia_N	***26***	227	3191	780	2464	1476	43	38	5	3	6	8259
East_Europe	***5***	45	907	270	628	29	289	13	5	2	4	2197
Four_Tigers	***5***	15	561	244	421	19	2	175	1	1	9	1453
India	***1***	12	146	53	177	8	1	4	54	0	2	458
Malaysia_Th	***0***	0	78	28	42	3	0	4	1	7	0	163
China	***1***	8	140	62	125	3	4	9	2	0	33	387
Total	***1579***	*12634*	*403340*	*197898*	*307738*	*8502*	*2499*	*2435*	*807*	*222*	*734*	*938388*

Source: own elaboration on EPO-CESPRI

Table 20: Citations matrix: : citations distribution by cited country for each citing country (EPO data)

Cited Country	Citing Country ***Latin_America***	CA	EU_4	JP	US	Australia_N	East_Europe	Four_Tigers	India	Malaysia_Th	China
Latin_America	**6,21**	0,13	0,12	0,05	0,13	0,12	0,16	0,04	0,62	0,00	0,00
CA	1,52	**19,13**	0,98	0,63	1,28	2,09	1,20	1,72	1,24	0,00	1,77
EU_4	*42,05*	*27,95*	***59,80***	*19,09*	*23,90*	*33,09*	*39,78*	*31,75*	*34,57*	*43,24*	*33,11*
JP	11,46	12,20	13,05	**56,61**	14,62	10,82	15,13	22,92	16,60	13,51	22,62
US	36,35	38,17	24,81	22,90	**58,81**	35,79	30,17	33,59	38,54	37,39	35,15
Australia_N	1,65	1,80	0,79	0,39	0,80	**17,36**	1,72	1,56	0,62	1,35	0,82
East_Europe	0,32	0,36	0,22	0,14	0,20	0,34	**11,56**	0,53	0,62	0,90	0,54
Four_Tigers	0,32	0,12	0,14	0,12	0,14	0,22	0,08	**7,19**	0,12	0,45	1,23
India	0,06	0,09	0,04	0,03	0,06	0,09	0,04	0,16	**6,69**	0,00	0,27
Malaysia_Th	0,00	0,00	0,02	0,01	0,01	0,04	0,00	0,16	0,12	**3,15**	0,00
China	0,06	0,06	0,03	0,03	0,04	0,04	0,16	0,37	0,25	0,00	**4,50**
Totale	*6,21*	*0,13*	*0,12*	*0,05*	*0,13*	*0,12*	*0,16*	*0,04*	*0,62*	*0,00*	*0,00*

Source: own elaboration on EPO-CESPRI

Figure 5. Latin American citations and knowledge flows from and to selected Geographical Areas.

USPTO PATENTS

CITING COUNTRIES

	Number of citing patents	(%)
Latin_America	1344	5,35
EU_4	2620	10,42
JP	1572	6,25
US	18090	71,98

← Knowledge

Citations →

Latin American Countries

← Knowledge

Citations →

CITED COUNTRIES

	Number of cited patents	(%)
Latin_America	1344	4,29
EU_4	4498	14,34
JP	2849	9,08
US	21234	67,70

EPO PATENTS

CITING COUNTRIES

	Number of citing patents	(%)
Latin_America	98	8,95
EU_4	466	42,56
JP	94	8,58
US	401	36,62

← Knowledge

Citations →

Latin American Countries

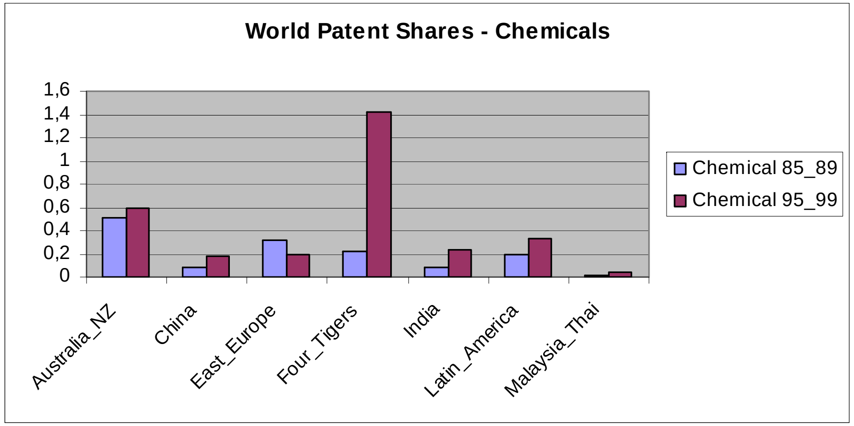
← Knowledge

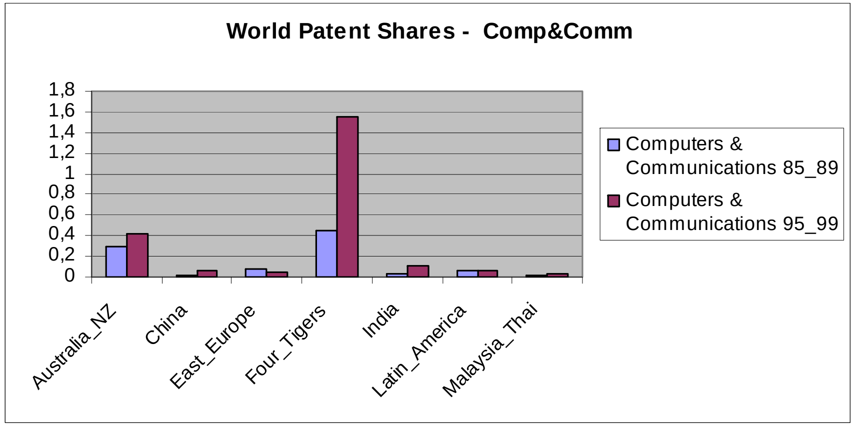
Citations →

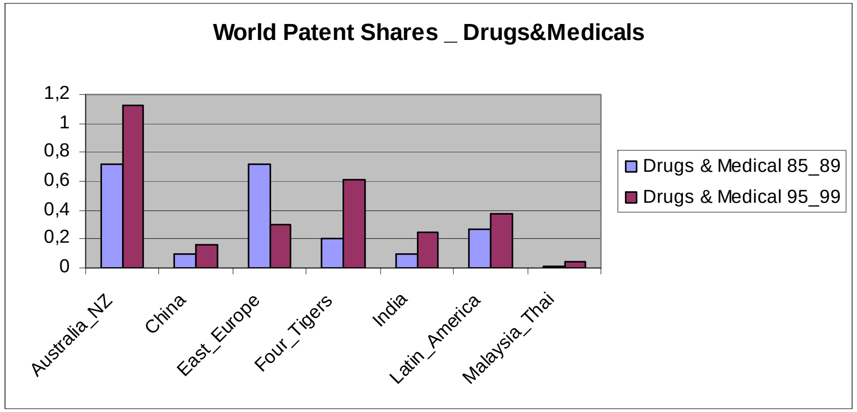
CITED COUNTRIES

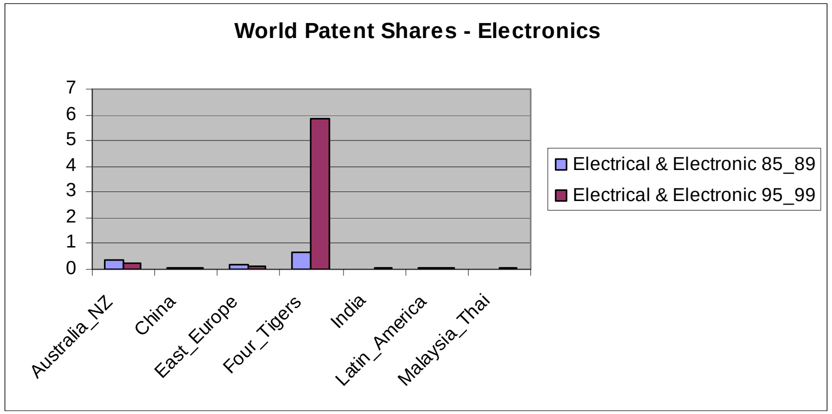
	Number of cited patents	(%)
Latin_America	98	6,21
EU_4	664	42,05
JP	181	11,46
US	574	36,35

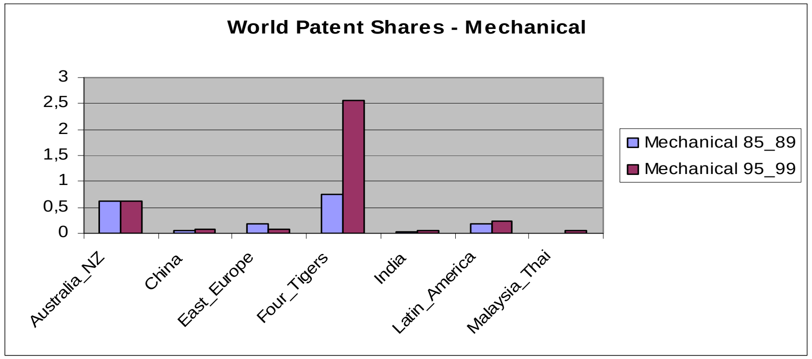
Panel 1: World patent share of different geographical areas in different sectors in two sub-periods (USPTO data)

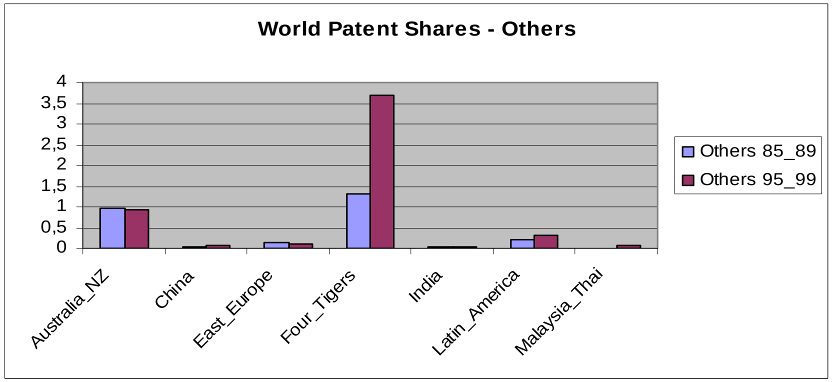




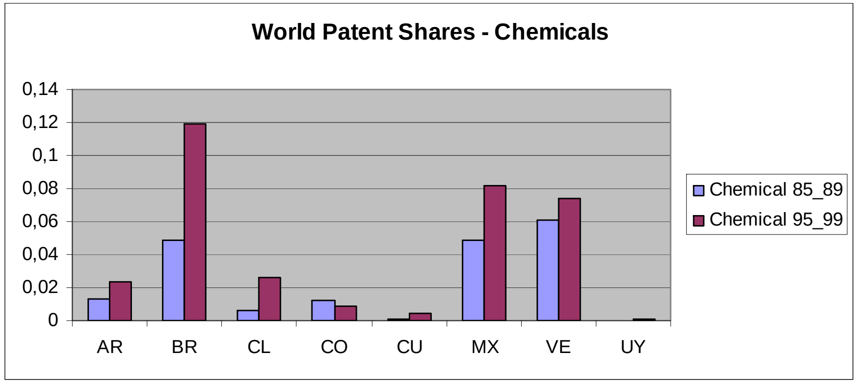


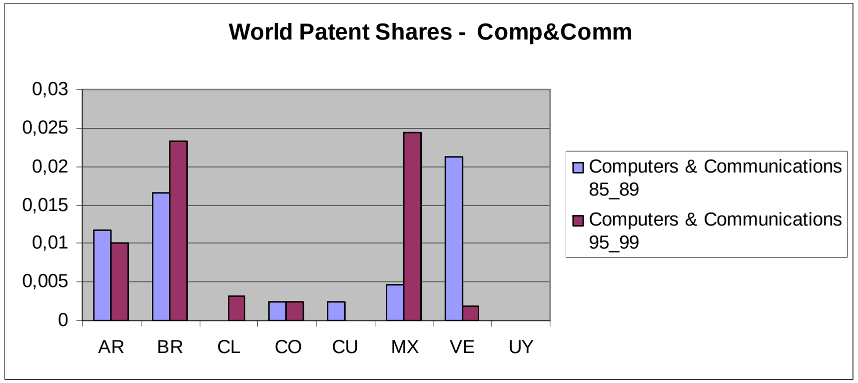


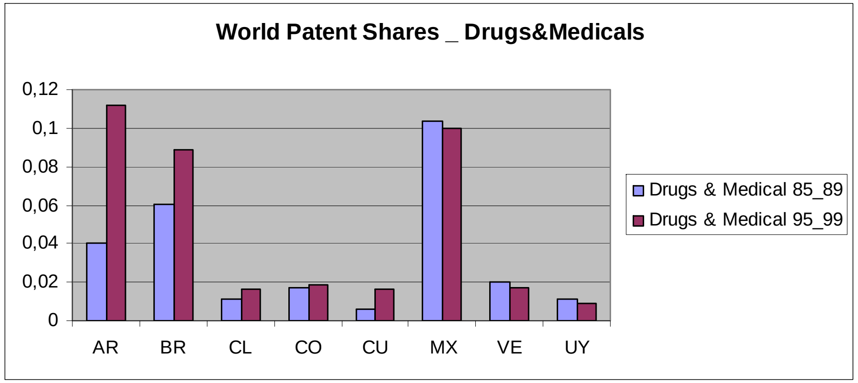


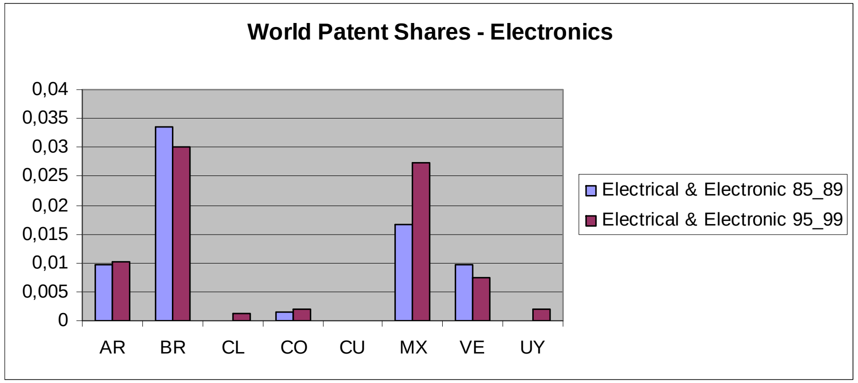


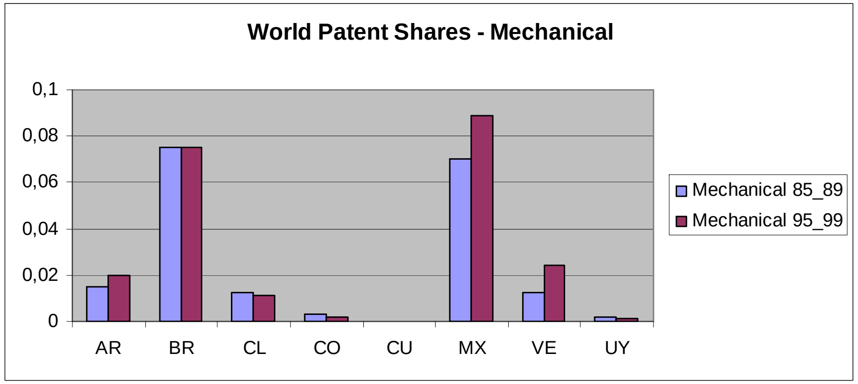
Panel 2: World patent shares for the selected Latin American countries in different sectors in two sub-periods (USPTO data)











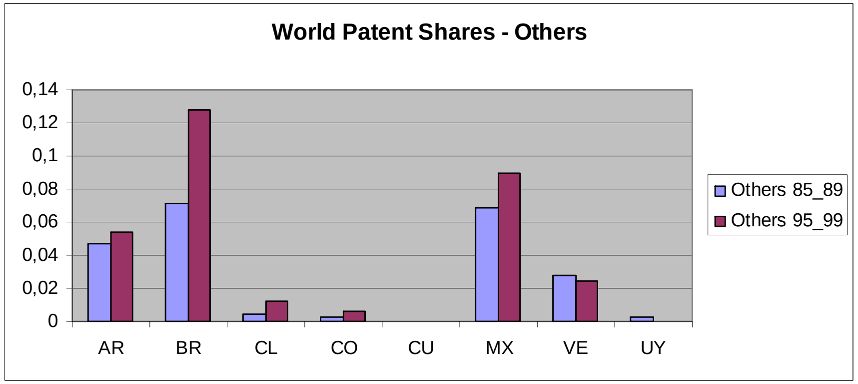


Table 21. World patent share of different geographical areas in different sectors in two sub-periods (USPTO data)

		Australia_NZ	China	East_Europe	Four_Tigers	India	Latin_America	Malaysia_Thai	JP	US
Chemical	85_89	0,506	0,082	0,317	0,217	0,080	0,189	0,011	20,283	51,222
Chemical	95_99	0,590	0,179	0,192	1,427	0,237	0,337	0,048	20,403	51,815
Computers & Communications	85_89	0,298	0,019	0,078	0,456	0,024	0,059	0,009	34,956	48,423
Computers & Communications	95_99	0,418	0,066	0,051	1,555	0,104	0,065	0,035	25,536	56,962
Drugs & Medical	85_89	0,713	0,092	0,718	0,199	0,092	0,268	0,009	12,211	60,136
Drugs & Medical	95_99	1,129	0,157	0,302	0,607	0,246	0,372	0,048	8,080	68,345
Electrical & Electronic	85_89	0,335	0,063	0,209	0,656	0,014	0,071	0,007	25,636	50,808
Electrical & Electronic	95_99	0,258	0,088	0,102	5,825	0,053	0,080	0,056	26,726	48,669
Mechanical	85_89	0,618	0,056	0,194	0,740	0,017	0,191	0,008	24,845	46,900
Mechanical	95_99	0,618	0,069	0,088	2,563	0,039	0,222	0,039	24,475	49,394
Others	85_89	0,956	0,048	0,149	1,313	0,032	0,223	0,015	12,509	60,584
Others	95_99	0,926	0,081	0,089	3,705	0,022	0,314	0,070	12,171	62,031

Source: own elaboration on USPTO-CESPRI

Table 22. World patent shares for the selected Latin American countries in different sectors in two sub-periods (USPTO data)

		AR	BR	CL	CO	CU	MX	VE	UY
Chemical	85_89	0,0133	0,0485	0,0061	0,0121	0,0012	0,0485	0,0606	0,0000
Chemical	95_99	0,0239	0,1194	0,0264	0,0085	0,0043	0,0819	0,0742	0,0009
Computers & Communications	85_89	0,0118	0,0165	0,0000	0,0024	0,0024	0,0047	0,0213	0,0000
Computers & Communications	95_99	0,0100	0,0232	0,0031	0,0025	0,0000	0,0245	0,0019	0,0000
Drugs & Medical	85_89	0,0404	0,0606	0,0115	0,0173	0,0058	0,1039	0,0202	0,0115
Drugs & Medical	95_99	0,1115	0,0886	0,0164	0,0186	0,0164	0,0995	0,0175	0,0087
Electrical & Electronic	85_89	0,0098	0,0335	0,0000	0,0014	0,0000	0,0167	0,0098	0,0000
Electrical & Electronic	95_99	0,0102	0,0300	0,0014	0,0020	0,0000	0,0273	0,0075	0,0020
Mechanical	85_89	0,0148	0,0752	0,0127	0,0032	0,0000	0,0699	0,0127	0,0021
Mechanical	95_99	0,0200	0,0750	0,0114	0,0021	0,0000	0,0885	0,0243	0,0014
Others	85_89	0,0474	0,0710	0,0045	0,0023	0,0000	0,0688	0,0282	0,0023
Others	95_99	0,0543	0,1280	0,0124	0,0062	0,0000	0,0900	0,0241	0,0000

Source: own elaboration on USPTO-CESPRI

Panel 4: Revealed Technological Advantages (eq. 1) of different geographical areas in different sectors in two sub-periods (USPTO data)

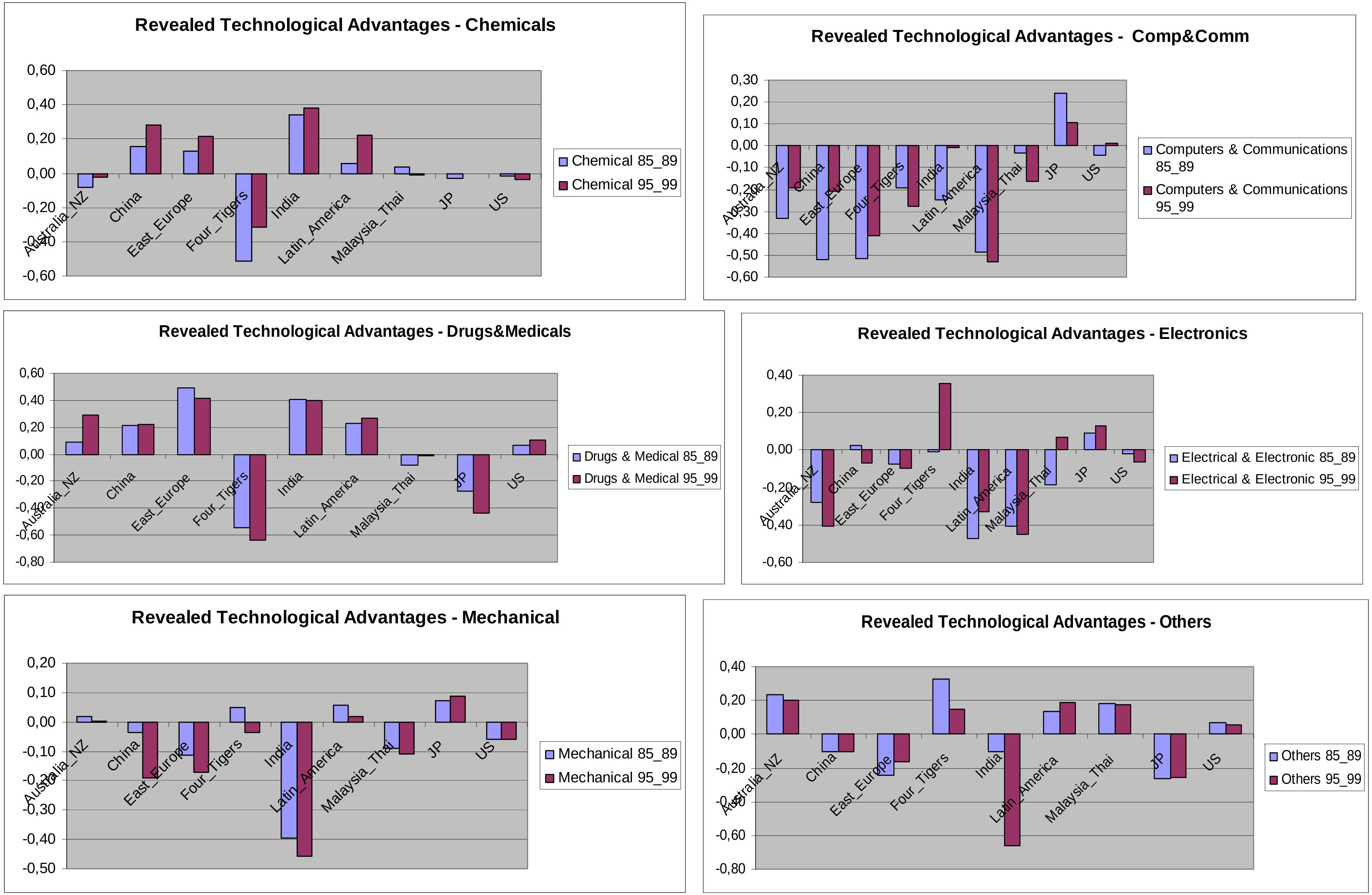
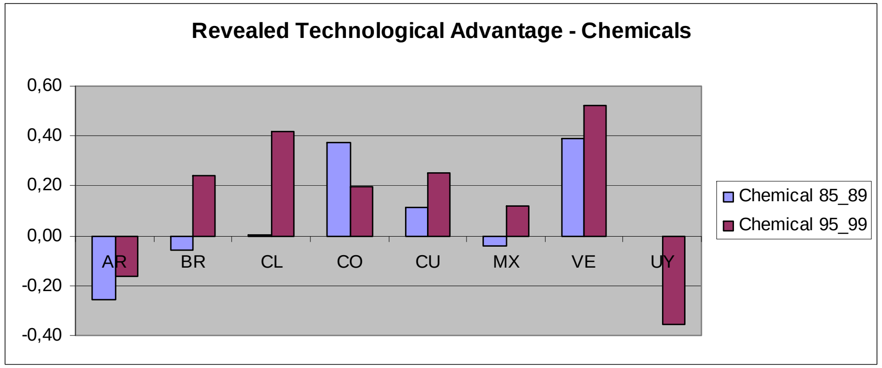


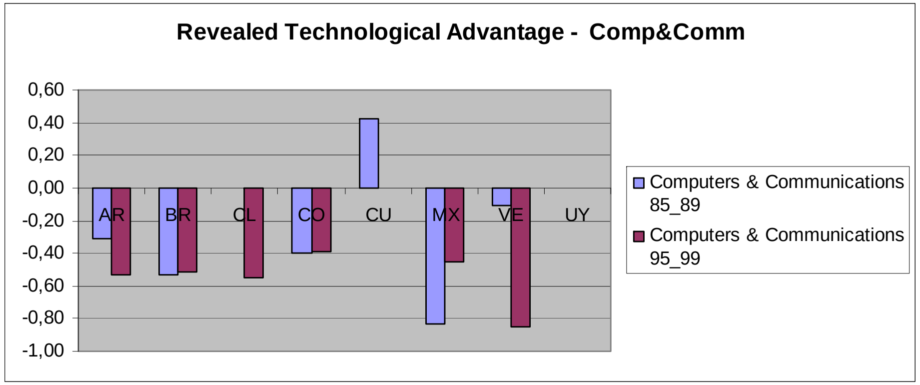
Table 23: Revealed Technological Advantages (eq.1) of different geographical areas in different sectors in two sub-periods (USPTO data)

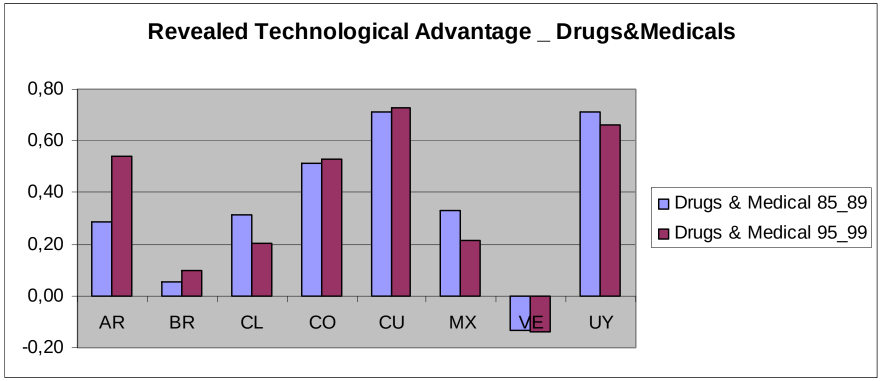
		Australia_NZ	China	East_Europe	Four_Tigers	India	Latin_America	Malaysia_Thai	JP	US
Chemical	85_89	-0,08	0,16	0,13	-0,51	0,34	0,05	0,04	-0,03	-0,01
Chemical	95_99	-0,02	0,28	0,22	-0,32	0,38	0,22	-0,01	0,00	-0,03
Computers & Communications	85_89	-0,33	-0,52	-0,52	-0,19	-0,25	-0,48	-0,04	0,24	-0,04
Computers & Communications	95_99	-0,19	-0,21	-0,41	-0,28	-0,01	-0,53	-0,16	0,11	0,01
Drugs & Medical	85_89	0,09	0,21	0,49	-0,54	0,41	0,23	-0,08	-0,27	0,07
Drugs & Medical	95_99	0,29	0,22	0,42	-0,64	0,40	0,27	-0,01	-0,44	0,10
Electrical & Electronic	85_89	-0,28	0,02	-0,08	-0,01	-0,47	-0,41	-0,18	0,09	-0,02
Electrical & Electronic	95_99	-0,41	-0,07	-0,10	0,36	-0,33	-0,45	0,07	0,13	-0,07
Mechanical	85_89	0,02	-0,03	-0,11	0,05	-0,40	0,06	-0,09	0,07	-0,06
Mechanical	95_99	0,00	-0,19	-0,17	-0,04	-0,46	0,02	-0,11	0,09	-0,06
Others	85_89	0,23	-0,11	-0,24	0,32	-0,11	0,14	0,18	-0,26	0,07
Others	95_99	0,20	-0,11	-0,16	0,15	-0,66	0,19	0,18	-0,26	0,06
Standard deviation 85_89 (a)		0,22	0,26	0,34	0,34	0,37	0,30	0,13	0,21	0,05
Standard deviation 95_99 (b)		0,26	0,21	0,30	0,36	0,44	0,36	0,12	0,23	0,07
(b)/(a)		*1,18*	*0,80*	*0,88*	*1,06*	*1,19*	*1,19*	*0,97*	*1,13*	*1,24*

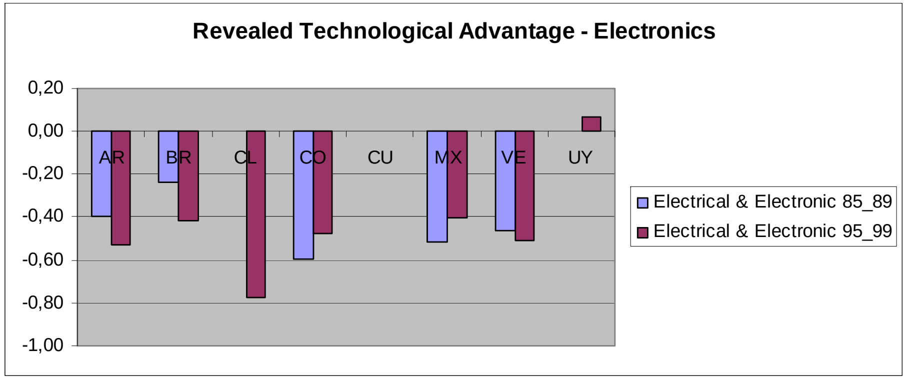
Source: own elaboration on USPTO-CESPRI

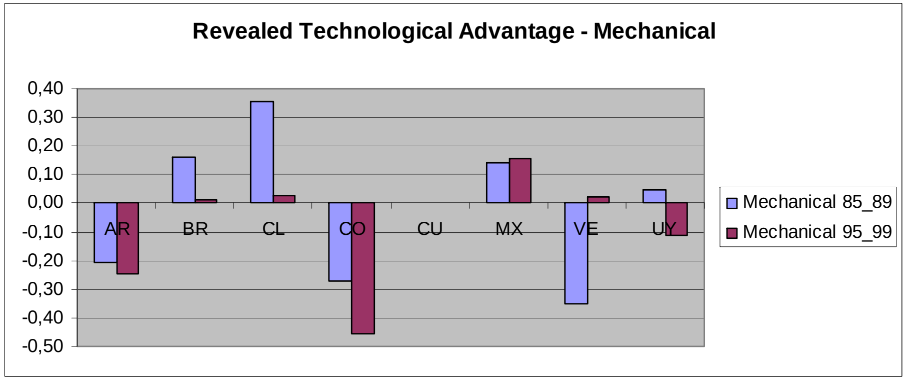
Panel 5: Revealed Technological Advantages (eq. 1) of selected Latin American countries in different sectors in two sub-periods (USPTO data)

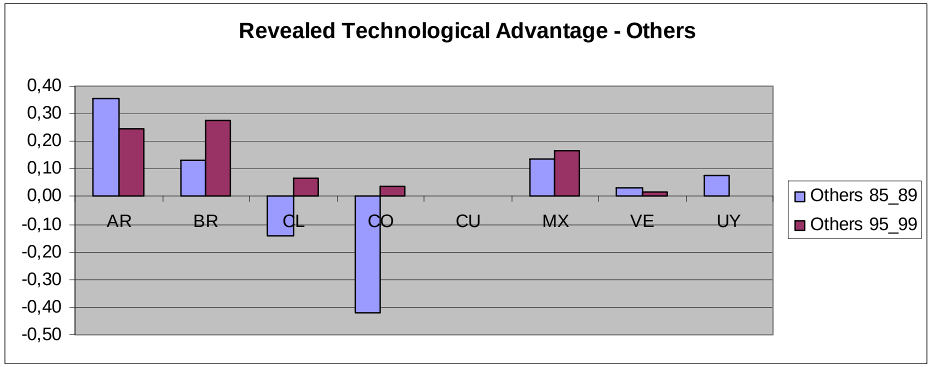












Tab. 24. Revealed Technological Advantages (eq. 1) of selected Latin American countries in different sectors in two sub-periods (USPTO data)

		AR	BR	CL	CO	CU	MX	VE	UY	St. Dev.	95_99/ 85_89
Chemical	85_89	-0,25	-0,06	0,00	0,37	0,11	-0,04	0,39	0,00	0.22	
Chemical	95_99	-0,16	0,24	0,42	0,20	0,25	0,12	0,52	-0,35	0.29	1.31
Computers & Communications	85_89	-0,31	-0,53	0,00	-0,40	0,42	-0,83	-0,11	0,00	0.38	
Computers & Communications	95_99	-0,53	-0,52	-0,55	-0,39	0,00	-0,45	-0,85	0,00	0.29	0.75
Drugs & Medical	85_89	0,29	0,05	0,31	0,51	0,71	0,33	-0,14	0,71	0.30	
Drugs & Medical	95_99	0,54	0,10	0,20	0,53	0,73	0,21	-0,14	0,66	0.31	1.03
Electrical & Electronic	85_89	-0,39	-0,24	0,00	-0,60	0,00	-0,52	-0,46	0,00	0.25	
Electrical & Electronic	95_99	-0,53	-0,42	-0,78	-0,47	0,00	-0,41	-0,51	0,07	0.28	1.12
Mechanical	85_89	-0,20	0,16	0,36	-0,27	0,00	0,14	-0,35	0,05	0.24	
Mechanical	95_99	-0,25	0,01	0,03	-0,46	0,00	0,16	0,02	-0,11	0.19	0.80
Others	85_89	0,36	0,13	-0,14	-0,42	0,00	0,14	0,03	0,08	0.23	
Others	95_99	0,24	0,27	0,07	0,04	0,00	0,16	0,02	0,00	0.11	0.49
St.dev. (a)	85_89	0,32	0,27	0,20	0,46	0,30	0,45	0,30	0,28		
St.dev. (b)	95_99	0,43	0,34	0,46	0,41	0,30	0,31	0,48	0,34		
(b)/(a)		*1,33*	*1,27*	*2,31*	*0,89*	*1,00*	*0,68*	*1,58*	*1,19*		

Source: own elaboration on USPTO-CESPRI

Tab. 25. Revealed Technological Advantages (eq. 1) of selected Latin American countries in different sectors in two sub-periods (EPO data)

		AR	BR	CL	CO	MX	UY	VE	CU	PA
Chemical	85_89	0,01	0,16	0,41	0,54	-0,14	0,38	-0,07	0	0
Chemical	95_99	-0,12	0,21	0,31	0,14	0,3	-0,36	0,45	0,47	0
Computers & Communications	85_89	-0,54	-0,19	0	0	-0,22	0	0	0	0
Computers & Communications	95_99	-0,49	-0,68	-0,5	-0,3	-0,58	0,25	-0,66	-0,61	0,09
Drugs & Medical	85_89	0,39	0,2	0	0	0,62	0	0,45	0,84	0
Drugs & Medical	95_99	0,49	0,18	-0,15	0,53	0,24	0,29	0,21	0,57	0,71
Electrical & Electronic	85_89	-0,16	-0,21	0	0	-0,58	0	-0,45	0	0
Electrical & Electronic	95_99	-0,15	-0,19	-0,28	-0,53	-0,14	0	-0,48	0	0
Mechanical	85_89	-0,22	-0,07	0,12	-0,18	-0,25	0,16	-0,43	0	0,16
Mechanical	95_99	-0,19	0,02	0,01	-0,38	-0,1	0,07	-0,33	-0,81	-0,59
Others	85_89	0,32	-0,01	0	0	0,17	0	0,53	0	0,62
Others	95_99	0,14	0,01	0,12	0,02	-0,1	-0,15	0,08	0	0

Source: own elaboration on USPTO-CESPRI

Table 26. Patents at the EPO by Country and Manufacturing sector

	Argentina	Brazil	Chile	Colombia	Mexico	Total
Chem & Pharma	91.15	192.85	26.1	16.3	111.7	438.1
Elect. Machinery	30.7	86.7	1.8	4	39.4	162.6
Instruments	63.2	97.9	6	15.6	35.8	218.5
Metals	20.6	78.75	7.9	1	29.85	138.1
Non Elect. Machinery	53.75	182.6	13.3	5	50.25	304.9
Transports	14	58	0	0	11.4	83.4
Total	273.4	696.8	55.1	41.9	278.4	

Table 27. Patents per million of employees by Country and Manufacturing sector

	Argentina	Brazil	Chile	Colombia	Mexico
Chem & Pharma	204.04	65.11	96.73	41.06	62.34
Elect. Machin	228.65	39.89	34.24	21.67	9.21
Instruments	2154.88	276.65	496.44	525.25	59.25
Metals & Meta products	29.47	17.68	17.30	2.99	11.79
Non Elect. Ma	264.63	50.16	97.25	36.68	33.50
Transports	25.28	19.62	0.00	0.00	2.75

Table 28. Value added per employee by Country and Manufacturing sector

	Argentina	Brazil	Chile	Colombia	Mexico	Average
Chem & Pharma	0.057	0.032	0.047	0.033	0.032	0.040
Elect. Machin	0.048	0.037	0.025	0.015	0.009	0.027
Instruments	0.012	0.017	0.014	0.015	0.007	0.013
Metals	0.048	0.028	0.042	0.024	0.021	0.033
Non Elect. Ma	0.029	0.022	0.023	0.018	0.013	0.021
Transports	0.033	0.022	0.016	0.030	0.020	0.024
Average	0.038	0.026	0.028	0.022	0.017	

Table 29. Normalized trade balance by Country and Manufacturing sector

	Argentina	Brazil	Chile	Colombia	Mexico	Average
Chem & Pharma	-0.486	-0.398	-0.500	-0.497	-0.351	-0.446
Elect. Machin	-0.867	-0.525	-0.937	-0.856	-0.017	-0.640
Instruments	-0.781	-0.677	-0.950	-0.847	-0.222	-0.695
Metals	-0.142	0.522	0.640	-0.419	-0.235	0.073
Non Elect. Ma	-0.731	-0.288	-0.921	-0.899	-0.276	-0.623
Transports	-0.393	0.050	-0.791	-0.847	0.154	-0.366
Average	-0.566	-0.220	-0.576	-0.727	-0.158	

Table 30. Correlation matrix for the variables in specification [1]

	Patents	Patents Intensity	Lab Productivity
Patents Intensity	0.1439*		
	0.033		
	220		
Labour Productivity	0.1359*	-0.1347*	
	0.0441	0.046	
	220	220	
Trade	0.0361	-0.2973*	-0.1334*
	0.5939	0	0.0481
	220	220	220

Table 31. Linear fixed effects regressions on specification [1]. Dependent variable: Log(Patent Intensity)# - p-value in parenthesis

				High Tech / Medium Tech (b)	Low Tech (b)	Larger Countries (c)	Smaller Countries (c)
Log (Lab_Prod)	0.13	-	-				
	(0.76)	-	-				
Log (Lab_Prod) (t-1)	-	0.39	-				
	-	(0.43)	-				
Log (Lab_Prod) (t-2)	-	-	0.03	0.32	0.77	0.31	0.73
	-	-	(0.93)	(0.64)	(0.26)	(0.56)	(0.24)
Trade	-0.95*	-	-				
	(0.025)						
Trade (t-1)	-	-0.52	-				
		(0.23)					
Trade (t-2)	-	-	-1.34**	-1.96**	-0.42	-0.83*	-8.47**
	-	-	(0.001)	(0.002)	(0.42)	(0.03)	(0.002)
n.obs.	220	198	176	96	80	144	32
R-squared (a)	0.88	0.88	0.90	0.92	0.88	0.92	0.96
Adj. R-squared	0.86	0.86	0.88	0.89	0.85	0.90	0.97
R-sq. within	0.78	0.77	0.75	0.82	0.75	0.69	0.95
Const.	yes	yes	yes	yes	yes	yes	yes
Time Dummies	yes	yes	yes	yes	yes	yes	yes

** 99% sig. level; * 95%; + 90%.

#zeroes have been set equal to one. A specific dummy allows those observations to have a separate intercept.

All columns estimated with fixed effects

(a) These R-squared include of the estimated unobserved individual effects,

(b) High and Medium Tech Industries are: Chemicals & Pharmaceuticals, Electrical Machinery and Instruments. Low Tech sectors are Metals, Transports and Non Electrical Machinery,

(c) Larger countries are Mexico, Argentina and Brazil, Smaller countries are Colombia and Chile

Figure 6. Labour Productivity, Trade and Patents.

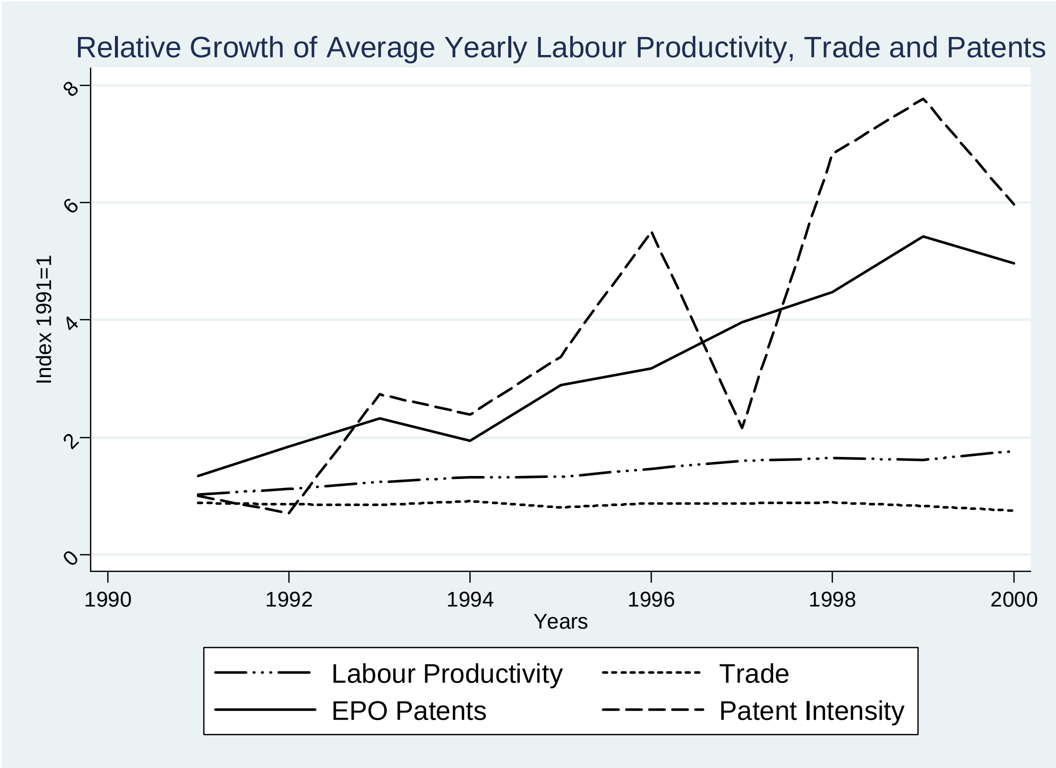


Table A1. Total number of patent applications at the national patent offices.

	Chile	Cuba	Brazil[(a)]	El Salvador	Panama	Perù	Dominican Republic
1990	-	259	7537	57	-	268	-
1991	-	236	6944	35	-	246	-
1992	1433	141	6474	110	-	277	-
1993	1682	130	6650	81	-	290	-
1994	2006	151	6497	83	-	396	-
1995	2081	138	7448	70	42	546	-
1996	2383	125	8057	70	110	618	-
1997	2920	142	12294	84	154	807	-
1998	3197	205	11720	116	174	980	125
1999	3202	237	17258	171	189	993	132
2000	3651	308	20818	212	170	1078	122
2001	3201	320	19992	185	214	984	157
2002	3007	342	16680	190	230	869	180
2003	2787	312	13910	200	260	922	203
2004	3353	299	18692	234	218	850	205
2005	3497	285	-	297	303	1052	227
2006	-	257	-	267	442	1271	296

Source: own elaboration on data from national patent offices
(a) Source: PATSTAT database.

Table A2. Share of patent applications by national residents.

	Chile	Cuba	Brazil[(a)]	El Salvador	Panama	Perù	Dominican Republic
1990	-	71,43	31,70	21,05	-	17,16	-
1991	-	88,14	33,40	28,57	-	12,60	-
1992	22,96	85,82	32,44	8,18	-	6,86	-
1993	20,27	90,00	36,53	9,88	-	10,34	-
1994	20,69	77,48	34,92	2,41	-	7,07	-
1995	15,47	76,09	36,35	5,71	9,52	4,21	-
1996	15,11	67,20	32,41	8,57	7,27	8,58	-
1997	9,35	75,35	21,82	10,71	3,90	6,20	-
1998	9,79	62,93	21,45	7,76	5,17	3,98	4,17
1999	10,84	46,41	16,51	3,51	4,76	4,93	5,60
2000	11,37	48,05	14,78	6,60	4,71	3,71	8,93
2001	12,90	44,69	16,50	3,78	3,74	3,66	6,08
2002	18,19	43,27	18,57	4,21	3,48	3,34	7,14
2003	18,16	48,72	26,25	2,00	5,38	3,47	8,56
2004	17,75	42,14	20,82	2,99	5,50	4,47	15,17
2005	16,39	36,84	-	1,68	3,96	2,57	3,65
2006	-	36,58	-	2,62	3,39	3,07	3,86

Source: own elaboration on data from national patent offices
(a) Source: PATSTAT database.

Table A3. Share of granted patents on total applications in the national patent offices.

	Chile	Cuba	Brazil[(a)]	El Salvador	Panama	Perù	Dominican Republic
1990		26,25	44,51	7,02		65,30	
1991		36,44	34,84	11,43		80,08	
1992	0,56	55,32	28,14	13,64		94,22	
1993	14,39	83,08	39,83	41,98		39,31	
1994	5,33	86,75	38,00	55,42		59,60	
1995	6,39	45,65	35,70	20,00	76,19	50,55	
1996	8,31	41,60	18,46	0,00	16,36	29,29	
1997	7,77	32,39	-	1,19	18,83	22,30	
1998	13,42	19,02	24,10	28,45	20,11	14,08	31,20
1999	13,12	30,80	18,65	18,71	14,29	27,29	23,48
2000	15,56	13,96	-	4,25	10,00	28,57	11,48
2001	12,68	30,63	17,95	4,32	57,01	54,57	210,19
2002	15,20	26,90	27,72	11,05	108,70	63,29	10,56
2003	8,29	28,53	-	9,00	58,46	59,11	17,73
2004	10,47	23,41	-	5,56	93,12	59,41	9,76
2005	8,89	31,23	-	7,07	74,92	35,74	0,88
2006		31,91		11,61	54,07	24,31	1,35

Source: own elaboration on data from national patent offices
(a) Source: PATSTAT database.

Table A4. Share of patent application in class A61K

	Chile	Cuba	Brazil[(a)]	Perù
1990	-	7,72	1,86	5,97
1991	-	13,14	1,42	7,72
1992	-	10,64	1,39	15,16
1993	-	20,77	0,66	8,97
1994	-	25,83	0,41	15,91
1995	-	23,91	0,47	9,34
1996	11,10	17,60	1,40	10,03
1997	13,67	18,31	0,81	10,16
1998	16,00	23,41	0,93	18,57
1999	16,53	20,68	0,52	16,21
2000	17,50	31,49	0,62	19,20
2001	12,60	40,94	0,99	18,60
2002	11,89	36,84	3,47	19,68
2003	6,87	39,74	8,45	21,91
2004	5,29	41,14	10,67	20,00
2005	7,47	40,35	5,65	22,24
2006	-	41,63	-	24,00

Source: own elaboration on data from national patent offices
(a) Source: PATSTAT database.

Table A5. Top 5 Applicants in the period 2000-2006.

CUBA	***Number of patents***
PFIZER	243
CENTRO DE INGENIERÍA GENÉTICA Y BIOTECNOLOGÍA	82
WARNER-LAMBERT COMPANY	61
UNIVERSIDAD CENTRAL DE LAS VILLAS	43
BAYER AKTIENGESELLSCHAFT	33
Total	*462*
Total in the sub period	*2123*
C5	*21,76*
PANAMA	***Number of patents***
PFIZER	402
WYETH	182
F. HOFFMANN-LA ROCHE AG.	105
WARNER-LAMBERT COMPANY	103
SCHERING	76
Total	*868*
Total in the sub period	*1837*
C5	*47,25*
PERU'	***Number of patents***
PFIZER	263
NOVARTIS AG;	225
F. HOFFMANN-LA ROCHE AG;	197
THE PROCTER & GAMBLE COMPANY;	166
WYETH;	162
Total	*1013*
Total in the sub period	*7026*
C5	*14,42*
EL SALVADOR	***Number of patents***
PFIZER	334
WYETH	157
ELI LILLY AND COMPANY	83
BAYER AKTIENGESELLSCHAFT - BAYER AG.	73
SCHERING AKTIENGESELLSCHAFT	66
Total	*713*
Total in the sub period	*1585*
C5	*44,98*
DOMINCAN REPUBLIC	***Number of patents***
PFIZER	318
BAYER AKTIENGESELLSCHAFT - BAYER AG.	113
COLGATE PALMOLIVE	89
WARNER-LAMBERT COMPANY	81
MERCK	58
Total	*659*
Total in the sub period	*1390*
C5	*47,41*
BRAZIL[(a)]	***Number of patents***
PFIZER	358
L'OREAL	297
ASTRAZENECA	178
BASF	71
HOFFMANN-LA ROCHE	69
Total	*973*
Total in the sub period [(a)]	*69274*
C5	*1,40*

Source: own elaboration on data from national patent offices. (a) Source: PATSTAT database and the period is 2001-2004

Tab. A6. Technological codes and number of patents for the technological class "Others".

Tech Codes	*Number of patents*	*Title*	*Tech Codes*	*Number of patents*	*Title*
26	1	Textiles: Cloth Finishing	33	7	Geometrical Instruments
28	1	Textiles: Manufacturing	43	7	Fishing, Trapping, and Vermin Destroying
38	1	Textiles: Ironing or Smoothing	101	7	Printing
66	1	Textiles: Knitting	181	7	Acoustics
69	1	Leather Manufactures	211	7	Supports: Racks
109	1	Safes, Bank Protection, or a Related Device	383	7	Flexible Bags
116	1	Signals and Indicators	434	7	Education and Demonstration
135	1	Tent, Canopy, Umbrella, or Cane	446	7	Amusement Devices: Toys
168	1	Farriery	122	8	Liquid Heaters and Vaporizers
169	1	Fire Extinguishers	172	8	Earth Working
190	1	Trunks and Hand-Carried Luggage	160	9	Flexible or Portable Closure, Partition, or Panel
223	1	Apparel Apparatus	229	9	Envelopes, Wrappers, and Paperboard Boxes
232	1	Deposit and Collection Receptacles	403	9	Joints and Connections
237	1	Heating Systems	5	10	Beds
279	1	Chucks or Sockets	119	10	Animal Husbandry
300	1	Brush, Broom, and Mop Making	507	10	Earth Boring, Well Treating, and Oil Field Chemistry
450	1	Foundation Garments	24	11	Buckles, Buttons, Clasps, Etc.
37	2	Excavating	53	11	Package Making
63	2	Jewelry	56	11	Harvesters
111	2	Planting	312	11	Supports: Cabinet Structure
224	2	Package and Article Carriers	431	11	Combustion
256	2	Fences	473	11	Games Using Tangible Projectile
269	2	Work Holders	47	12	Plant Husbandry
281	2	Books, Strips, and Leaves	248	12	Supports (e.g., for holding articles, etc.)
283	2	Printed Matter	15	13	Brushing, Scrubbing, and General Cleaning
449	2	Bee Culture (propagating, raising, caring for bees)	36	13	Boots, Shoes, and Leggings
463	2	Amusement Devices: Games	40	13	Card, Picture, or Sign Exhibiting
2	3	Apparel	126	13	Stoves and Furnaces
12	3	Boot and Shoe Making	165	13	Heat Exchange
59	3	Chain, Staple, and Horseshoe Making	273	14	Amusement Devices: Games
108	3	Horizontally Supported Planar Surfaces	277	14	Seal for a Joint or Juncture
139	3	Textiles: Weaving	132	15	Toilet
177	3	Weighing Scales	70	16	Locks
236	3	Automatic Temperature and Humidity Regulation	134	16	Cleaning and Liquid Contact with Solids

368	3	Horology: Time Measuring Systems or Devices	138	16	Pipes and Tubular Conduits
14	4	Bridges	175	17	Boring or Penetrating the Earth
112	4	Sewing	432	17	Heating
299	4	Mining or In Situ Disintegration of Hard Material	110	18	Furnaces
412	4	Bookbinding: Process and Apparatus	4	19	Baths, Closets, Sinks, and Spittoons
460	4	Crop Threshing or Separating	297	19	Chairs and Seats
57	5	Textiles: Spinning, Twisting, and Twining	285	22	Pipe Joints or Couplings
249	5	Static Molds	215	25	Bottles and Jars
441	5	Buoys, Rafts, and Aquatic Devices	206	31	Special Receptacle or Package
472	5	Amusement Devices	405	31	Hydraulic and Earth Engineering
68	6	Textiles: Fluid Treating Apparatus	99	38	Foods and Beverages: Apparatus
84	6	Music	220	38	Receptacles
131	6	Tobacco	428	57	Stock Material or Miscellaneous Articles
182	6	Fire Escape, Ladder, or Scaffold	52	58	Static Structures (e.g., Buildings)
292	6	Closure Fasteners	137	60	Fluid Handling
373	6	Industrial Electric Heating Furnaces	62	68	Refrigeration
404	6	Road Structure, Process, or Apparatus	426	68	Food or Edible Material: Processes, Compositions, and Products
452	6	Butchering	166	78	Wells (shafts or deep borings in the earth, e.g., for oil and gas)
30	7	Cutlery			

Source: own elaboration on USPTO-CESPRI

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.

JEL Codes: O30, O10, O11

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

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

[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

[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]

[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

[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,

[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 [...] ".

[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]

[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.

[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:

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

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):

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

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 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 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 $X_{h,i,t}$:

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

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

$$IS_{h,i,t} = \prod_f R^{\lambda_{h,f,j,t}}_{f,j,t} \qquad (6)$$

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.

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

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:

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

*foreign*R&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 (*foreign*R&D_cit) is calculated as follows:

[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.

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

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 (*foreign*R&D*_coinv*), based on co-inventorship behaviour, is calculated as follows:

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

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

[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,

[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]

[24] Only 4^{th}, 5^{th} and 6^{th} 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.

6.5 Differences across sectors

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.

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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									
Year (application year)	Argentina	Brazil	Chile	Colombia	Cuba	Mexico	Uruguay	Venezuela	All Latin American patents	All patent applications at USPTO
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									
Year (priority year)	Argentina	Brazil	Chile	Colombia	Cuba	Mexico	Uruguay	Venezuela	All Latin American patents	All patent applications at EPO
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

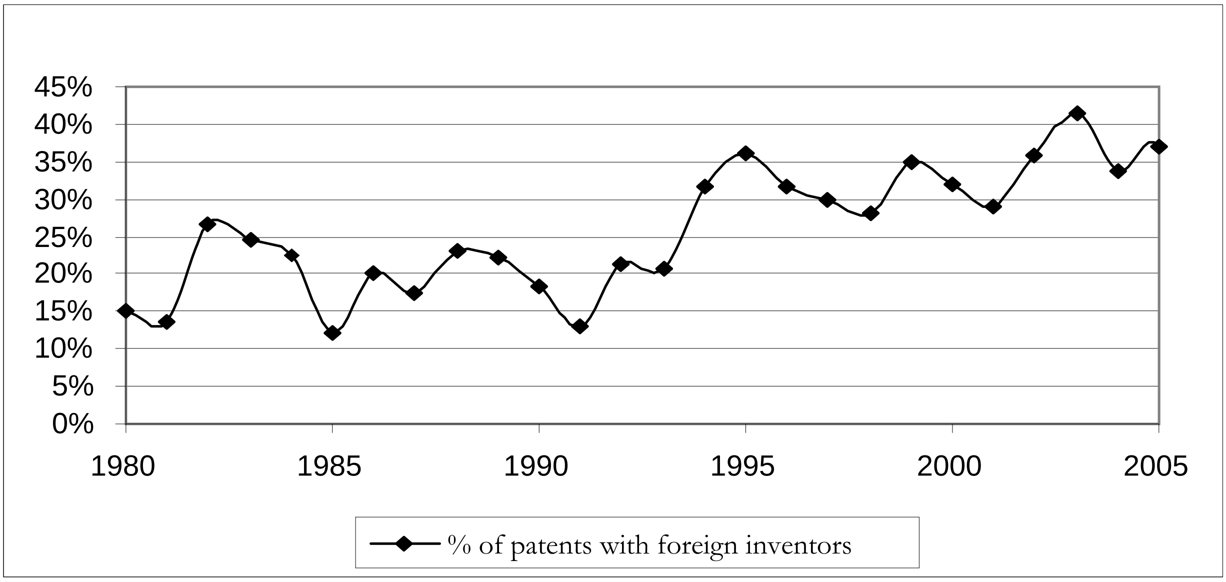

Fig. 1 Share of international co-invented patents in the total Latin American patents by inventors (USPTO)

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

	Textiles and food		Chemicals and pharma		Metals		Machinery		Transport	
COEFFICIENT	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. 4^{th}, 5^{th}, and 6^{th} lags of dependent variable are used.