SUBSIDIARIES INVOLVEMENT IN TECHNOLOGICAL DEVELOPMENT OF TELECOMMUNICATION INDUSTRY: RESULTS FROM S&T INDICATORS

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Abstract:

This paper aims to analyse and measure the results related to the participation of Brazilian subsidiaries of foreign telecommunication suppliers in the Global Product Development processes of these companies. Considering this main goal, it is presented a quantitative analysis on the involvement in technological development by subsidiaries of transnational telecommunication equipment suppliers, especially the Brazilian units, using two indicators of science and technology: patents and bibliometric data. Similar data were also collected for other developing countries that directly compete with Brazil in the telecommunication sector. For patents, it was considered international and national databases by analysing patents issued by companies. The North-American USPTO (United States Patent and Trademark Office) was used mainly to analyse participation of Brazilian inventors in patents applied internationally. And, of course, for national analysis it was used data from the Brazilian institute of intellectual property (INPI - Instituto Nacional de Propriedade Intelectual). Bibliometric data searches were made from SCI (Science Citation Index), a North-American database edited by ISI (Institute for Scientific Information), which includes different knowledge areas. This combination between patents and bibliometric data intends to widely cover R&D activities, once patents are concerned with applying research and experimental development (for later production and commercialisation of products), and scientific publications are usually related to basic or applied research. The examination of these data

was enriched with information from previous qualitative researches, which evidenced some public policies to stimulate local technological activities in the companies studied. However, it is possible to conclude from the quantitative results that the involvement of Brazilian subsidiaries is inferior when compared to the involvement of other analysed developing countries. The situation is worse when the results of these countries are compared to those of developed countries.

Keywords: telecommunication, subsidiaries, technological development, patents, bibliometric data

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1. Introduction

There is no doubt about the importance of technological development for industrial competition and the growth of companies and countries. Technological innovation is used as a means of boosting competition and productivity, especially in rapidly changing sectors of the economy and in turbulent and competitive markets like the present one, mainly influenced by the globalisation process. Intending to be more competitive, companies spread their Research and Development activities worldwide (Cantwell, 1989, Reddy, 1997, 2000; Dunning, 1999). Transnational companies (TNC) are the main agents of product development internationalisation, identifying needs in one country, developing solutions in another and spreading the results of these innovations around the world (Bartlett & Ghoshal, 1992).

Considering the importance of product development as a generator of new knowledge, which is very significant for the competitiveness of companies and countries acting globally, it is fundamentally important for developing nations to integrate product development teams. Otherwise, these countries simply become hosts for manufacturing activities (mainly because of the companies' interest in regional markets), which do not lead to guarantee of competitive advantage, neither to ensure local continuous investments.

Countries like Brazil, with reasonable environment to support Research and Development (R&D) when compared to its neighbours, can become a favourite target for foreign direct investments in R&D units, either for global product development or only for adapting products to the regional market.

Participating in Global Product Development (GPD), Brazilian subsidiaries can improve their technological knowledge basis, increasing their competitive advantages and perhaps contributing to the country growth, since local teams may improve their abilities and then exchange knowledge with national companies, especially suppliers and customers. Besides, it is common to involve local universities and research centres in the product development process, allowing them to be in contact with new technologies and to share infrastructure facilities with foreign companies.

The telecommunication sector is especially important because it was recently restructured in Brazil, after the privatisation of the telephony system (Telebrás System). Besides,

telecommunication equipment development in Brazil had an interesting history of relative success in the recent past.

Preliminary studies (Dias & Galina, 2004) list some conditions in Brazil that have attracted product development activities to the country and point to the tendency of Brazilian teams to participate in global product development in the sector, implying knowledge exchange between local subsidiaries and the headquarters. One of the most important factors to pull these investments towards Brazil is the existence of a local law, called the "informatics law", which establishes fiscal incentives to companies that manufacture technological products. In order to obtain benefits, companies must invest locally in R&D activities and part of this investment must be destined to projects co-operatively developed with Brazilian research institutes.

The authors' previous empirical studies showed that these and other public policies stimulate local technological activities in the companies studied, but do not prove the participation of the Brazilian subsidiaries quantitatively. To measure this kind of participation, it is possible to use Science and Technology (S&T) indicators (OECD, 1994). One of them is related to patents grants - international or national. Considering this, one of the goals in this paper is to present a study of the Brazilian subsidiaries involvement in the patent issued to transnational telecommunication suppliers, by analysing databases of patents issued by companies to the North American system (USPTO - *United States Patent and Trademark Office*). These databases were mainly used to analyse participation of Brazilian inventors in patents applied outside Brazil.

Intending to complement this study, a similar search for data of the same companies (suppliers) was made to analyse the subsidiaries' participation in technological development inside Brazil. For this study, databases from the Brazilian institute of intellectual property (INPI - Instituto Nacional de Propriedade Intelectual), the national office that administrates issues relating to patents into the country, were accessed.

Considering the fragility of the results when only statistical analysis with patents is used, since these are imperfect indicators when used alone (Pavitt, 1988), it is necessary and prudent to combine them with other S&T indicators. Therefore, in the study presented here, bibliometric indicators were also considered, allowing us to evaluate the importance of research developed by the studied companies for knowledge generation and to analyse projects developed co-operatively between the companies and local universities / research centres.

Since the indicators (patents and bibliometric data) are widely used to compare the technological development of countries or regions, this paper also presents a comparison between the Brazilian involvement and the participation of other developing countries, especially the strongest competitors of Brazil in the telecommunication industry, namely China, India, Israel, Ireland, Hungary and Russia.

Therefore, this work combines quantitative data from two of the most important and used S&T indicators (patents and bibliometric results) with information from case studies previously made (Galina, 2004) in order to allow a deeper analysis of Brazilian subsidiaries involvement in the technological development of the telecommunication industry. However such combination is showed here in a very summarised way because this is not the proposal of this paper.

2. Methodology

The largest telecommunication companies with units located in Brazil were studied (Anuário Telecom, 2001). They are all transnational equipment suppliers. The enterprises chosen for this study were the North American Lucent and Motorola, the Canadian Nortel (Northen Telecom), the Japanese NEC, the French Alcatel, the Swedish Ericsson, the German Siemens and the Finish Nokia.

For the case studies, previously made with some of the companies mentioned above, structured questionnaires were used to interview people from R&D and production departments. The subjects discussed in these interviews were mainly related to global and local R&D (description, difficulties, tendencies, connections between subsidiaries and headquarters, and so forth); factors to attract R&D to Brazil; interfaces with local universities and research centres.

Searches in both patent databases (INPI and USPTO) were made via the Internet. Data from ten years (1994 – 2003) were collected and comparisons between two periods (1994 – 1998 and 1999 – 2003) were made. The last period studied (1999 – 2003) is particularly important because of remarkable changes in the telecommunication area, with new communication technologies and mobile telephony strength (Fransman, 2001). In Brazil, this was a period of relevant restructuring in the area after the privatisation of Telebrás, the former governmental telephony operation system, in 1998, promoting the entrance of new equipment suppliers and the improvement of established ones.

Usually, international patent application means that the product to be patented is obviously innovative and relevant to the company. The involvement of employees from a foreign subsidiary in the innovation process may be an indication of co-operation between such subsidiary and the global network for technological development in the transnational company.

For the international patent analyses, the USPTO database was chosen because this system has the highest number of patents granted to foreign companies, explaining the relevance of the database for this work. Searches in the USPTO database are much more detailed and flexible than in INPI's, which means that it is possible to search in many different ways, using the North-American system, allowing a more specific and detailed data set. On the other hand, searches in the domestic database (INPI) were indispensable for the results presented in this paper because they lead to a more specific analysis.

Another indicator used to measure the involvement between headquarters and Brazilian subsidiaries is related to bibliometric data, i.e. the number of scientific papers published by important magazines and journals. Bibliometric data come from SCI (Science Citation Index), a North-American database edited by ISI (Institute for Scientific Information), which is the widest and most important bibliometric database in engineering and technology, areas closely related to telecommunication.

It is worth mentioning that, while patents are concerned with applying research and experimental development, (for later production and commercialisation of products), scientific publications are usually related to basic or applied research. So, with these two kinds of S&T indicators, all R&D activities are covered (OECD, 1994).

The bibliometric searches at SCI database were also made via the Internet. This database covers a branch of knowledge on scientific issues dealing with 5300 periodicals on the following subjects: human science, environment, technology and medicine. Besides, this is the multidisciplinary database that covers the largest number of scientific publications in Latin America. In 1997, Latin America's publications represented 2.3% of the total number of papers registered in SCI (RICYT, 1999).

Data from each of the selected indicators, used to measure the Brazilian participation in technological development, were compared to data from other developing countries, whose subsidiaries were widely mentioned by the interviewees in the companies studied as important players in global product development, evidencing that they are the main competitors of Brazilian subsidiaries. In general, units located in India, Ireland and Israel compete with Brazilian units in software development and the Chinese subsidiaries in hardware

development. Hungary is a new entrant in software development and some companies, mainly Europeans (for instance, Ericsson), are locating some of their R&D activities there. Russia is the newest entrant and, as it can be seen by the numbers presented in this paper, its representation is still not significative.

3. Quantitative Data

3.1. Patents

Studies of diverse nature may be developed using patent data and the conclusions are the most different. The most common use of statistical patent data is for surveying sectors/industries, countries and companies, or for formulating questions and hypotheses for future exploratory studies. This paper shows analyses of the current situation, focusing on questions such as the involvement of Brazilian subsidiaries in the GPD and a comparison between Brazil and other countries.

Some other studies with patents were used in this work for a better analysis of the data found here. One of them, developed by Albuquerque (2000), compares patents granted nationally and internationally to companies located in Brazil. This work concludes that developing countries have important technological activities locally. The activities, however, are not globally significant. They are, for example, related to local adaptation of foreign innovations, a situation that does not guarantee technological growth for the country. It is also confirmed in the telecommunication industry, whose involvement of Brazilian subsidiaries is more intense in the local adaptation of products, in spite of global involvement in the development of some niches.

Another research considered was specifically made in the telecommunication sector by Schmoch (1996). It shows that patent flows – application of patents in foreign countries – reflect flows of technology. The author analysed different strategies of internationalisation of patents by many companies, including the seven studied here (remembering that Lucent was still part of AT&T at that time; the division of the companies happened only in 1996).

There is also another work developed by Guellec & Potterie (2001) that was important for analysing the data found here. It points not only to the existence of "differences in the extent of internationalisation across countries (page 1265)", but also to the characteristics of co-operation between teams and countries. These authors also confirm that the major aim of MNC firms when establishing research facilities abroad is to adapt their products to local conditions.

It is important to consider that, in the case of software, the most important product developed in the telecom sector with the participation of Brazilian subsidiaries, it is more common to register a copyright than to apply to a patent. . However, in the telecommunication industry, especially in the telephony area, even software related inventions can be – and usually are – registered as patents because they are closely linked to improvement in hardware (Schmoch, 1996).

The patents of companies studied here are mainly applied in the electricity section or, according to the International Patents Classification (IPC), in section H, which treats not only of electrical products, but also of electronic and telecom products. The Brazilian INPI uses the IPC system, while USPTO uses the North-American classification system. An analogy between the latter classes/sections and the IPC sections, allows searches through the USPTO database using the international classification, a fact that was immensely useful for comparisons between data from both institutes. IPC class 04 of section H (communication techniques) is the closest to telecommunication, consequently, the one which receives more patent applications from the firms studied; for a few firms (NEC and Nokia), 95% of patents applied at INPI are classified in section "H04".

This classification was only used in general searches; in the specific ones with companies, unless it is indicated, the classification was not used, because the enterprises selected for this study act mainly - or uniquely – as telecommunication equipment and systems suppliers. Siemens was treated sometimes as an exception because this company is the most diversified of them all, acting in different segments besides telecommunication.

3.1.1. International Patents

The USPTO database search was made in both periods previously mentioned: between 1991 and 1995 and between 1996 and 2000. The flexibility to combine different searches led to diversified information and important analyses. In one of these analyses, the number of patents was verified considering Brazil as the country of patentees (inventors or companies), in order to show a general situation of the country in terms of patents granted in general terms without considering each specific company. Results presented in Table 1 are not very encouraging. They show that the participation of Brazil, even with an increase of 80% from one period to another, is low not only as the home country of the inventor, but also as the home country of the patent assignee, at the time of patent issue. Numbers from Russia and Hungary are even worse.

The quantity of patents is extremely low and the situation is worse when compared to

other developing countries like India, Israel, Ireland and China. In comparison to India and China, Brazil features the worst increase.

Table 1 – Patents issued to companies and inventors from developing countries (Source: USPTO)

		1994-1998	1999-2003
BRAZIL			
	Company	202	365
	Inventor	426	793
INDIA			
	Company	131	717
	Inventor	370	1360
ISRAEL			
	Company	1624	3163
	Inventor	3093	5666
CHINA			
	Company	170	907
	Inventor	476	2269
HUNGARY			
	Company	138	128
	Inventor	265	321
IRELAND			
	Company	239	477
	Inventor	468	961
RUSSIA			
	Company	32	1
	Inventor	130	13

Among the countries, the best situation is that of Israel, that has a much more impressive number of patents granted (even with a comparatively low increase). However, its historical path is different from the others: with the support of the United Nations and the United States of America to its industry, and with constant threats of war, promoting growth in some areas like information technology is paramount. The number of patents representing an entire country is low (for all of them), though. The numbers for some companies are larger than those for some countries, especially in the second period, as seen in Table 2.

It is important to differentiate the participation of inventors and subsidiaries in the development process that originated the patented product. When there is the participation of a local inventor, but his/her respective unit does not apply for the patent, there is indication that the unit research team is not involved in the research, which was probably developed outside the unit. Another possible reason for such situation is that the subsidiary may have no autonomy or power to confront the headquarters with an application for an international patent. Therefore, whenever possible, it is worth separating information related to the subsidiary from that related to the inventor while searching for patent data.

A more specific search was made at the USPTO' database with the names of each of the

studied companies and their respective countries. Thus, all patents applied for by the subsidiary, instead of by the headquarters were found. The result is presented in Table 2 and clearly shows that the subsidiaries from the developing countries studied, maybe because of the motives listed above, did not have patents issued to USPTO under their names, with the exception of the NEC's Indian unit that had one patent granted. It is interesting to observe that only three patents had Brazilian inventors involved, two from Ericsson and another from Lucent; and only one patent was issued by a Brazilian subsidiary (Ericsson).

Once more, Israel is easily noticed as the best player when the total of patents by country is analysed. Israel has the best results due to the patents granted to the North-Americans Motorola and Lucent, especially in the second period, yet the country had no patent issued under its name. Noticeably, more than 2% of patents granted to Motorola in the second period had participation of inventors from Israel, a significant number. Ireland must also be highlighted.

Table 2 – Patents issued to the companies studied – participation of selected countries measured by number of patents issued to subsidiaries (units) and by inventors (Source: USPTO)

		Country	BRAZIL		INDIA		ISRAEL		CHINA		HUNGARY		IRELAND		RUSSIA	
		Total	Unit	Inventor	Unit	Inventor	Unit	Inventor	Unit	Inventor	Unit	Inventor	Unit	Inventor	Unit	Inventor
Alcatel	A	1020	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	1817	0	0	0	1 (0,06%)	0	0	0	0	0	0	0	0	0	0
Ericsson	A	1067	0	1 (0,09%)	0	0	0	0	0	0	0	2 (0,19%)	0	0	0	0
	B	3733	1 (0,03%)	1 (0,03%)	0	1 (0,03%)	0	0	0	1 (0,03%)	0	15 (0,4%)	1 (0,03%)	21 (0,56%)	0	0
Lucent*	A	3455	0	1 (0,03%)	0	1 (0,03%)	0	12 (0,35%)	0	0	0	0	0	0	0	0
	B	5043	0	0	0	13 (0,26%)	0	15 (0,3%)	0	3	0	0	0	3 (0,06%)	0	0
Motorola	A	5999	0	0	0	2 (0,03%)	0	105 (1,75%)	0	4 (0,07%)	0	0	0	2 (0,03%)	0	0
	B	4795	0	0	0	4 (0,08%)	0	110 (2,29%)	0	7 (0,15%)	0	0	0	7 (0,15%)	0	0
NEC	A	5939	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	9654	0	0	1 (0,01%)	2 (0,02%)	0	0	0	0	0	0	0	0	0	0
Nokia	A	658	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	2224	0	0	0	0	0	1 (0,04%)	0	3 (0,13%)	0	2 (0,09%)	0	0	0	0
Nortel	A	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	1834	0	0	0	2 (0,11%)	0	2 (0,11%)	0	0	0	0	0	7 (0,38%)	0	0
Siemens	A	3345	0	0	0	0	0	0	0	0	0	0	0	1 (0,03%)	0	0
	B	6062	0	0	0	2 (0,03%)	0	3 (0,05%)	0	4 (0,07%)	0	0	0	1 (0,02%)	0	0

A: from 1994 to 1998; B:from 1999 to 2003
**AT&T in the period from 1994 to 1995*

It is possible to check that the results found for each country and presented in Table 2 are really low, in comparison with another analysis that used data from subsidiaries located in developed countries and from their headquarters. One of the limitations of this analysis is the impossibility of pinning down the USA as the inventor or assignee country at the USPTO database. Therefore, no data were found for either North-American company (Motorola and

Lucent) or for the subsidiaries of other companies located in USA.

This would be useful information since North-American subsidiaries are very much involved in product development in all the companies studied. However, for the purpose of comparing the results of some developed countries with the results presented above, the data in Table 3 are enough. It shows the percentage of patents granted to headquarters and to some of the most involved subsidiaries between 1999 and 2003.

The majority of applied patents are under the names of the companies' headquarters. In some of them, most of the patents are issued by the headquarters; this is the case of NEC, followed by Nokia and Nortel, whose headquarters have respectively 98%, 97% and 97% of the total of applied patents by the companies at USPTO.

In the patents applied for by Nokia, Germany is the strongest participant, with 4% of the total, which represents 70% of the patents granted to Nokia' subsidiaries. It is possible that the participation of North-American subsidiaries is relevant; at least, this is the information obtained from the case studies, when the interviewees mentioned that units located in the USA actively participate in many important researches for the companies.

The participation of North-American units must be even more intense at NEC, as signalled by the fact that the North-American subsidiaries of this company have patents applied for in Brazil, and as pointed out in the next section of this paper. According to data presented in Table 3, German units participate in two other companies: Alcatel and Ericsson, while the German Siemens has reasonable participation of its subsidiaries from Sweden. Comparing the numbers of these subsidiaries to the numbers of units from the countries considered in table 2, a very pessimistic scenario can be drawn. As mentioned above, the only subsidiaries located in these developing countries and that have patents under their names are the Indian unit of NEC, representing only 0,01% of the total of NEC's patents, and the Brazilian and Irish subsidiaries of Ericsson, representing 0,03% of Ericsson's patents.

To make a clearer comparison between subsidiaries from the developing countries studied and the ones from developed countries (not considering USA) that apply for patents at USPTO, it is worth analysing Table 4, which shows inventor participation percentages from these units.

These data show that the participation of inventors from headquarters is lower than the number of patents granted under their name. The largest difference is for Nokia, whose headquarters have applied for 97% of the patents, whereas only 69% of them were invented by Finish researchers.

Thus, here is the proof that the subsidiaries participate more as "inventors" rather than as

"owners" of patents. A curious datum comes from the Alcatel subsidiary located in the Netherlands: it has 3% of the total of patents granted to the company with only 0.7% of local inventors' participation. On the other hand, the Belgian subsidiary of the same company is one of the strongest collaborators in the inventor field (6%), but has only one patent under its name (0.06%).

Table 3 – Patents issued to the headquarters (HQ) and to some subsidiaries in the period between 1999 and 2003 (Source: USPTO)

Company	HQ	Germany	Switzerland	Others
Alcatel	74%	0,3%	0,1%	Netherlands: 3% Belgium: 0,06%
Ericsson	63%	0,2%	0,2%	Japan: 0,05%
NEC	98%	0%	0,01%	France: 0%
Nokia	97%	1%	0%	Japan: 0,04%
Nortel	97%	0,2%	0%	France: 1%
Siemens	69%	-	0,9%	Sweden: 1,7%

Table 4 – Participation of inventors of patents issued to the headquarters (HQ) and to some subsidiaries in the period between 1999 and 2003 (Source: USPTO)

Company	HQ	Germany	Switzerland	Others
Alcatel	41%	17%	0,4%	Netherlands: 0,7% Belgium: 6%
Ericsson	52%	3,2%	0,1%	Japan: 0,7%
NEC	97%	0,01%	0,02%	France: 0,04%
Nokia	69%	3,9%	0,2%	Japan: 1,1%
Nortel	51%	0,4%	0%	France: 1,9%
Siemens	66%		1,2%	Sweden 1,8%

3.1.2. Domestic Patents

Searches through the Brazilian INPI databases also covered two periods (1994-1998 and 1999-2003). In both periods, the number of patents granted/applied for by the companies studied varied widely (table 5). Some of them increased their application for local patents, while others substantially decreased theirs. Nortel and Lucent, for example, increased their participation from one period to another by269% and 190% respectively. These companies intensified their businesses in Brazil after privatisation: Nortel in mobile telephony (TDMA technology) and Lucent in fixed telephony with the acquisition of two Brazilian companies (Batik and Zetax). Other companies, Alcatel, Ericsson and Motorola, decreased the number of their applications for patents at INPI.

Searches at INPI's database are less flexible than at the USPTO base, but this is not relevant for this work and its results. One of the limitations when using INPI data refers to the address (specific country) of inventors or companies. Users are not allowed to search this field through the online database. Thus, since it is almost impossible to relate the inventor's name of each product in a determined company to his/her respective country, it is not possible to access the number of patents registered at the institute by Brazilian inventors or by inventors of any other nationality.

Table 5 – Regional patent application by the companies studied (Source: INPI)

	1994-1998	1999-2003
Alcatel	79	29
Ericsson	1049	465
Lucent*	147	426
Motorola	485	227
NEC	61	160
Nokia	157	318
Nortel	13	48
Siemens	405	460

**AT&T in the period from 1994 to 1995*

Despite the difficulties in searching by country, it was easy to find the location of companies because the names of local subsidiaries are available. The participation of local units was found by the Brazilian names of each company.

Table 6 presents these results. Since the number of patents registered at INPI is larger than the ones registered at USPTO, participation percentage is presented instead of number of patents. Although the number of patents applied for by Brazilian subsidiaries is higher at INPI, it is still not very impressive. Many units of the companies located in other countries have better indices of patent application at INPI than the Brazilian affiliates. For instance, the Ericsson unit in the US has 9.7% of participation in the period from 1992 to 1995 (period A) against only 3.5% of the Brazilian subsidiary. Results are worse from 1996 to 2000 (period B), when the participation of Ericsson' local unit decreased to 0.6% and the North-American participation reached 33%. These results are probably influenced by the CDMA (*Code Division Multiple Access*) technology, a standard used in local mobile telephony. At Ericsson, this technology is developed and is under the responsibility of its USA subsidiaries. It is worth to highlight that the period considered for this specific search was different from the previously used periods since recent searches at the INPI database were not possible; results from another previous work were used (Galina, 2003).

Table 6 – Patents applied for by the headquarters, by the Brazilian subsidiary and by other subsidiaries (Galina, 2003)

(Source: INPI)

		HQ	Brazil	Others
Alcatel	**A**	**96%**	**4%**	-
	B	**95%**	**0%**	**USA: 5%**
Ericsson	**A**	**83%**	**3,5%**	**USA: 9,7%**
	B	**65%**	**0,4%**	**USA: 33%**
Lucent*	**A**	**100%**	**0%**	-
	B	**100%**	**0%**	-
Motorola	**A**	**99,3%**	**0%**	**United Kingdom: 0,7%**
	B	**98,6%**	**0%**	**United Kingdom: 1%**
				Israel: 0,4%
NEC	**A**	**38,5%**	**46%**	-
	B	**81%**	**11%**	
Nokia	**A**	**100%**	**0%**	-
	B	**100%**	**0%**	-
Siemens	**A**	**88%**	**6,6%**	**Japan: 0,6%**
	B	**70%**	**4,5%**	**Japan: 1,6%**
				USA: 1,5%

A – 1992 a 1995; B – 1996 a 2000

*** AT&T in the first period (A)**

Another interesting datum from the INPI database is related to the priority of the patent, in other words, the country in which the patent was first applied for. From 1992 to 2000, 4480 patents had the USA as a priority in a total of 5,765 patents for the section/class H04; a number that corresponds to 78%. This indicates that the patents applied for locally at INPI were probably for global products.

3.2. Bibliometric

Bibliometric data are used, in general, as an indicator of a country's position in terms of relevant scientific publications. Usually, when different regions are compared, data searches are made using many databases, allowing researchers to deal with a large number of relevant periodicals and analysing different science fields. Before presenting the results, it is important to compare the position of Brazil to that of other studied countries. Two sources were used with such intent.

The first one is regional and includes Ibero American and Inter-American science and technology indicators. This is the Ibero American Network on Science and Technology Indicators (RICYT), created by the Ibero American Programme of Science and Technology for Development (Programa *Iberoamericano de Ciencia y Tecnología para el Desarrollo –*

CYTED), supported by the Organisation of American States (OAS) a.k.a. Organizacção dos Estados Americanos (OEA) (RICYT/CYTED/OEA, 1998). Two indicators dealing with bibliometric data are presented in this paper:

- publications in multidisciplinary databases, using SCI, PASCAL (*Bibliographie Internationale*) and ICYT (*Índice Español de Ciencia y Tecnología*) bases; and
- publications in thematic databases, using bases such as INSPEC (Physics Index), COMPENDEX (Engineering Index) e CA (Chemical Abstracts).

According to these indicators, between 1996 and 1997, Brazil had a better position when compared to other Latin American countries, followed by Mexico and Argentina. However, if we add the numbers of these three countries, the result is lower than that of Spain in any of the databases used. Sometimes, the same happens when all the publications of Latin American and Caribbean countries are added. Thus, bibliometric results for these regions are not encouraging indicators of S&T. In spite of this, the same material emphasises that international bibliometric databases encompass only part of the Ibero American scientific publication. It also certifies that SCI comprises less than 1% of the region's scientific magazines or journals.

The second data source used here is the Science and Engineering indicator, published by the NATIONAL SCIENCE FOUNDATION, NSF (2000), which collects data and also works with other bases (ISI/SCI, CHI Research Inc./*Science Indicators*). Table 7 shows, in science and Engineering fields, data from the previously studied countries and from Mexico and Argentina, countries whose bibliometric indicators, together with Brazil's, are the best in Latin America. It is clearly shown that the scientific production in Brazil is superior in numbers when compared to the other two Latin American countries proving the Brazilian supremacy shown by the RICYT indicators cited earlier. The Brazilian indicators are also better than Hungary's and Ireland's. However, bibliometric results in Brazil are worse than those from India, Israel, China, or Russia.

The co-operation between companies and countries for scientific production was also analysed for Brazil and each of the other countries studied. Therefore, bibliometric data used here are related to scientific and technical papers computed in ISI/SCI database. This base was chosen because it is multidisciplinary and it is the most important international source of scientific publication in the fields of engineering and technology. Data from two periods were

used: from 1994 to 1998 (period A) and from 1999 to 2003 (period B) and are presented in Table 8.

These data represent publications in which at least one of the authors is from a company studied and one from an institution or even a company from the countries selected. In this manner, it is possible to find scientific researches made co-operatively between the considered companies and institutions studied or other companies located in each of the countries.

Table 7 – Scientific and technical papers in the science and engineering fields (% of total) (Source: NSF, 2004)

	1992	1996	2001
Brazil	0,19	0,26	0,45
Mexico	0,11	0,13	0,21
Argentina	0,13	0,15	0,22
India	0,54	0,58	0,64
Israel	0,79	0,82	0,9
China	0,37	0,5	0,86
Hungary	0,18	0,18	0,22
Ireland	0,13	0,14	0,21
Russia	0	0,57	0,82

Table 8 – Papers published by countries and companies (Source: SCI)

	TOTAL		BRAZIL		MEXICO		ARGENTINA		INDIA		ISRAEL		CHINA		HUNGARY		IRELAND	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Alcatel	789	805	1	3	0	0	2	0	0	2	0	0	1	1	0	0	2	4
Ericsson	298	607	1	3	0	0	0	0	0	2	0	1	1	9	4	51	0	5
Lucent*	5133	4101	17	17	16	17	16	3	14	50	113	106	7	36	10	14	9	5
Motorola	1208	1564	2	5	3	9	0	0	18	10	3	8	3	32	0	1	3	4
NEC	2698	2563	5	3	1	5	0	2	22	31	27	50	6	19	0	0	0	3
Nokia	178	486	0	0	0	0	0	0	0	2	0	0	0	6	0	6	0	3
Nortel	223	472	0	0	1	8	0	0	0	2	1	2	1	8	0	0	0	2
Siemens	2141	2049	4	4	2	0	0	2	14	6	10	4	3	18	15	14	6	1
	TOTAL:		30	35	23	39	18	7	68	105	154	171	22	129	29	86	20	27

A: from 1994 to 1998; B:from 1999 to 2003
**AT&T in the period from 1994 to 1995*

The first information we have from these data is the superior number of papers by Lucent (and by AT&T in the period A), when compared to other companies' publications; with the exception of the number of papers by NEC and India together, all the other numbers are below the AT&T/Lucent mark in each country. It is interesting to notice that the quantity of papers published by Israeli institutions or companies is absolutely superior to that of other countries in the first period. Another interesting consideration is the impressively increasing percentage for China and Hungary: respectively 486% and 196% from period A to B. Yet one other interesting datum is from Mexico, whose total of publication increased by 70% from

one period to the other, the best participation between the Latin American considered countries.

Siemens and NEC were the only companies that decreased the publication numbers from period A to B; all the other companies increased their numbers. AT&T/Lucent, differently from what is shown in Table 8, increased the number of publications; when we add AT&T' with Lucent' published papers, we have more than 8000 as a total in period B, a higher number than in period A. The most significant increase was Nokia's (1739%), in spite of being the company with fewer papers published. Lucent is the company with the largest number of publications.

Another interesting datum is that Motorola, Lucent, NEC and Siemens significantly increased their involvement with China. Motorola also improved co-operation with Brazil, but decreased its action in India. Siemens decreased its involvement with all countries, except China. NEC participation increased in all countries, except for Brazil (67% decrease) and Hungary (remained with no shared publication).

The three Latin American countries studied have a clearly inferior position when compared to the other countries studied (except Ireland), and Brazil lost its slight advantage in the region for Mexico in the second period (in absolute numbers). However, in general, the number of papers published co-operatively by the companies and Brazil or Mexico is really small when compared to the whole number of publications by these enterprises. The highest number of papers (17 for Lucent) is also the most significant Brazilian involvement with the companies scientific production according to this indicator (published papers).

Analysing the publications with Brazilian participation in the last period (1998-2003), we find 35 papers published with the companies selected, indicating an increase of 16% from period A (30 papers). By comparison, CPqD, the most important Brazilian telecommunication research centre before the privatisation of Telebras, had 22 papers published from 1991 to 1995 and 28 papers from 1996 to 2000.

These data related to the increase in publications numbers are more interesting when compared to data presented in Table 7, which shows the global Brazilian participation in science and technology in three different periods, showing raises of about 36% from the first to the second period and 73% from the second to the third. In spite of being much lighter, an increase of 16% in the number of papers published by the companies and Brazil shows that companies´ behaviour is still considering joint actions to local institutions. This partnership between companies and universities or research centres arises in the telecommunication industry in Brazil due mainly to the informatics law´ exigencies of contributes to direct of

investments in projects co-operatively developed with Brazilian research institutes. These fiscal incentives certainly prompt companies to look for local partners for co-operative research projects.

Table 9 shows the companies units and the Brazilian universities or institutions that co-operatively research. Most papers are by headquarters, but there are some foreign subsidiaries publishing with Brazilian institution. It is interesting to observe that only one was written by the local subsidiary (Ericsson) and a Brazilian university; this same subsidiary has one paper published with an institution from Chile.

The diversity of Brazilian institutions is impressive because of the small number of publications, but still concentrated in some states, mainly in the South or the Southeast regions, the most developed in Brazil. There are a total of 27 papers mapped out in 15 universities (two of them are private), 3 research centre and 1 company.

Table 9 – Companies units and Brazilian institutions with papers published co-operatively in from 1999 to 2003 (Source: SCI)

Company	Local of Unit	Brazilian Institution
Alcatel	Canada	Oracle Brasil - Brasília - DF
	USA	ITA - Dept Elect Engn
	Belgium	Puc - RS
Ericsson	Chile - Universidade do Chile	Ericsson Brasil - Indaiatuba - SP
	Brazil - Indaiatuba - SP	Unicamp
Lucent	USA	UFRGS - Inst Fis
	USA	Observatório Nacional - RJ
	USA	Unicamp - Inst Fis
	USA	UnB - Inst Fis
	USA	Inst. Tecnol. de Barretos - SP
	USA, Denmark	Unicamp
	USA	UFMG - Dep Fis
	USA	UFSCar - Dep Fis
	USA	Univ. Fed. Amazonas - Dep Fis
Motorola	USA	Univ. Federal Ceará - Dep Fis
	USA	Univ. Federal Pernambuco - Dep Fis
	USA	Univ. Federal Bahia - Inst Fis
	USA	USP - Inst Fis - SP
	USA	Inst Nacl Tecnol Informat - Campinas
	USA	UFRGS - Inst Fis
NEC	Japan	USP - ICMC - São Carlos
	USA	USP - Inst Fis - São Carlos
Siemens	Germany	Unicamp - Inst Fis
	USA	Univ. Federal Pernambuco - Dept Engn Elect
	Germany	UFF
	Germany	Univ. Federal Rio Grande do Norte
	Germany	Inst Energy & Nucl Res - São Paulo

4. Conclusions

This paper combines qualitative information from case studies previously made in some companies with results from science and technology indicators (quantitative data) to present the current involvement in the GPD of Brazilian subsidiaries of transnational companies in the telecommunication industry, which is the main goal of this work.

Using the quantitative results obtained, it is possible to conclude that Brazilian subsidiaries are not very much involved in GPD. Information presented for both bibliometric data and patent grants - either national or international - shows an unfavourable picture for the Brazilian subsidiaries when compared to subsidiaries from other developed countries that directly compete to Brazil in the telecom field. Therefore, this S&T indicators do not prove that the participation of local units in R&D global projects, verified empirically in the case studies, leads to the expectations in terms of S&T results, which means that the Brazilian participation does not seem to be effective for the growth of local subsidiaries and of the country if we consider S&T indicators.

According to the case studies, all the companies interviewed have local product development and maintain partnership with national universities and research centres. Other important data to prove, not only the existence of product development in subsidiaries, but also the involvement of these companies and the research centres located in Brazil, was presented by the Brazilian Ministry of Science and Technology (Ministério de C&T – MCT, 2000).

However, these case studies also show that the subsidiaries are more involved with local or regional adaptation of products already created than with global product development. Besides, it can be concluded from the cases that the Brazilian participation is only in some niches of products.

According to the indicators used, quantitative data are more pessimistic and confirm that if there is a participation of local subsidiaries as shown by the case studies, it does not seem to be very significant. The worst results were found at USPTO database, which shows that the participation of Brazilian subsidiaries is really small. Brazilian data are more unfavourable when compared to the ones from other developing countries such as India, China and Israel both in participation of local subsidiaries or inventors and in the total of patents applied for by the telecommunication industry. According to the indicators used here, Israel is the best positioned among them all.

Companies argue that it is cheaper and easier to centralise globally patents applications in one office. This is one possible reason for not having patents at the USPTO issued by Brazilian subsidiaries, however, as showed in this paper, other subsidiaries from different

countries (especially the developed ones) have patents applied and granted in name of the own subsidiary. So, this argument is not completely and easily acceptable.

Studying the local database (INPI), it can be seen that the participation of Brazilian subsidiaries is better, but, in general, it has decreased in the last years. A similar behaviour is noticed in the participation of companies' headquarters, proving that product development tasks are becoming decentralised to subsidiaries (but not to the Brazilian ones). One interesting fact is the increase in North-American subsidiaries participation.

Another important information about patents was found: most telecom products (section H) patented locally (at INPI) do not have Brazil as the 'priority country', a sign that the products manufactured and commercialised in the country are global products. In addition, if we combine this information with data concerning the number of patents applied in the name of Brazilian subsidiaries (very small), we may conclude that these units have barely been involved in GPD.

In general aspects, data concerned to both national and international patents show that Brazilian subsidiaries participation is insignificant. This result is contradictory when compared to information from the case studies and from reports by MCT. This can possibly indicate that the researches made locally (by Brazilian subsidiaries) concern to the development of non-innovative products or low technological level, so they are not easily patented – especially in external markets.

A better result for the Brazilian units is the bibliometric indicator, but even this quantitative result is worse than the ones presented by the other developing countries studied, including Mexico. The Informatics Law, from which all the companies studied receive fiscal benefits, must have influenced this indicator. This law urges partnerships between companies and universities or research centres located in Brazil.

Even with a good result among Latin American countries, a positive picture is not guaranteed because the participation of these three Latin American countries is inexpressive worldly speaking. This indicator also shows that the involvement of local subsidiaries in scientific production is almost null (the best position is the headquarters') and that the participation of national research institutes or universities is diversified even with a small number of publications.

Thus, S&T indicators analysed and presented here do not show favourable results for the participation of Brazil in global product development of telecommunication equipment and service transnational suppliers. This is a relevant conclusion since those indicators are widely used to measure S&T results, to compare the technological development of countries and to

estimate results of public policies.

However, it is worth mentioning that these indicators are widely used to measure S&T results, but they are limited and, if used alone, do not prove for sure whether the companies are involved in the GPD or not, and also, they do not demonstrate if this involvement is relevant for the growth of local teams and for the technological development of the country. Information like this can only be safely analysed with a combination of quantitative indicators and qualitative studies, as attempted here. Although these comparison, it would be interesting if, in future studies, the quantitative data presented and discussed here could be combined with other quantitative indicators, such as social and economical.

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