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Immature systems of innovation:

Introductory notes about a comparison between South Africa, India, Mexico and Brazil based on science and technology statistics[(**)]

ABSTRACT

This paper compares the national systems of innovation of four countries (South Africa, India, Mexico and Brazil). This paper dialogues with the line of research of Amsden (2001), focusing on countries of the "rest".

This paper initially locates these four countries in the international context. Then it focuses on the technological dimension (presenting data on USPTO patents) and on the scientific dimension (based on statistics of scientific papers indexed by the ISI). Finally this paper investigates the interactions between science and technology (inter-sectorally, inter-regionally and inter-temporally).

This investigation suggests the existence of "partial connections" between science and technology working in these "immature" NSIs.

JEL CLASSIFICATION: O00; O30

KEY WORDS: science and technology, development, catching up, national systems of innovations

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INTRODUCTION

This paper compares the national systems of innovation of four countries (South Africa, India, Mexico and Brazil) using data from patents and scientific papers statistics. This comparison is preliminary, introductory and exploratory.

Why does this paper focus on these four countries?

According to various classifications, South Africa, India, Mexico and Brazil rank in similar positions. For the UNDP (2001), according to the "technology achievement index" (TAI, henceforth) these four countries are ranked at "intermediate" levels, as they are not neither among the "leaders" nor among the "marginalized". Furthermore, according to the "human development index" (HDI, henceforth) these four countries are ranked at "medium human development" level (see section I, below). In this regard, it seems that these four countries share a need of social inclusion and of deep adjustments in their systems of innovation to be responsive to the demands of their population as a whole.

This paper has two motivations: first, to look closer to a special set of countries ("immature" NSIs) as a further step of an investigation that discussed a broader set of countries (Bernardes et all, 2003); and second, to establish a dialogue with the line of research of Amsden (2001), focusing on countries of the "rest".

Previous work on a tentative typology of national systems of innovation has put together these four countries as "immature systems of innovation" (Bernardes et all, 2003). The performance of these four countries may be easily differentiated from the trajectory of catching up countries as South Korea and Taiwan (Silva, 2003). Therefore, it is worthwhile a closer look on these four countries, investigating what do they have in common and what differentiate them.[1]

Why might the data on science and technology be useful for the evaluation of these non-developed countries?

Amsden (2001) puts forward one reason for this focus on scientific and technological resources, as she evaluates the WTO restrictions for new developmental strategies and points where the maneuvering room is: "any developmental strategy will have to revolve around regionalism and R&D broadly defined" (p. 292).

[1] Amsden (2001) is a starting point. However, she does not include South Africa among the "rest". The inclusion of South Africa can be supported by Fine & Rustomjee (1996) discussion on the role of the "minerals-energy complex" in South African industrialization. Fine & Rustomjee discuss import substitution industrialization – South Africa "completed the first stage of industrialization ... during the 1950s" (p. 219) -, industrial policies (p. 127), the role of state-owned firms (p. 147). These characteristics typify the "rest" in Amsden book.

As the regional policies are increasingly intertwined with innovation policies, it is worthwhile to evaluate what the statistics from science and technology may show.[2] In her book, Amsden (2001, p. 278) gathers data on R&D expenditures of non-developed countries and introduces a dialogue with the literature on systems of innovation (in her discussion on "nurturing knowledge-based assets", pp. 277-281). This dialogue is important and one conjecture of this paper is that statistics on technological and scientific production may improve the evaluation of these strategic dimensions for catching up processes.

The comparison between so different countries is difficult, but the investigation of common trends might be useful, as they inform more accurate analysis of countries in (broadly) similar levels of development.

This paper is divided into six sections. The first section presents the data and their sources. The second locates the four countries in the international context. The third focuses on the technological dimension, presenting data on patents. The fourth turns to the scientific dimension, based on statistics of scientific papers. The fifth section combines the data from the previous sections to evaluate the interactions between science and technology, suggesting three ways to investigate these interactions. The sixth section concludes the paper.

I- DATA SOURCES

This paper uses patent data from the USPTO gathered through its site (www.uspto.gov) for the comparisons of section II, for a closer look on the technological production of the four countries investigated in section III, and for the evaluation of interactions with science in section V. The scientific publications data are from the ISI (www.isiknowledge.com), and they are used for the comparisons of section II, and for the evaluation of interactions with technology in section V. The scientific publications data for section IV were prepared by the *Ministério de Ciência e Tecnologia*, using ISI databases.

These indicators are not used in Amsden's book. In her book, Amsden uses mainly R&D expenditures as the indicator for discussions related to technology (Amsden, 2001, pp. 238-245 and pp. 277-281). The use of USPTO patents and papers indexed by the ISI statistics contribute for international comparisons because they follow similar rules for different countries. This is not the case of R&D statistics that are not very reliable for less developed countries. Amsden is aware of these problems and she uses, for instance, in Table 9.15 (p. 278) two different criteria - S&T and R&D – to compare 12 different countries.

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[2] For the articulation between regional and innovation policy, see chapter 9 ("Die Regionalstruktur von Innovationstätikeit und Innovationspotenzialen") of a report prepared by the Fraunhofer Institute für Systeminnovation (BMBF, 1999).

However, these two indicators of science and technology have a lot of problems and are far from perfect indicators. The literature has both used these data and warned about their problems, limitations and shortcomings.

Scientific papers, the data collected by the ISI, have various shortcomings, from language bias to the quality of research performed: there could be important research for local needs that does not translate in international papers, but only in national publications not captured by the ISI database. There is a huge literature on the problems of this indicator (Patel & Pavitt, 1995; Velho, 1987). Paper citations improve the quality of this indicator, but it would not be so useful for this paper, further biasing the data against papers produced in countries with low developed scientific institutions.

Patents, the USPTO data, also have important shortcomings, from commercial linkages with the US to the quality of the patent: again, local innovation necessarily is limited to imitation in the initial phases of development, and imitation or minor adaptations do not qualify for a patent in the USPTO. There is a huge literature on the problems of this indicator (Griliches, 1990; Patel & Pavitt, 1995).

For less developed countries, other problems must be pinpointed. Probably, USPTO patents and papers indexed at the ISI are "tips of icebergs": they do not represent the whole scientific and technological production of these countries. For patents, as discussed in a previous paper (Albuquerque, 2000) on Brazil, there are important differences between patenting at national offices and at the USPTO. For instance, in the Brazilian case the steel industry is among the leading sectors at the national office but it disappears at the USPTO statistics. Another important difference is the position of research institutions: for the 1990s, there are five of them among the top 20 at the national office (three universities, a health research institute and a agricultural research institute) and none at the USPTO. This problem has also been identified for the Mexican case: the leading patent institution at the national patent office (between 1980 and 2002) is the *Instituto Mexicano Del Petroleo*, which ranks only in the 25th position at the USPTO (see Table VI, below).

One important remark is on an limitation of patent statistics in relation to high-tech areas: 1) software technology has been a relevant product of India (D'Costa, 2002) and Brazil (MIT/SOFTEX, 2002) but its performance is not captured by these statistics; 2) biotechnology industry is an emerging industry, with potential at least in India (New York Times, 08/16/2003)[3] and Brazil (Souza, 2001), but it is a very young sector that is not well represented in these statistics.

Thus, this paper acknowledges these important limitations, and this literature must be kept in mind to qualify the results discussed in the next sections.

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[3] The Indian state of Karnataka hosts 85 biotech firms, among them Biocon India Ltd, with almost 900 workers (NYT, 08/16/2003).

II- IMMATURE SYSTEMS OF INNOVATION IN THE INTERNATIONAL CONTEXT

The four countries are large countries, geographically (from 1.221 million km2 – South Africa – to 8.547 km2 – Brazil)[4] and demographically (population ranging from 41 million – South Africa – to 980 million – India) (World Bank, 2000). In all these countries an intermediate position may be indicated (economically, technologically and scientifically).

They show a singular combination of a relative technological backwardness and a relative social backwardness. According to Table their human development indexes between 0.57 and 0.80 (all countries are ranked at "medium level of human development"), and their technological achievement indexes between 0.20 and 0.40 (these four countries are either "potential leaders" or "dynamic adopters").

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INSERT TABLE I

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Inequality is a key problem in these four countries, as the Gini indexes shown in Table I pinpoint. It is important to stress the high level of income concentration indicated for South Africa, Brazil and Mexico, especially how the Brazilian and Mexican indexes (59.1 and 51.9, respectively) are similar to the post-apartheid index for South Africa (59.3). Although the Indian Gini index (37.8) is the lowest among the four countries, the inequality problems in India are pervasive: "in some respects, at least, economic and social inequalities are sharper in India than in sub-Saharan Africa" (Drèze & Sen, 2002, p. 69). And, as Amsden (2001, pp. 201-206) stresses, unequal income distribution has (blocking) implications to economic performance of the "rest".

This general framework of inequality has important implications for this paper. First, the scientific and technological dimensions are embedded with this problem. A report from The Government of the Republic of South Africa (2002, p. 15) highlights a key challenge for the post-apartheid innovation system: the need to "expand to cope with the needs of 40 million people as opposed to a mere 5-6 million" (The Government of the Republic of South Africa, 2002, p. 15). This statement (adjusting the numbers) could be true for the Brazilian case (see Machado et all, 2003), for the Indian case (Drèze & Sen, 2002, pp. 67, stresses the failure in basic education "which stands in sharp contrast with a relatively good record in higher education and scientific research"). Therefore, social inclusion is a key task for these four countries, and the innovation systems cannot be isolated from this social change. Probably, the health sector provides the most visible example of this need of social inclusion: the *Global Forum on Health Research* (2002) points "neglected diseases", and these four countries host some of them. These diseases should be research priority

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[4] France has 0.552 million km2.

on their scientific and technological agenda, and changes in the innovation systems are necessary for the establishment of these new priorities.

Second, these inequality issues are expressed at the regional level, as these four countries display important “regional contrasts”, which are identified in this paper below as regional concentration of technological and scientific resources (see sections III and IV, below).

The World Bank (2000, pp. 266-267) indicates that scientists and engineers per million people (data for 1985-1995) are broadly similar, with the exception of South Africa: South Africa 938; India 149; Mexico 213; Brazil 168 (for general reference: Spain: 1,210; USA 3,732).

The statistics of patents and scientific publications per million people locate these four countries in neighbor positions. It can be seen from Figure I that South Africa, India, Mexico and Brazil cluster in relatively nearby positions.

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INSERT FIGURE I

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The data are as follows: 1) South Africa: 79,54 papers per million people and 2.78 patents per million people; 2) India: 16.37 and 0.09; 3) Mexico: 41.15 and 0.60; 4) Brazil: 51.33 and 0.45.

Two boundaries conform the position of the four countries.

First, a low boundary: all four countries have systematic scientific and technological production, are placed at the upper level of the less-developed countries (according to Figure I), they have institutions and firms that sustain this systematic production of science and technology.

Second, a high boundary: they are below a “threshold” level that would trigger a virtuous interaction between science and technology (Bernardes et all, 2003). This “threshold level” for 1998 data (Figure I) is in the neighborhood of 150 papers per million people. The distance from these four countries and the developed countries (USA, Japan) and from the catching up countries (South Korea, Taiwan) should be noticed.

These two boundaries typify the “in-between” position of “immature” NSIs.

The difference with catching up countries in a inter-temporal approach can be seen in Figure II, were USPTO patents granted selected countries are plotted (1980-2002). The leading countries are represented by the USA and Japan, the catching up countries are represented by South Korea. It is important to notice that South Korea starts from a position behind South Africa, Brazil and Mexico (total of patents) and overcomes all during the 1980s. South Africa, India, Mexico and Brazil show a sort of “convergence”, displaying a moderate growth (see Table II) during this period. And China’s performance is included, showing how China starts behind the four countries and “join the group” at the end of the 1980s.

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INSERT FIGURE II

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The data presented in this section, especially Figures I and II, suggest a qualification on Amsden (2001, pp. 281-282) interpretation of the division between “independents” and “integrationists”. Probably, the main problem with this division is to put together India, Korea and Taiwan. The use of science and technology indicators as reference indicates that Korea and Taiwan are, probably, in a different cluster from South Africa, India, Mexico and Brazil. Korea and Taiwan, during the 1990s, are leaving the “rest” (Nelson & Pack, 1999).

III- THE TECHNOLOGICAL DIMENSION AND RELATED STATISTICS

Once the international position of South Africa, India, Mexico and Brazil has been identified, this section focuses on the inward situation of the technological capabilities of these innovation systems.

Table II shows the aggregate patenting data from the four countries (1981-2001). Table II indicates a stead increase in the patenting activities throughout the three periods (1981-1987, 1988-1994, 1995-2001), both for the criterion of “resident inventors” and “resident assignees” (firms and institutions). In the latter criterion, the exception in this trend is Mexico: in 1988-1994 there was a slight decrease in the number of patents granted by the USPTO.

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Table III presents data on two different criteria: nationality of inventor/assignee and the nature of the assignee (individual). These two criteria indicate some features of less-developed countries.

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In regard to the nationality of the assignee, Table III shows the important role of foreign assignees of patents with the first inventor resident. India has the greater share of patents with foreign assignees (33%)[5] and South Africa the smaller share (18%), in between Brazil (26%) and Mexico (19%). These shares are an

[5] These data have some caveats. In the Indian case, the numbers from Table III may be overestimated given the participation of Indian researchers in laboratories abroad. For instance, 15 patents with Indian residents as first inventors were assigned to The US Government in this period (see Table V, below). In this regard, the “Indian diaspora” and the role of “the expatriate community ... largely trained in India elite institutions such as the Indian Institute of Technology and the Indian Institute of Management” (D’Costa, 2002, pp. 221-222) should be taken into consideration.

indication that the transnational corporations with subsidiaries in these countries are performing some R&D in these locations.[6]

With respect to the share of individuals in patenting - a well-know proxy for level of development (Penrose, 1973) - Table III displays high shares, ranging from 16% in the case of India to 46% in the case of Mexico, in between South Africa (38%) and Brazil (26%). The overall share of individuals in foreign patenting in the USPTO (data for 1986-1999) is 11,82% (see Appendix Table 06-12, NSB, 2002).

Tables IV, V, VI and VII list the leading patenting firms and institutions for the four countries.[7] Some common features and some structural differences may be hinted in these tables.

South Africa's leading patenting firms/institutions are presented in Table IV.

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Table IV indicates the important role of public institutions in the South African case. At least seven institutions are present in this Table (South African Invention Development Corporation, CSIR, Mintek, Atomic Energy Corporation, Water Research Commission, Council for Mineral Technology and National Energy Council).

Noteworthy here is the role of firms and institutions connected to what Fine & Rustomjee (1996) call the "minerals-energy complex" (institutions: Atomic Energy Corporation, Council for Mineral Technology and National Energy Council; firms: AECI – explosives -, General Mining Union Corporation, Sasol).

Finally, only four foreign firms are among the 20 patenting leaders.

India's leading patenting firms/institutions are in Table V.

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INSERT TABLE V

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Table V shows a high concentration of Indian patenting activities. India has the higher CR4 among the four (0,45).

Table V highlights the role of the Council of Scientific & Industrial Research (with 233 patents out of 883), demonstrating the weight of public institutions in the Indian technology sector.

[6] However, these data may have an opposite problem: the share of TNC local R&D might be underestimated, for their subsidiaries may deposit patents in the USPTO by themselves, and in this case the subsidiaries would count as resident firms.

[7] Following Patel & Pavitt (1995) methodology, these Tables present data for USPTO patents that have the first inventor resident in the country.

There are nine foreign firms among the patenting leaders, an indication of the R&D activities of transnational corporations in India. The presence of patents deposited by government agencies form the United States might be an indication of the Indian diaspora (D'Costa, 2002).

Mexico's leading patenting firms/institutions are in Table VI.

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Two Mexican firms Hylsa (metallurgy) e Vitro (holding) lead the top 25 patenting assignees. Mexican research institutions are important (Centro de Investigacio y de Estudios Avanzados del IPN, Instituto Mexicano de Investigaciones Siderurgicas, UNAM, Centro de Investigacion y Assistencia Tecnica del Estado de Queretaro and Instituto Mexicano del Petroleo).

A comparison between the top patenting firms/institutions at the national office and at the USPTO shows different leaders: at the Mexican patent office, for 1980-2002, the leading institutions are the Instituto Mexicano del Petroleo and UNAM. The leader at the USPTO, Hylsa, ranks in the fifth position, after Vitro (4^{th} position) (Mesquita, 2003).

Table VI shows that there are nine foreign assignees (all from the US) among the top 25 of Mexico.

Finally, Brazil's leading patenting firms/institutions are presented in Table VII.

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Table VII shows that only firms are in the top 22 patenting assignees in the Brazilian case. As in the Mexican case, the data from the national patent office are different: there are five research institutions among the patenting leaders in the Brazilian patent office (Unicamp, Embrapa, Fiocruz, USP and UFMG).[8]

State-owned firms have important role in Table VII: Petrobrás is the leader, also in the Brazilian patent office, and Companhia Vale do Rio Doce and Telebrás were privatized during the 1990s.

Foreign assignees are in the list: seven firms from the US and one from Switzerland. A foreign-owned Brazilian firm is in the list (Mercedes-Benz do Brasil) . And a German firm acquired Metal Leve in the 1990s.[9]

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[8] A comparison among reports based on domestic patents indicates a difference on the role of institutes: Mexican and Indian institutes own a greater share of domestic patents than the Brazilian institutes. Comparing these data with Indian and Mexican data, differences are shown: 1) Mexico: firms, 0.231; institutes, 0.165; individuals, 0.604 (Aboites, 1996, for 1980-1992); 2) India: firms, 0.382; institutes, 0.249; individuals, 0.364 (Rajeswari, 1996, for 1974-1992); 3) Brazil: firms, 0.61; institutes, 0.032; individuals, 0.355 (Albuquerque, 2000).

Summing up these data and presenting the main technological specializations of these countries, Table VIII displays the five leading technological sectors, according to the WIPO classification.

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In terms of concentration in technological classes, India has shows the higher CR4 (0.55) and the other three have similar CR4s, varying from CR4=0.21 in the South African case to CR4=0.26 in the Brazilian case. In the Indian case, this concentration probably derives from a high correlation between the pharmaceutical firms present in Table IV and the activities of CSIR.

Table VIII shows the leading role of A61 (Medical or Veterinary Science), always in first place, except for India. Table VIII also indicates differences in technological specializations: South Africa in E04 (Building) and B65 (Conveying, Packing); India in C07 (Organic Chemistry); Mexico in C03 (Glass) and C21 (Metallurgy of Iron); Brazil in F16 (Engineering Elements, Machines) and B65 (Conveying, Packing). Only India does not have B65 among her top 4.

With respect to differences on individual patents vis-à-vis institutional (firms and institutions) patents South Africa is an exception. South African patenting patterns are the same for individual patents and in institutional patents: the class A61 leads in both. In the Indian case, A61 leads among individuals, while C07 (Organic Chemistry) leads among institutions. In Mexico, the leadership in individual patents is of class A61 and in institutional patents in class C03 (Manufacture, Shaping Process). In the Brazilian case, F16 leads among the institutional patents and A61 leads in individual patents.

Table IX divides the technological production (patent data) in three periods (1981-1987, 1988-1994 and 1995-2001).

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INSERT TABLE IX

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With respect to the of leading technological classes (and their stability) during the three periods, the four countries display similarities and differences.

In terms of WIPO sections (the broader classification), India clearly shows a concentration in section C: 10 references out of 18. The leading classes of India are from only 4 sections. Mexico has 6 references to section C and 5 for section A. As for India, Mexico also has leading classes among 4 sections. South Africa and Brazil have leading classes distributed among 6 sections, but none has more than five references.

[9] The number of foreign assignees in the Brazilian and in the Indian cases might indicate that the division suggested by Amsden (2001) between “independents” and “integrationists” needs more discussion, when data for S&T are evaluated.

One similarity is the presence of the A61 class (Medical or Veterinary Science): this class is always among the leading classes. Differences are on the next two leading classes: E04 (Building) and H01 (Basic Electric Elements) for South Africa, C07 (Organic Chemistry) and C08 (Organic Macromolecular Comp.) for India, none for Mexico, and B65 and F16 (Engineering Elements, Machines) for Brazil. The pattern of stability is similar, as South Africa and India have four classes in common between the first and the last period, while Mexico and Brazil have three.

South Africa shows a persistent technological specialization, as three classes are present in all periods: A61, E04 and H01. F16 leads in the second period but disappear from the top in the last period.

India has a concentration on technological classes chemistry-related: C07 (Organic Chemistry) and C08 (Organic Macromolecular Comp.) leads in the three periods, together with A61. After 1988 another chemistry–related sector joins the top: C12 (Biochemistry, Genetic Eng.). It is important to highlight the presence of A01 (Agriculture) in two periods. The last period has a new class (G06: computing, calculating), that could be related to the software boom in India.

Mexico presents an unstable behavior, as only one class (A61) is present in all three periods. Furthermore, the leading class of the first period (C03: Glass) drops the list in the last period.

Brazil shows the leadership of A61 in the two last periods, coming from a 5th position in the first period. Agriculture (A01) leads in the first period, but drops the list in the two following periods. Brazil is the country with more references to section F.

Looking to the regional level, from Table X can be seen the five leading patenting states.

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The geographical concentration of technological production is high, indicating a pattern between the "oligocentric concentration" and the "monocentric concentration" (BMFB, 1999, p. 89). South Africa has 63% of her technological production in Gauteng, India has 36% in Maharashtra, Mexico has 24% in Nuevo Leon and Brazil has 50% of its patents in the state of São Paulo. Compared to the USA, which is identified as having a "multicentric concentration" (BMFB, 1999, p. 89), the general pattern of these immature innovation systems is more concentrated, probably a reflection of the general inequalities discussed in section II. There are two groups in this regard: South Africa and Brazil in a "tight" "oligocentric concentration", and India and Mexico with a "weak" "oligocentric concentration".

IV- THE SCIENTIFIC DIMENSION AND RELATED STATISTICS

The international position of the immature systems of innovation is reported in section II. Section III takes a further step in this respect and investigates the distribution of scientific disciplines and different types of scientific specialization.

The first question is on how distributed are the national production among the various scientific disciplines.

The starting point for this comparison is a suggestion from Pavitt (1998, p. 801), based upon the paper from Lattimore & Revesz (1996). Lattimore & Revesz (1996, p. 13-14) have studied "patterns of comparative advantage in publications", classifying the countries in four categories, according to their "fields of relative research strength": Medical, Natural Resources, Industry, and Mixed. Pavitt (p. 801) criticized their identification of the fields of relative strength based on citations and not papers. This section reorganizes the categories from Lattimore & Revesz using statistics of published papers, and not citation. Following a methodology suggested by Lattimore & Revesz (1996), that have organised a ranking of "international specialisation", an indicator is calculated: variance of scientific revealed comparative advantage per country, VSRCA, hereafter).[10] As Lattimore & Revesz explain, this indicator measures the "broadness" of a country's scientific capability.

The data for this analysis is from the ISI. The scientific production of each country is divided among 105 subdisciplines, covering the ISI Science Citation Index Expanded and also ISI Social Sciences Citation Index and the ISI Arts and Humanities Citation Index (this set is broader than the used in Figure I, which uses only the SCI).

Table XI organizes the according to the stage of formation of NSIs. The division in three "types" of NSIs follows Silva (2003), for two years (1981 and 2001). Examples of "mature" NSIs are USA, Japan, Sweden, "immature" NSIs are the four of this paper, "countries without systematic S&T" are countries that had neither a patent granted by the USPTO nor a paper indexed by the ISI.

Table XI shows that the VRSCA decreases as the NSIs improve, both for 1981 data and for 2001 data.

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The lowest VSRCA average is for "mature" NSIs (0.552 in 1981 and 0.370 in 2001), the highest is the average for "countries without systematic S&T" (34,046 in 1981 and 8,238 in 2001). These averages

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[10] VSRCA = var [(Pi,j/Pi,world)/(Pallfields,j/Pallfields,world)] (Lattimore & Revesz, 1996, p. 15), where P = scientific papers; from the country i, and scientific field j.

confirm Lattimore & Revesz suggestion that more developed countries may have "broader" scientific capabilities, with their production more evenly distributed across the whole range of scientific disciplines. It is important to note that the "immature" NSIs are a more differentiated set of countries, as their variance is big, both for 1981 and for 2001. While the variance of the averages of VRSCA for mature NSIs are smaller than the averages, in the "immature" NSIs they are greater than their respective averages.

Table XI provides a benchmark for the evaluation of the four "immature" NSIs. Table XII shows the VRSCA for them.

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The values of VRSCAs for the four "immature" NSIs are higher than the average for "mature" NSIs, both for 1981 and 2001. Brazil has the lower VRSCA in both years (respectively 0,6616 and 0,4258), but they are greater than the averages for the "mature" NSIs (according to Table X). South Africa has the higher VRSCA of the group, but its value is lower than the average for the "immature" NSIs, as shown in Table X.

Comparing the values for 1981 and 2001, South Africa and India had their VRSCAs increased while Mexico and Brazil had their VRSCAs decreased.

The second question is about the countries' specialization.

It can be seen from Table XIII all scientific disciplines with a SCRA greater than 2 (1981, 1991 and 2001). A SRCA greater than 2 suggests a specialization of the country in question on that discipline. Hence, Table XIII displays the scientific specialization of the four countries.

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South Africa shows a steady leadership of Geology/Petroleum/MiningEngineering in the three periods. The significant specialization in Geology/Petroleum/MiningEngineering (SRCA = 8.732 in 2001) also explains the high VSRCA for South Africa (Table XII). Besides, looking to the leading scientific disciplines in 2001, South Africa is the only country that has three disciplines with SRCA greater than 4.

India also presents a steady leadership of one scientific discipline throughout the three periods: Agriculture/Agronomy. Chemistry and related disciplines keep leading positions throughout the three periods. The main change is the rise of Biotechnology and Applied Microbiology (SRCA = 1.981 in 1981; 2.053 in 1991 and 3.390 in 2001), reaching the second position.

Mexico shows a change in the leading discipline (General and Internal Medicine in 1981 and Entomology/Pest Control in 1991 and 2001).

Brazil also shows a change in the leading discipline (from Environmental Medicine and Public Health in 1981 to Agriculture/Agronomy in 1991 and 2001). All the disciplines with SRCA greater than 2 in 2001 are related to biology and health. Probably this is an important difference between Brazil and the other three "immature" NSIs: the other three show a more disperse scientific specialization (in Table XIII, South Africa shows for 2001 Geology and Entomology; India, Biotechnology and Metallurgy; Mexico, Entomology and Space Science).

Following Lattimore & Revesz's (1996) classification, with respect to "fields of relative research strength", India and Mexico may be classified as "Mixed", South Africa as "Mixed with a bias towards natural resource" and Brazil as "Mixed with a bias towards Medical".

The third question is the geographical distribution of scientific production in 2000. Table XIV shows that this distribution is also highly concentrated.

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Although concentrated, in contrast to the distribution of technological production, scientific production is more evenly distributed in South Africa and in India. The leading state in South Africa is Gauteng, with 40.28% of national production and in India the state of Maharashtra concentrates 14.05%. In the Brazilian and Mexican cases, the concentration in the leading state overcomes the 40% level.

Table XIV hints that while India may have a "multicentric concentration" for scientific production, the other three countries with variations in the degree of their "oligocentric concentration".

V- THE INTERACTIONS BETWEEN SCIENCE AND TECHNOLOGY

This section evaluates the interactions between science and technology in three ways: inter-sectorally, inter-regionally and inter-temporally. The evaluation of inter-sectoral and inter-regional connections (or the misconnection) between science and technology is based on the data from sections III and IV and from Silva (2003).

V.1- INTER-SECTORAL INTERACTIONS

Inter-sectorally the question is whether or not are there connections between the scientific specialization and the technological specialization. The literature suggests ways to investigate the links between science and technology. Klevorick et all (1995) is an important starting point for this investigation, and their findings are used as a reference for this sub-section.

This question focuses on Tables VIII, IX and XIII.

South Africa shows a considerable specialization in Geology/Petroleum/MiningEngineering (SRCA = 8.732 in 2001). This is a hint of a connection between the structure of the economy - the “mineral-energy complex”, according to Fine & Rustomjee (1996) - and its scientific production. This relationship does not appear directly in the patent statistics (probably the mining activities have a low propensity to patent). Technological classes as F16, B65 and H01 could be correlated to the complex. The leading presence of A61 in technology (Tables VIII and IX) is correlated to the presence of Animal sciences, Veterinary Medicine/Animal Health and other four biology-related scientific disciplines with a SRCA greater than 2 in 2001 (Table XIII).

India displays a more straightforward correlation between the leading technological sectors (Tables VIII and IX) and the leading scientific disciplines (Table XIII). Chemistry and related disciplines have leading positions throughout the three periods (Table IX) and Organic Chemistry is the leading technological class in patent statistics (Tables VIII and IX). The rise of Biotechnology in the scientific dimension and leading positions of other health-related disciplines (Veterinary, SRCA = 3.193) may be associated to the position of “Medical or Veterinary Science” (class A61 in Tables VIII and IX) and related to the opportunities for biotech in India (New York Times, 08/16/2003). The leading position of Agriculture/Agronomy in the scientific dimension is associated with the top positions of A01 class (Agriculture) in 1981-1987 (4^{th} position) and in 1995-2001 (5^{th} position) in Table IX.

Mexico shows a connection between a leading technological class (A61, “medical or veterinary science”) and the leading scientific disciplines (there are four biology-related disciplines out of seven scientific disciplines with SRCA greater than 2 in 2001). In the 2001 data, Metallurgy as a scientific discipline has a SRCA = 1.752 (ranking in 11^{th} position), clearly related to the second leading technological class (metallurgy of iron) in 1981-1994.

Brazil has Agriculture/Agronomy in the leading position, as in India. The USPTO data capture the importance of this sector for Brazil only during the first period (1981-1987). In the INPI data, however, EMBRAPA - the leading institution in agricultural research - ranks in the 6^{th} position for the period 1990-2000. The concentration in 2001 in biology and health-related disciplines might be feeding interactions with the health sector, which has an expressive presence in the patent statistics. The position of the health-related disciplines might also be related to the formation of new biotech firms (Souza, 2002).

V.2- INTER-REGIONAL INTERACTIONS

Inter-regionally, the question is whether or not there is a correspondence of the leading region in technological production and the leading region in scientific production. This question turns the focus to Tables X and XIV.

Comparing Tables X and XIV, there are two groups of countries. First: South Africa, India and Brazil have the same state leading both the technological and the scientific production (Gauteng, Maharashtra and São Paulo, respectively). Mexico has a regional disconnection between their leading technological regions (Delhi and Nuevo Leon, respectively) and their leading scientific regions (DF, respectively).

According to a *Wired* report (Hilner, 2000), there are 46 locations worldwide identified as "technology hubs". Four "technological hubs" are in the "immature" NSIs of this paper: Gauteng (South Africa), Bangalore (India), São Paulo and Campinas (in the state of São Paulo, Brazil).

Mexico is the only "immature" NSI without an identified "technological hub", according to *Wired*. In the other cases, only in India the "technological hub" identified is not within the state that leads both the scientific and the technological production.[11]

V.3- INTER-TEMPORAL INTERACTIONS

Inter-temporally the question is whether or not do the two dimensions co-evolve. Silva (2003) investigates this dimension, finding a sort of "polynomial relationship" between the data for articles per million people and patents per million people for various developed countries and for catching up countries. Silva (2003) shows a non-linear relationship between improvements in the scientific dimension and in the technological dimension.

Silva (2003) organizes data for "immature" NSIs and the graphs shown in Figure III are drawn from his work. The observation of these inter-temporal trends may provide another important information: an overall evaluation of the performance of these countries during two decades (that in the Latin American countries has been called as the "lost decades"). Although hard economic times, in regard to the S&T dimension the situation was not of pure decline. Figure III shows that for India, Mexico and Brazil, the last year of the time series (year 2000, dot 20, in the Graphs) is in a better position vis-à-vis the first year (year 1980, dot 1) of the time-series (both in papers per million people and patents per million people). South Africa is the exception. Brazil seems to have resisted well, with a gradual rise in scientific and technological terms throughout all the period (although in relative terms, the Brazilian share in the world technology almost the same, when 1980 is compared to 2000 – but this is a positive result).

[11] According to Hilner (2000) "We rated each zone from 1 to 4 according to the factors that make the Valley a stronghold: the ability of area universities and research facilities to train skilled workers or develop new technologies; the presence of established companies and multinationals to provide expertise and economic stability; the population's entrepreneurial drive to start new ventures; and the availability of venture capital to ensure that the ideas make it to market". The results for the cities in the "immature" NSIs are as follows: Gauteng (Universities: 1, Established companies: 1, Start ups: 1, Venture capital: 1); Banglore (Universities: 3; Established companies: 4; Start ups: 3; Venture capital: 4); São Paulo (Universities: 1; Established companies: 3; Start ups: 3; Venture capital: 2); and Campinas (Universities: 4; Established companies: 3; Start ups: 1; Venture capital: 0)

China is included for comparative reasons (as she is included in Figure II). According to Silva, among the "immature" NSIs, only Brazil display the "polynomial relationship" identified for developed and catching up countries. China also displays this pattern.

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INSERT FIGURE III

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What Brazil and China have in common, according to Figure III? They show a constant increase in their scientific productions. Presumably this is an important reason for a positive relationship between science and technology. In the Mexican case, from 1991 (dot 11) onwards the scientific production has resumed a consistent growth pattern and a "polynomial pattern" can be seen.

With respect to the position of the scientific production in 1991, from Figure III can be seen that for South Africa and India this year's production is not the lower of the whole period. Thus, for both South Africa and India at least a partial decline in scientific production took place, a general decline for the South African case, partial decline with a further increase for the Indian case.

In the South African case, the government reports a drop in R&D expenditures between 1990 (1.1% of the GDP) and 1994 (0.7% of the GDP) and the beginning of a structural rearrangement in the post-apartheid era (The Government of the Republic of South Africa, 2002, p. 15). This report mentions the "termination of key technology missions (such as military dominance in the subcontinent and energy self-sufficiency) by the previous government" (p. 15). Certainly there are huge costs in a transition to a post-apartheid NSIs, with more people to serve and new needs to fulfil.

V.4- A PRELIMINARY BALANCE

The overall balance of the interactions between science and technology in these "immature" NSIs must be done by a combination of these three ways discussed preliminarily in this section.

As a contribution to the evaluation of the intermediate stage of the four immature NSIs, this section shows that they all have at least one connection identified among the three dimensions evaluated:

1) inter-sectorally, all countries display, at least, a partial connection between scientific production and technological production;
2) inter-temporally, Mexico (at least during the 1990s) and Brazil present a co-evolution of scientific and technological production;
3) inter-regionally, South Africa, India and Brazil have the same state leading both the scientific and the technological production.

VI- CONCLUDING REMARKS: FEATURES OF "IMMATURE" NSIs AS STARTING POINT FOR A NEW PHASE OF GROWTH

The data presented and discussed in this paper points to similarities and differences between the four "immature" NSIs:

1) in common, they share an international position below the "threshold level" of mutually reinforcing science and technology interactions, below the "critical mass" level for and adequate science and technology production;
2) in common, they share an important participation of individuals, foreign firms and state-owned firms and institutions in their technological production;
3) there are important differences in the technological specialization of these countries, although they all have an important participation of health –related classes;
4) they show a common trend in terms of regional concentration of technological activities, with a general trend towards an "oligocentric concentration";
5) there are important differences in scientific specialization of these countries, although, once more, health-related disciplines are among the leading disciplines;
6) integrating the data on science and on technology and assessing the interactions between them, there is a pattern of "partial connection" in all "immature" NSIs (and probably this is a feature specific to these NSIs);
7) these "partial connections" are very important because they indicate that, even below the "threshold" level for a "virtuous circle" between science and technology, something is in operation in "immature" NSIs (the more disaggregated data identify this): "islands of efficiency" are present.

Certainly the uneven nature of South Africa, India, Mexico and Brazil is reflected in their NSIs. Heterogeneity is a structural feature of these countries, in social, industrial and in the science and technology dimensions. The partial connections between science and technology (section V) have a positive side, as they demonstrate that something is already working in these NSIs. This leads to an important question: whether or not these "islands of efficiency" will be able to push the rest of the country and to spillover to other less dynamic sectors.

As the structuralist approach has shown since long time ago, the polarity between modernization and marginalization is related to inadequacy of technology (Furtado, 1987). Therefore, changes in the NSIs to adjust the technological progress to the needs of underdeveloped countries are priorities in their agenda.

"Critical mass" conditions are crucial. This can be seen in the health sector: although health-related scientific disciplines and technological sectors are present in the four countries, their international relevance is very limited: only 5% of world health R&D is devoted to "the health needs of developing regions" (WHO, 1996, p. xxxvi). The position below the "threshold level" shared by the four countries may be a reason for this global gap.

As section II summarizes, the four countries have to increase their S&T capabilities, which implies a huge increase in the number of people involved in these activities. This increase, by its turn, depends heavily on social change and broader educational attainments in general.

These data delineate a possible starting point for catching up processes in these four countries. Following the arguments of Amsden (2001) on the role of R&D strategies for new developmental strategies, it is clear that these four countries are not beginning from nothing. On the contrary, in regard to the level of formation of their S&T institutions (and interactions), probably they are in a better position than were South Korea and Taiwan during the 1970s (their starting point for catching up).

Amsden (2001) reiterates the role of pre-war manufacturing experience for the post-war industrialization of the "rest". In fact, this pre-war manufacturing experience differentiated the "rest" from the "remainder". In this sense, for the growth perspectives in the initial decades of this new century, the experience with S&T during the two last decades might be as important. The partial connections identified in section V between science and technology institutions might matter for this incoming new phase. Certainly, for strategic reasons, the new developmental policies must be deeply guided by scientific and technological investments, and the overcoming of "thresholds" levels are central targets for public policies.

Vis-à-vis the East Asian catching up, the level of formation of S&T institutions in South Africa, India, Mexico and Brazil and the partial connections identified in this paper are signs of a best staring point. However, as continental countries and as countries with deep social inequalities, probably they have also higher obstacles to overcome than Korea and Taiwan.

REFERENCES

ABOITES, J. (1996) *Analysis of patenting activity in Mexico* (Preliminary draft). Mexico (mimeo).

ALBUQUERQUE, E. (2000) "Domestic patents and developing countries: arguments for their study and data from Brazil (1980-1995)". *Research Policy*, v. 29, n. 9, pp. 1047-1060.

ALBUQUERQUE, E. (2001) Scientific infrastructure and catching up process: notes about a relationship illustrated by science and technology statistics. *Revista Brasileira de Economia*, v. 55, n. 4, pp. 545-566.

AMSDEN, A. (2001) *The rise of "the rest"*: challenges to the West from late-industrializing economies. Oxford: Oxford University.

BERNARDES, A.; ALBUQUERQUE, E. (2003) Cross-over, thresholds and the interactions between science and technology: lessons for less-developed countries. *Research Policy*, v. 32, n. 5, pp. 867-887.

BMBF (1999) *Zur technologischen Leistungsfähigkeit Deutschlands*. Berlin: BMBF.

D'COSTA, A. P. (2002) Uneven and combined development: understanding India's software exports. *World Development*, v. 31, n. 1, pp. 211-226.

DOSI, G.; FREEMAN, C.; FABIANI, S. The process of economic development: introducing some stylised facts and theories on technologies, firms and institutions. *Industrial and Corporate Change*, v. 3, n. 1, 1994.

DRÈZE, J.; SEN, A. (2002) *India*: development and participation. Oxford: Oxford University.

FINE, B.; RUSTOMJEE, Z. (1996) *The political economy of South Africa*: from minerals-energy complex to industrialisation. London: Westview.

FREEMAN, C. (1996) The greening of technology and models of innovation. *Technological Forecast and Social Change*, v. 53, pp. 27-39.

FURTADO, C. (1987) Underdevelopment: to conform or to reform. In: MEIER, G. (ed) *Pioneers of development.* Second Series. Oxford: Oxford University/World Bank.

GLOBAL FORUM FOR HEALTH RESEARCH (2002) *The 10/90 Report on health research 2001-2002*. Geneva: Global Forum for Health Research.

HILNER, J. (2000) Venture capitals. *Wired*, 7 August (http://www.wired.com/wired/archive/8.07/silicon.html)

INSTITUTE OF SCIENTIFIC INFORMATION. www.webofscience.fapesp.br, 2000.

KIM, L.; NELSON, R. (2000) (eds). *Technology, learning, & innovation*: experiences of newly industrializing economies. Cambridge: Cambridge University.

KLEVORICK, A.; LEVIN, R.; NELSON, R.; WINTER, S (1995). On the sources and significance of inter-industry differences in technological opportunities. *Research Policy*, v. 24, p. 185-205.

LATTIMORE, R.; REVESZ, J. (1996) Australian science: performance from published papers. Bureau of Industry Economics, Report 96/3, Australian Government Printing Office: Canberra.

MIT/SOFTEX (2002) *Indústria de software no Brasil*: fortalecendo a economia do conhecimento. Campinas: SOFTEX.

MEIER, G.; SEERS, D. (eds) (1984) *Pioneers in development*. Oxford: Oxford University/World Bank.

NATIONAL SCIENCE BOARD (2002) *Science and Engineering Indicators - 2002*. Arlington, VA: National Science Foundation (www.nsf.gov).

NELSON, R. (ed). (1993) *National innovation systems*: a comparative analysis. New York, Oxford: Oxford University, 1993.

NELSON, R.; PACK, H. (1999) The Asian miracle and modern economic growth theory. *The Economic Jounal*, v. 109, July, pp. 416-436.

NEW YORK TIMES (2003) How India's Mother of Invention Built an Industry (08/16/2003, captured at www.nytimes.com)

PATEL, P.; PAVITT, K. (1995) Patterns of technological activity: their measurement and interpretation. In: STONEMAN, P. (ed.) *Handbook of the Economics of Innovation and Technological Change*. Oxford: Blackwell.

PAVITT, K. (1998) The social shape of the national science base. *Research Policy*, v. 27, n. 8, pp. 793-805.

PENROSE, E. (1973) International patenting and the less-developed countries. *The Economic Journal*, London, v. 83, n. 331, p. 768-788.

RAJESWARI, A. R. (1996) Indian Patent Statistics - An Analysis. *Scientometrics*, v. 36, n. 1, pp. 109-130.

SILVA, L. (2003) *Padrões de interação entre ciência e tecnologia: uma investigação a partir de estatísticas de ciência e tecnologia*. Dissertação de Mestrado. Belo Horizonte: Cedeplar-UFMG.

SOUZA, S. (2001) *Potencialidades da biotecnologia em Minas Gerais*: um estudo de empresas e suas relações com universidades. Belo Horizonte: Cedeplar-UFMG (Disseertação de mestrado).

THE GOVERNMENT OF THE REPUBLIC OF SOUTH AFRICA (2002) *South Africa's national research and development strategy*. Pretoria: The Government of the Republic of South Africa.

WORLD BANK (1999) *Knowledge for development*: World Development Report 1998/1999. Oxford: Oxford University.

WORLD BANK (2000) *Entering the 21st Century*: World Development Report 1999/2000. Oxford: Oxford University.

WORLD BANK (2003) *World Bank Indicators* (available at www.worldbank.org/wdi)

WORLD HEALTH ORGANIZATION (1996) *Investing in health research and developmen*t. TDR/Gen/96.1 (www.who.org).

APPENDIX: TABLES AND FIGURES

TABLE I

Comparison between the HDI (Human Development Index) and the TAI (Technological Achievement Index)

Country	Rank HDI	Value HDI	Rank TAI	Value TAI	Literacy Rate (% greater than 15 years) (1999)	Gini Index	GDP per capita (PPP US$) (1999)	Life expectancy at birth (years) (1999)
Brazil	69	0,750	43	0.311	84.9	59.1	7,037	67.5
India	115	0,571	63	0.201	56.5	37.8	2,248	62.9
Mexico	51	0,790	32	0.389	91.1	51.9	8,297	72.4
South Africa	94	0,702	39	0.340	84.9	59.3	8,908	53.9

Source: Human Development Report 2001, (author's elaboration)

TABLE II

Patents from Brazil, India, Mexico and South Africa (1981-2001)

Country	1st resident inventor				1st resident assignee[1]			
	1981-1987	1988 -1994	1995-2001	Total	1981-1987	1988-1994	1995-2001	Total
Brazil	191	349	632	1172	87	206	336	629
India	84	157	642	883	18	58	392	468
Mexico	294	305	506	1105	112	98	240	450
South Africa	633	794	877	2304	317	333	387	1037

Source: USPTO, 2002 (author's elaboration)
(1) Individual patents excluded.

TABLE III

Description of the type of patents in accordance with two different **criteria**

		1st resident assignee				1st resident inventor				
		Resident Firms/Inst.								
Country		1st nac. inv.	1st foreign inv.	Individual	Total	1st assignee Resident Firms/Inst	Individual	Foreign assignee	NI	Total
Brazil	Patents	592	37	302	931	592	302	276	0	1170
	%	64	4	32	100	51	26	24	0	100
South Africa	Patents	989	48	882	1919	986	882	424	12	2304
	%	52	3	46	100	43	38	18	1	100
Mexico	Patents	402	48	503	953	389	503	212	1	1105
	%	42	5	53	100	35	46	19	0	100
India	Patents	454	14	139	607	454	139	290	0	883
	%	75	2	23	100	51	16	33	0	100

Source: USPTO 2002, (author's elaboration)

TABLE IV

The top 20 assignees according to the first resident inventor - South Africa (1981-2001)

1st assignee	Country	Patents
South African Invention Development Corporation	ZA	45
AECI Limited	ZA	31
CSIR	ZA	29
Circuit Breaker Industries Limited	ZA	16
Lilliwyte Societe Anonyme	LU	15
General Mining Union Corporation Limited	ZA	15
HL&H Timber Products -proprietary- Limited	ZA	13
Technology Finance Corporation -proprietary- Limited	ZA	13
Denel -proprietary- Limited	ZA	12
Sasol Technology PTY Limited	ZA	12
Boart International Limited	ZA	12
Mintek	ZA	11
Atomic Energy Corporation of South Africa Limited	ZA	11
Water Research Commission	ZA	11
Council for Mineral Technology	ZA	10
Zarina Holding C.V.	NL	10
National Energy Council	ZA	10
Crucible Societe Anonyme	LU	10
Implico B.V.	NL	9
Rotaque -proprietary- Limited	ZA	9
PF	NA	882
Total	-	**2304**

Source: USPTO 2002, (author's elaboration)

TABLE V

The top 20 assignees according to the first resident inventor – India (1981-2001)

1 st assignee	Country	Patents
Council of Scientific & Industrial Research	IN	233
Hoechst Aktiengesellschaft	DE	42
Ranbaxy Laboratories Limited	IN	32
Texas Instruments Incorporated	US	31
General Electric Company	US	19
Dr. Reddy's Research Foundation	IN	18
The United States of America as represented by the Administrator of the	US	15
Indian Oil Corporation Limited	IN	12
Panacea Biotec Limited	IN	11
National Institute of Immunology	IN	11
Lupin Laboratories Limited	IN	11
Dabur Research Foundation	IN	9
Lever Brothers Company	US	9
International Business Machines Corporation	US	9
Indian Petrochemical Corporation Limited	IN	8
Monsanto Company	US	6
Ciba-Geigy Corporation	US	6
Gem Energy Industry Limited	IN	6
Natreon Inc.	US	5
Unilever Home & Personal Care USA, division of Conopco, Inc.	US	5
PF	NA	139
Total	**-**	**883**

Source: USPTO 2002, (author's elaboration)

TABLE VI

The top 25 assignees according to the first resident inventor – Mexico (1981-2001)

1 st assignee	Country	Patents
Hylsa S.A. de C.V.	MX	55
Vitro Tec Fideicomiso	MX	33
Centro de Investigacion y de Estudios Avanzados del I.P.N.	MX	17
T & R Chemicals, Inc.	US	15
Godinger Silver Art Co., Ltd.	US	15
Vidrio Plano de Mexico, S/A	MX	14
Hewlett-Packard Company	US	13
Servicios Condumex S.A. de C.V.	MX	11
Carrier Corporation	US	10
Instituto Mexicano de Investigaciones Siderurgicas	MX	10
Procesadora de Ceramica de Mexico S.A. de C.V.	MX	8
Universidad Nacional Autonoma De Mexico, UNAM,	MX	7
Colgate-Palmolive Co.	US	7
Investigacion Fic Fideicomiso	MX	7
Vitrocrisa Cristaleria, S.A. DE C.V.	MX	7
National Semiconductor Corporation	US	6
Centro de Investigacion y Asistencia Tecnica de Estado de Queretaro, A.C.	MX	6
Vidriera Monterrey, S.A.	MX	6
Tendora Nemak, S.A. de C.V.	MX	5
Fabricacion de Maquinas, S.A.	MX	5
Industrias John Deere S.A.de C.V.	MX	5
Yale University	US	5
Diamond Technologies Company	US	5
Process Evaluation and Development Corp.	US	5
Instituto Mexicano del Petroleo	MX	5
PF	NA	503
Total	**-**	**1105**

Source: USPTO, 2002 (author’s elaboration)

TABLE VII

The top 22 assignees according to the first resident inventor - Brazil (1981-2001)

1st assignee	Country	Patents
Petróleo Brasileiro S/A - PETROBRÁS	BR	133
Empresa Brasileira de Compressores S/A - Embraco	BR	53
Carrier Corporation	US	29
Metagal Indústria e Comércio Ltda	BR	26
Metal Leve S/A Indústria e Comércio	BR	26
Indústrias Romi S/A	BR	13
Forjas Taurus S/A	BR	12
Companhia Vale do Rio Doce	BR	11
Kortec AG	CH	10
Grendene S/A	BR	9
Telecomunicações Brasileiras S/A - Telebrás	BR	9
Praxair Technology, Inc.	US	8
Multibrás S.A Eletrodomésticos	BR	8
U.S. Philips Corporation	US	7
SMAR Research Corporation	US	7
The Whitaker Corporation	US	6
Metalgrafica Rojek Ltda	BR	6
Bettanin Industrial S/A	BR	5
Termolar S/A	BR	5
Chicopee	US	5
Mercedes-Benz do Brasil S/A	BR	5
McNeil-PPC, Inc.	US	5
PF	NA	302
Total	**-**	**1172**

Source: USPTO, 2002 (author's elaboration)

TABLE VIII

Leading technological classes, according to the WIPO classification (1981-2001)

Country	Class (WIPO)	Class title	Patents	CR4
South Africa	A61	Medical or Veterinary Science	143	0,21
	E04	Building	108	
	B65	Conveying; Packing	104	
	H01	Basic Electric Elements	103	
Total			**2151**	
India	C07	Organic Chemistry	198	0,55
	A61	Medical or Veterinary Science	169	
	C08	Organic Macromolecular Comp	54	
	C12	Biochemistry; Genetic Eng	43	
Total			**868**	
Mexico	A61	Medical or Veterinary Science	86	0,25
	C03	Manufacture, Shaping Processes	52	
	B65	Conveying; Packing	48	
	C21	Metallurgy Of Iron	48	
Total			**952**	
Brazil	A61	Medical or Veterinary Science	97	0.26
	F16	Engineering Elements; Machines	75	
	B65	Conveying; Packing	58	
	F04	Positive-Displacement Machines	45	
Total			**1065**	

Source: USPTO, 2002 (author’s elaboration)

TABLE IX
Leading technological classes of patents, according to the WIPO classification
(1981-2001)

Country	1981-1987		1988-1994		1995-2001	
	Class	Patents	Class	Patents	Class	Patents
South Africa	(A61) Medical or Veterinary Science	37	(F16) Engineering Elements; Machines	46	(A61) Medical Or Veterinary Science	68
	(G01) Suring; Testing	34	(A61) Medical Or Veterinary Science	38	(H01) Basic Electric Elements	44
	(F16) Engineering Elements; Machines	33	(B01) Physical Or Chemical Processes	37	(B65) Conveying; Packing	43
	(B65) Conveying; Packing	32	(E04) Building	37	(E04) Building	40
	(E04) Building	31	(H01) Basic Electric Elements	36	(A01) Agriculture	33
	(H01) Basic Electric Elements	23	(G01) Suring; Testing	36	(B01) Physical Or Chemical Processes	33
	Total	**618**	**Total**	**744**	**Total**	**789**
India	(C07) Organic Chemistry	17	(A61) Medical Or Veterinary Science	32	(C07) Organic Chemistry	153
	(C08) Organic Macromolecular Comp	11	(C07) Organic Chemistry	28	(A61) Medical Or Veterinary Science	128
	(A61) Medical Or Veterinary Science	9	(C08) Organic Macromolecular Comp	12	(C12) Biochemistry; Genetic Eng	36
	(A01) Agriculture	5	(B01) Physical Or Chemical Processes	11	(G06) Computing; Calculating	31
	(C04) Cements; Concrete; Ceramics	4	(C22) Metallurgy; Treatment	6	(A01) Agriculture	31
	(B32) Layered Products	3	(C12) Biochemistry; Genetic Eng	5	(C08) Organic Macromolecular Comp	31
	Total	**84**	**Total**	**154**	**Total**	**630**
Mexico	(C03) Manufacture, Shaping Processes	33	(A61) Medical Or Veterinary Science	24	(A61) Medical Or Veterinary Science	33
	(A61) Medical Or Veterinary Science	29	(C21) Metallurgy Of Iron	19	(B65) Conveying; Packing	28
	(C21) Metallurgy Of Iron	19	(C07) Organic Chemistry	11	(F16) Engineering Elements; Machines	17
	(B65) Conveying; Packing	14	(B01) Physical Or Chemical Processes	9	(C12) Biochemistry; Genetic Eng	15
	(F16) Engineering Elements; Machines	10	(B05) Spraying or Atomising	9	(A47) Furniture; Domestic Articles	14
	(F02) Combustion Engines	9	(C03) Manufacture, Shaping Processes	8	(A01) Agriculture	14
	Total	**270**	**Total**	**266**	**Total**	**416**
Brazil	(F16) Engineering Elements; Machines	12	(A61) Medical Or Veterinary Science	29	(A61) Medical Or Veterinary Science	60
	(A01) Agriculture	12	(F04) Positive-Displacement Machines	24	(F16) Engineering Elements; Machines	43
	(B65) Conveying; Packing	10	(F16) Engineering Elements; Machines	20	(B65) Conveying; Packing	35
	(B60) Vehicles In General	8	(B23) Machine Tools; Metal-Working	16	(F25) Refrigeration Machines	26
	(A61) Medical Or Veterinary Science	8	(E21) Earth Or Rock Drilling;	15	(F04) Positive-Displacement Machines	20
	(H01) Basic Electric Elements	8	(B65) Conveying; Packing	13	(G01) Measuring; Testing	20
	Total	**179**	**Total**	**324**	**Total**	**562**

SOURCE: USPTO, 2002 (author's elaboration)

TABLE X

Leading patenting states (1981-2001)

Country	State	Patents
South Africa	Gauteng	1460
	Western Cape	301
	Kwa Zulu Natal	161
	North West	51
Total		**2304**
India	Maharashtra	317
	Delhi	122
	Karnataka	104
	Andhra Pradesh	66
Total		**883**
Mexico	Nuevo Leon	275
	DF	271
	Estado de Mexico	88
	Jalisco	88
Total		**1105**
Brazil	São Paulo	595
	Rio de Janeiro	230
	Rio Grande do Sul	115
	Santa Catarina	77
Total		**1170**

Source: USPTO, 2002 (author's elaboration)

TABLE XI

VSRCA (average and variance)

Type of NSI	1981			2001		
	n	average	variance	n	average	variance
"Mature" NSIs	17	0,552	0,146	24	0,370	0,076
"Immature" NSIs	37	5,435	109,060	45	2,940	20,578
Countries without systematic S&T	22	34,046	10547,110	24	8,238	56,828

Source: Silva 2003, MCT 2003, (author's elaboration)

TABLE XII

Variance of scientific revealed comparative advantage (VSRCA) selected countries (1981, 2001)

Country	1981		2001	
	position[1]	vsra	position[1]	vsra
Brazil	15	0,6616	20	0,4258
India	17	0,6911	34	0,7596
Mexico	18	0,7260	28	0,5528
South Africa	28	0,9671	50	1,1869

Source: MCT, 2003 (author's elaboration)

Note: [1] Relative position in a sample of 118 countries

TABLE XIII

Scientific Revealed Comparative Advantage (SRCA): immature NSIs

Country	1981		1991		2001	
	Discipline	SRCA	Discipline	SRCA	Discipline	SRCA
BRAZIL	Environmt Med & Public Hlth	4.824	Agriculture/Agronomy	5.914	Agriculture/Agronomy	3.976
	Molecular Biology & Genetics	3.714	Biology	5.128	Dentistry/Oral Surgery & Med	3.234
	Multidisciplinary	3.265	Medical Res, General Topics	4.078	Biology	2.761
	Biology	3.238	Public Hlth & Hlth Care Sci	3.574	Entomology/Pest Control	2.482
	Animal Sciences	2.502	Space Science	3.512	Biotechnol & Appl Microbiol	2.196
	Agricultural Chemistry	2.387	Experimental Biology	2.544	Medical Res, General Topics	2.167
	Entomology/Pest Control	2.131	Molecular Biology & Genetics	2.287		
			Environmt Med & Public Hlth	2.238		
			Physics	2.167		
INDIA	Agriculture/Agronomy	3.852	Agriculture/Agronomy	5.759	Agriculture/Agronomy	5.467
	Multidisciplinary	3.343	Chemistry	3.458	Biotechnol & Appl Microbiol	3.390
	Engineering Mgmt/General	3.331	Environmt Engineering/Energy	3.218	Veterinary Med/Animal Health	3.193
	Chemistry	3.070	Engineering Mgmt/General	3.155	Organic Chem/Polymer Sci	2.789
	Environmt Engineering/Energy	2.578	Inorganic & Nucl Chemistry	2.658	Multidisciplinary	2.669
	Animal Sciences	2.470	Veterinary Med/Animal Health	2.427	Engineering Mgmt/General	2.498
	Organic Chem/Polymer Sci	2.315	Organic Chem/Polymer Sci	2.420	Metallurgy	2.481
	Plant Sciences	2.295	Materials Sci and Engn	2.350	Chemistry	2.471
			Multidisciplinary	2.329	Food Science/Nutrition	2.386
			Social Work & Social Policy	2.288	Materials Sci and Engn	2.247
			Animal Sciences	2.279	Chemical Engineering	2.014
			Metallurgy	2.099		
			Biotechnol & Appl Microbiol	2.053		
MEXICO	General & Internal Medicine	5.766	Entomology/Pest Control	3.976	Entomology/Pest Control	4.134
	Rheumatology	4.171	Rheumatology	3.948	Aquatic Sciences	3.135
	Engineering Mathematics	3.010	Space Science	3.558	Biotechnol & Appl Microbiol	2.650
	Economics	2.906	Agriculture/Agronomy	2.526	Optics & Acoustics	2.630
	Agricultural Chemistry	2.722	Psychiatry	2.503	Space Science	2.607
	Civil Engineering	2.047	Environmt Engineering/Energy	2.399	Biology	2.574
	Pharmacology/Toxicology	2.040	Agricultural Chemistry	2.384	Plant Sciences	2.000
			Biotechnol & Appl Microbiol	2.321		
			Biology	2.302		
			Animal & Plant Sciences	2.160		
SOUTH AFRICA	Geol/Petrol/Mining Engn	6.477	Geol/Petrol/Mining Engn	8.976	Geol/Petrol/Mining Engn	8.732
	General & Internal Medicine	5.066	Multidisciplinary	4.211	Animal Sciences	4.338
	Veterinary Med/Animal Health	4.357	Animal Sciences	3.897	Entomology/Pest Control	4.014
	Animal Sciences	4.322	General & Internal Medicine	3.637	Philosophy	3.174
	Aquatic Sciences	2.419	Aquatic Sciences	3.225	Veterinary Med/Animal Health	2.919
	Dentistry/Oral Surgery & Med	2.333	Entomology/Pest Control	3.193	Environ Studies, Geog & Dev	2.787
	Engineering Mathematics	2.322	Archaeology	3.034	Multidisciplinary	2.755
			Veterinary Med/Animal Health	2.719	Environment/Ecology	2.654
			Plant Sciences	2.622	Plant Sciences	2.643
			Inorganic & Nucl Chemistry	2.429	Political Sci & Public Admin	2.603
			Classical Studies	2.362	General & Internal Medicine	2.266
			Environment/Ecology	2.306	Aquatic Sciences	2.251
			History	2.077	Biology	2.139
			Philosophy	2.036	Education	2.088

SOURCE: ISI 2003, (author's elaboration)

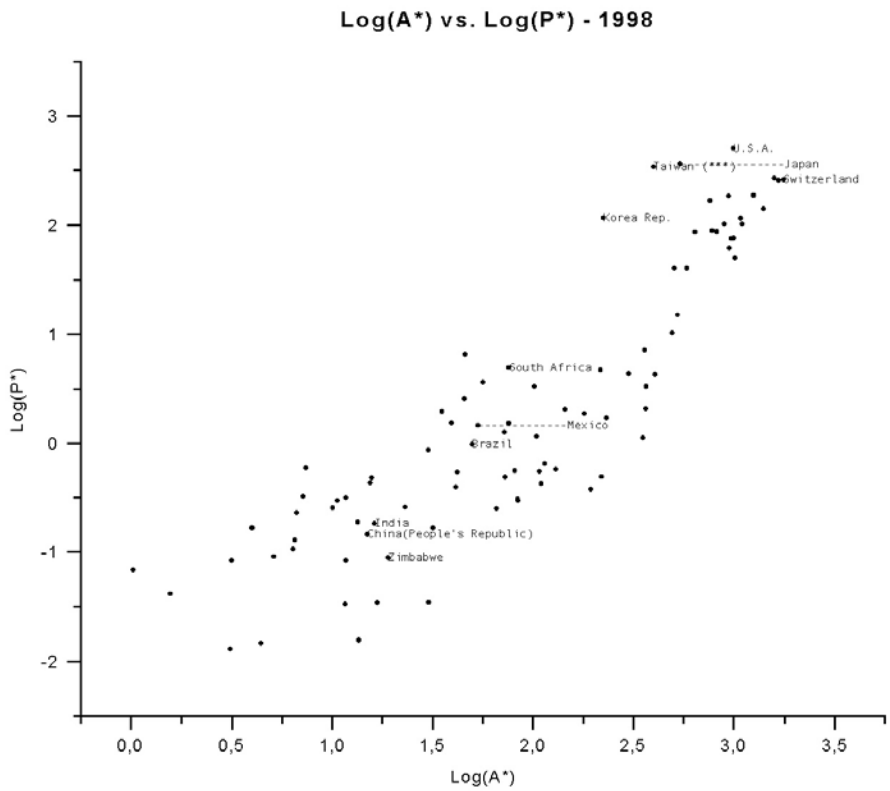
TABLE XIV

Leading states in scientific publication -2000

Country	State	Papers
South Africa	Gauteng	2806
	Western Cape	2170
	KwaZulu Natal	1069
	Eastern Cape	360
Total		**6966**
India	Maharashtra	4844
	Tamil Nadu	4032
	Uttaar Pradesh	4021
	W Bengal	3808
Total		**34475**
Mexico	DF	5383
	Morelos	682
	Puebla	464
	Guanajuato	394
Total		**9946**
Brazil	São Paulo	4410
	Rio de Janeiro	1860
	Minas Gerais	874
	Rio Grande do Sul	696
Total		**10286**

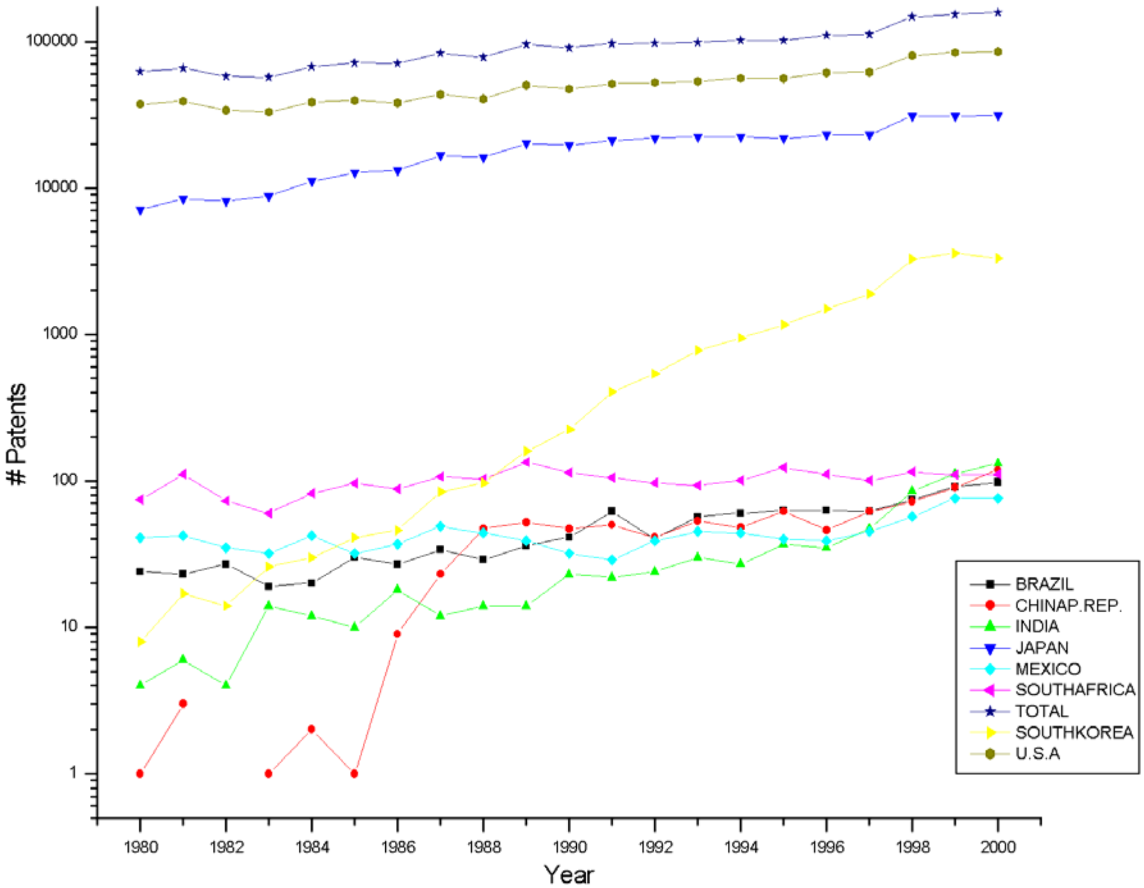
Source: ISI, 2003 (author's elaboration)

Figure I



SOURCE: Bernardes et all (2003)

Figure II
USPTO patents from selected countries (1980-2000)

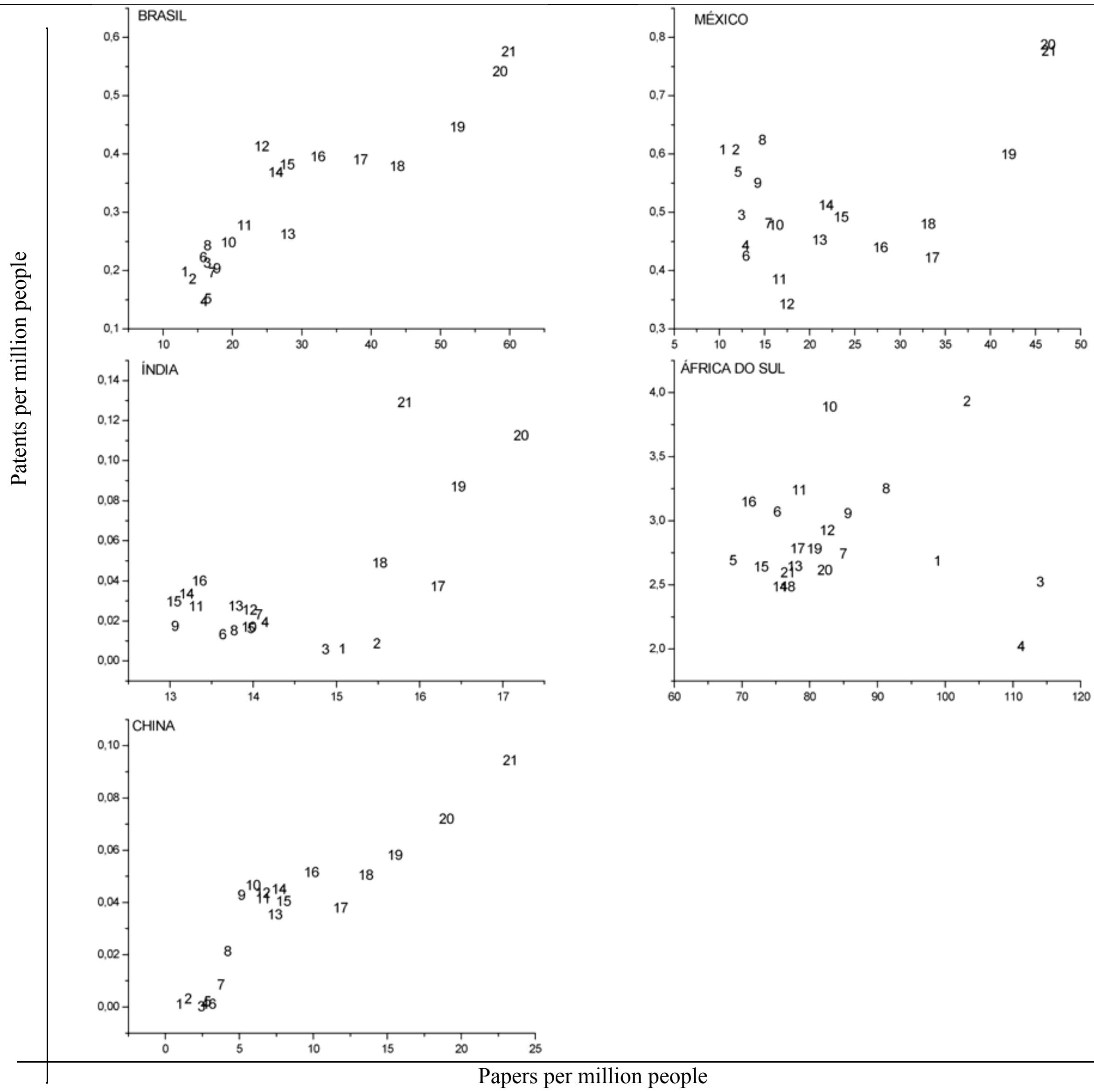


Source: USPTO (2001), author's elaboration

FIGURE III

Patents per million people and papers per million people (selected “immature” NSIs)

(1980 – 2000)



Source: Silva (2003)