The Role of Science in Innovation in a Developing Country: a Case Study of Brazilian Patenting Activity

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Abstract

This work analyzes the Brazilian profile of patents issued by USPTO from 1976 to 2003 and a sample of patent applications (March 2001 to August 2003), in order to identify the increasing influence of academic knowledge on technological development through non-patents references cited. Data analyzed were type and number of citations, scientific and technical journals cited (indexed or non-indexed, basic or applied), their impact factor, and the technological area from publications cited during the period. We also analyzed a Korean sample of patents to compare with the performance of a country with a completely different recent history of technological development. Data suggest that Brazilian patents show a recent and increasing linkage with scientific knowledge, mainly with biomedical research from indexed journals, indicating the growing influence of some research areas in the development of new processes and products.

Introduction

Patents are frequently used as a measure of innovation effort, and have relation with new products and processes. Patent data is a useful indicator and represent a comprehensive, in-depth technological activity information resource providing useful data about technical change, serving as a means of measuring inventive output over time. Inventions have important economic benefits to a nation because they often result in new or improved products, more efficient manufacturing processes, or even new industries. Inventors can obtain patents from government-authorized agencies, like the *U.S. Patent and Trademark Office* (USPTO), for inventions judged to be new, useful, and not obvious. Although USPTO grants several types of patents, this discussion is limited to utility patents only (inventions).

According to Narin *et al.* (1997), some methodological points about the use of U.S. patent information are important to be mentioned: 1) Patent data is complex, because one can count data in many ways: several patents can cite a paper and a single patent can cite many papers. In addition, papers could have multiple authors from different institutions, supported by more than one agency what gives rise to various complexities in interpretation; 2) Limitation to science references on patent front-page, ignoring references in the patent text. Front-page references should be the most important, since U.S. patent examiners rely specifically on them to establish patent's novelty. Further, from a practical standpoint, these text references are extremely difficult to extract, as they are scattered about an enormous amount of text.

When a U.S. patent is granted, it typically contains "References Cited" on its front-page, including references to foreign, and US patents, and to non-patent references (NPRs). NPRs are a mixed set of references to papers, meetings, books and many non-scientific sources, such as industrial standards, technical disclosures and engineering manuals, for example. All references together, link the issued patent to the earlier cited prior art, and limit its claims. They point out where essential and related art already exists, and delineate the property rights of the invention as determined by USPTO. A study conducted by Narin *et al* (1988) evaluated the representation level of the front-page science references found that approximately half of all the science references are there.

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These "references cited" on U.S. patents are a fundamental requirement of patent law. To be issued, a patent must satisfy three general criteria: it must be useful, novel, and not obvious. The novelty requirement is the main factor leading to the references that appear on the patent front-page. It is responsibility of the patent applicant and his attorney, along with the patent examiner, to identify, through various references cited the important prior art on which patent improves. These references are chosen and screened by patent examiners, who are "not called upon to cite all that are available, but only the best". Therefore, references that appear in the front-page, does not represent, necessarily, the knowledge and technology first used by the inventor.

Scientific journals represent the distillation and refinement of months/years of work. Unlike less formal means of scientific communication that also appear in patent NPRs, authors' peers usually review journal papers and then editors examine them before publication is allowed. Consequently, scientific and engineering journals are the most authoritative records of research. It suggests that scientific and engineering papers cited by patents could be a good source of information on transfer of scientific results to patents.

Many scientists and economists believe that public science is a driving force behind high technology and economic growth. They also believe that transfer of publicly supported knowledge to industry is an important part of technology transfer process. Narin *et al*. (1997) have provided strong evidence that basic research performed at national academic institutions is an important driving force for technological and economic development. They pointed out that 73% of papers cited on U.S. patent studied were produced in American universities.

In the highly science-dependent fields such as biotechnology, the great majority of NPRs are, in fact, science references. However, in many other fields including some electronics areas and many of mechanical areas, most of NPRs are not, in fact, science references, and this differentiation is likely to be important, since it seems that the linkage to science is the driving force behind many important areas of technology. In fact, McMillan *et al*. (2000) suggested that American biotech industry, which is based on basic knowledge, is composed of small firms with close ties to university scientists, and depends on public science for scientific research. This association is even more pervasive in biotech companies than in other areas such as pharmaceutical, where there is a strong tradition of collaborations with academia.

Science references in U.S. patents are independent indicators that link science and technology. Despite limitations, they effectively trace scientific underpinnings of technical innovations, at least the knowledge that has been publicly disclosed. These indicators are an appropriate proxy for quantifying the relation of a technology field to a science domain, and can be used further to trace back to the agencies that fund scientific research. According to Meyer (2001), it is possible to distinguish three major applications of science citation in patents analysis: 1) Follow general science orientation of fields over time by revealing a web of science and technology linkages; 2) Measure the intensity of science and technology interaction; and, 3) Track potential knowledge flows between scientific and technological fields.

The aim of this work is to analyze the Brazilian profile of patents issued by USPTO from 1976 to 2003 and filing patents from 2001 to 2003, in order to identify the increasing influence of academic knowledge on technological development through non-patents references (NPRs) cited. Data analyzed were type and number of citations, scientific and technical journals, journal impact factor and papers' technological area during the period. We also studied a Korean sample of granted patents to compare with the performance of a country with a completely different recent history of technological development.

Data suggest that patents with Brazilian inventors show a recent and increasing linkage with scientific knowledge, mainly with biomedical research from indexed journals, indicating the growing influence of some research areas in the development of new processes and products.

Methodology

For patent analysis was used USPTO patent databases: 1) Patent Grant Database that includes patents from 1976 to the present, offering the most complete bibliographical information about US patents including abstracts, full texts and all citations to other patents and to science and technology literature; and, 2) Published Patent Applications Database created in January 2001. It is important to note that in this database, documents are available as filed, all citations scattered in the text bringing two problems: find citations and delete repeated ones.

The volume of data brings the necessity of using data mining software to have an automatic data processing using more complex/sophisticated tools. Analysis in this study was not done with software; database was "manually" constructed with direct hands-on data analysis.

For scientific data was used *ISI Web of Knowledge* that is the most comprehensive research database available including sciences, social sciences, arts and humanities. Database includes 23,000 journals, 110,000 conference proceedings, beside other information.

We analyzed all utility patent issued to Brazil by USPTO from 1976 to 2003, comparing with a sample of a hundred issued patents to South Korea in the same period. Except for 1978 – 1988, when the number of Korean patents granted was less than a hundred. We adopted this procedure, because the number of Korean patents is higher than Brazilians during the period. Data was collected in a random way.

Patenting activity of these two countries was used because, despite the fact that they have different patenting systems that differ in standards application, system of granting patents and, mainly, has different level of technological development, the important fact is that both countries have a recent history of development.

U.S. patents that were used in this study from Brazil and Korea were downloaded from USPTO databases cited before for the whole period studied, using Assignee Country (ACN) as address to search utility patents. Different types of data classification were established: 1) Classification based on type of institution: industry, research and individuals; and, 2) Technological sectors using *International Patent Classification* (IPC)[1]. This index allowed us to segregate patents in different technological sectors for each year studied. The IPC is a hierarchical system divided into sections, classes, subclasses and almost 70,000 groups and subgroups that cover all technologies developed until now; and, 3) "References Cited" existent in patent front-page; these citations were classified in patent references for residents or non-residents, and in NPRs. We classified NPRs into scientific (Sc) and non-scientific references (NSc); and subdivided (Sc) references into two groups of scientific source, as books and conferences proceedings; and, scientific journals. Analysis of (Sc) references was related to: 1) Scientific or technological field; 2) Basic or applied journals that were divided taken into account the title and/or the editorial policy; 3) Journals impact factor indexed by ISI or non-indexed; and, 4) Impact factor of journal cited, also according to ISI.

The review process that leads up to the official grant of a new patent in U.S. may take as long as four years. Consequently, examination of year-to-year trends in patents granted will not always reveal the most recent changes in patenting activity. The number of patent applications filed with USPTO provides an earlier, even though less certain, indication of changes to patterns of inventiveness. Yet, current trends in new patent applications help to revise observations made from U.S. patents granted. So, in order to verify the influence of scientific knowledge in Brazilian technology recently developed, we also analyzed applications made from March 2001 to August 2003 that were still in exam when the study was carried.

[1] IPC is available in WIPO website http://www.wipo.int/classifications/fulltext/new_ipc/ipcen.html.

Results and Discussion

Since a patent obtained in a country conveys no protection outside this country, it is common in the world of "international market place", try to obtain patents in more than one country. As a result, significant foreign inventions are usually patented in U.S. because it presents such an important market. U.S. patenting system is quite representative of world's technology and covers the whole range of technology, from old but still active classes representing such basic mechanical to most modern genetics technologies. Thus, U.S. patent system represents not only U.S. technological effort but, largely, foreign technological effort as well. For example, the growth of U.S. patent documents issued to non-residents represents the growth of foreign technological capabilities since early 1960's mirrored by the growth of U.S. patent documents issued to non-residents. In 1963, only 18% of U.S. patents were issued to foreign countries. However, by the end of 2007, foreign share was 48% (USPTO).

According to Narin *et al.* (1997), patents issued by USPTO to Americans and to developed countries like United Kingdom, France, Germany and Japan presented a steady increase in linkage between science and technology development, but this connection is increasing fastest mainly for U.S. and U.K. patents. This linkage seems to have three major characteristics: i) Is subject specific, i.e., most citations are to a very narrow section of literature, as patents in biotechnology primarily cite publications in clinical medicine and basic biomedical research; ii) Patent citations are quite national, i.e., U.S.-generated patents heavily cite U.S.-authored scientific papers; and, iii) 73 % of science citations on front-pages of U.S. industry patents are scientific publications public funded, mainly basic science, that is having impact in U.S. patent system, particularly in U.S. and U.K. patents that are heavily involved in biotechnology, drug and medicine technologies, which are the most science-linked.

Patents issued to Brazil by USPTO, despite the low numbers, had an increase of 14.1 folds from 1978/79 (n=16) to 2002/03 (n=226). A modest increase, if we compare with South Korea that had an increment of 3,865 folds from 1978/79 (n=2) to 2002/03 (n=7,730). In both countries, patents were mainly issued to industries. In Brazilian case, most industries are private and just one public. It is interesting to note that the public industry is the Brazilian state oil company (Petrobrás), the major Brazilian patentee in U.S.

According to IPC index, Brazilian patents are concentrated particularly in section B that represents technologies related to physical or chemical processes, machines for carrying out those processes, machines in general, micro-structural technologies, nanotechnology and vehicles. Different from Korean patents sample that are concentrated, mainly, in sections H (electricity) and G (physics) (Figure 1). Brazilian concentration in section B is probably related with Petrobrás' patents. From 1976 to 2003, the company got 161 utility patents that were 21.8% of all utility patents issued to Brazil in the period (n=739), and 34.2% (n=55) of these applications were granted in section B.

As previous mentioned, patent applications cite "prior art" and these citations have traditionally been to other patents, but increasingly, these citations include scientific and technical articles. The percentage of U.S. patents, which cited at least one such article rouse more than 10-fold between 1987 and 2002 and more than six-fold in the average number of citations per patent, and seems to be related to the development in life sciences fields of biomedical research and clinical medicine (NSF, 2004).

Figure 2 shows the relation between total number of references to other patents and to NPRs in Brazilian and Korean patents, classified in periods of two years. Despite the fact that these countries have different technological development, for both of them, we found the same pattern, much more references to patents than to non-patents, because traditionally, patents cite patents. In 2002/03, for example, USPTO granted 135 patents to Brazil, which contained 1,593 references, 1,412 to other patents (88.6%) and 181 NPRs (11.4%). In the same period,

in Korean sample we found 2,041 references, 1,891 to other patents (93%), and only 150 to NPRs (7%) of all references found in the front pages of these patents.

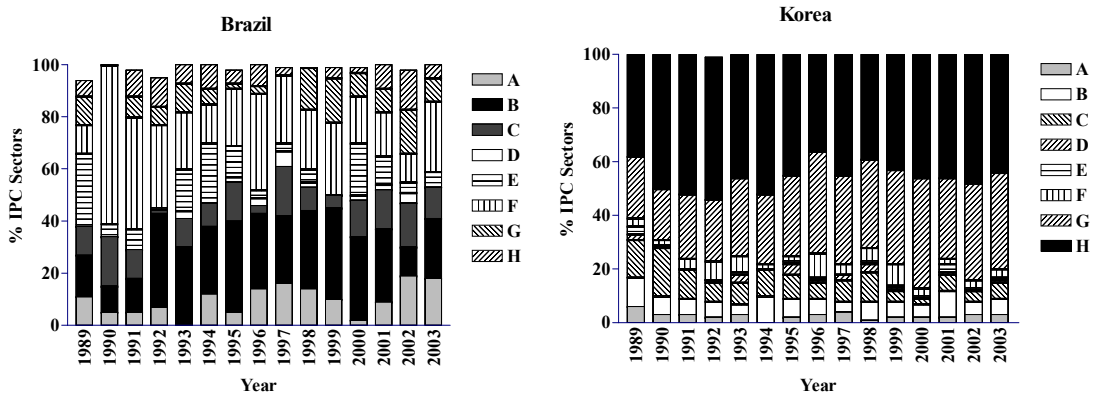

Figure 1: Comparison between utility patents granted by USPTO to Brazil and in the Korean sample from 1976 to 2003, classified according to the International Patent Classification. Source: USPTO database. A – Human necessities; B – Performing operations and Transporting; C – Chemistry and Metallurgy; D – Textiles and Paper; E – Fixed constructions; F – Mechanical engineering, lighting, heating, weapons, blasting; G – Physics; and H – Electricity.

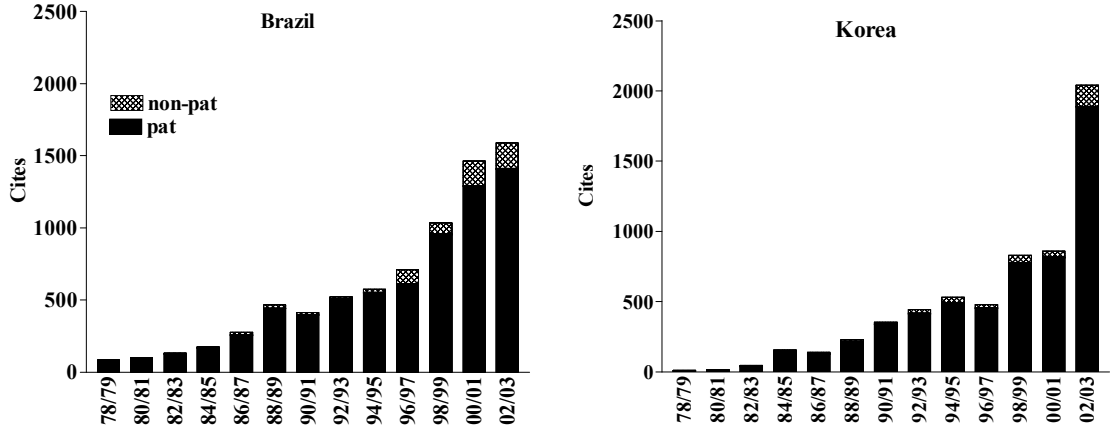

Figure 2: Comparison between patents references (■) and non-patents references (NPRs) (▒) found in utility patents issued by USPTO to Brazil and in the Korean sample from 1978 to 2003, arranged in two years periods. Source: USPTO database.

It is important to remember, that patents analyzed in this study were not from a specific field. In Brazilian case we got total number of patents granted in all areas during the period studied, and in the Korean case, we got just a random sample that included all sections. However, McMillan *et al.* (2000) showed that in a biotechnology patents' sample were found 10,335 patent citations and 23,286 non-patent ones, a relation of 2.2 NPRs to each patent citation. It is possible that the same correlation also exists in Brazilian patents.

Figure 3 shows the evolution in NPRs percentage, divided in science (Sc) and non-science based (NSc) found in the front page of Brazilian patents (3A) and in Korean sample (3B) in relation to total number of NPRs in the period studied. Data shows that utility patents issued started to have NPRs since the end of eighties, but the great expansion in scientific and technical citations in Brazilian patents really occurred since 1996/97 period. The total number

of patents that have NPRs in their front-pages is also increasing, as shown in Figure 3C (Brazil) and 3D (Korean sample). Data suggest that the linkage between knowledge and technological development in Brazil is also quite recent and seems to be increasing.

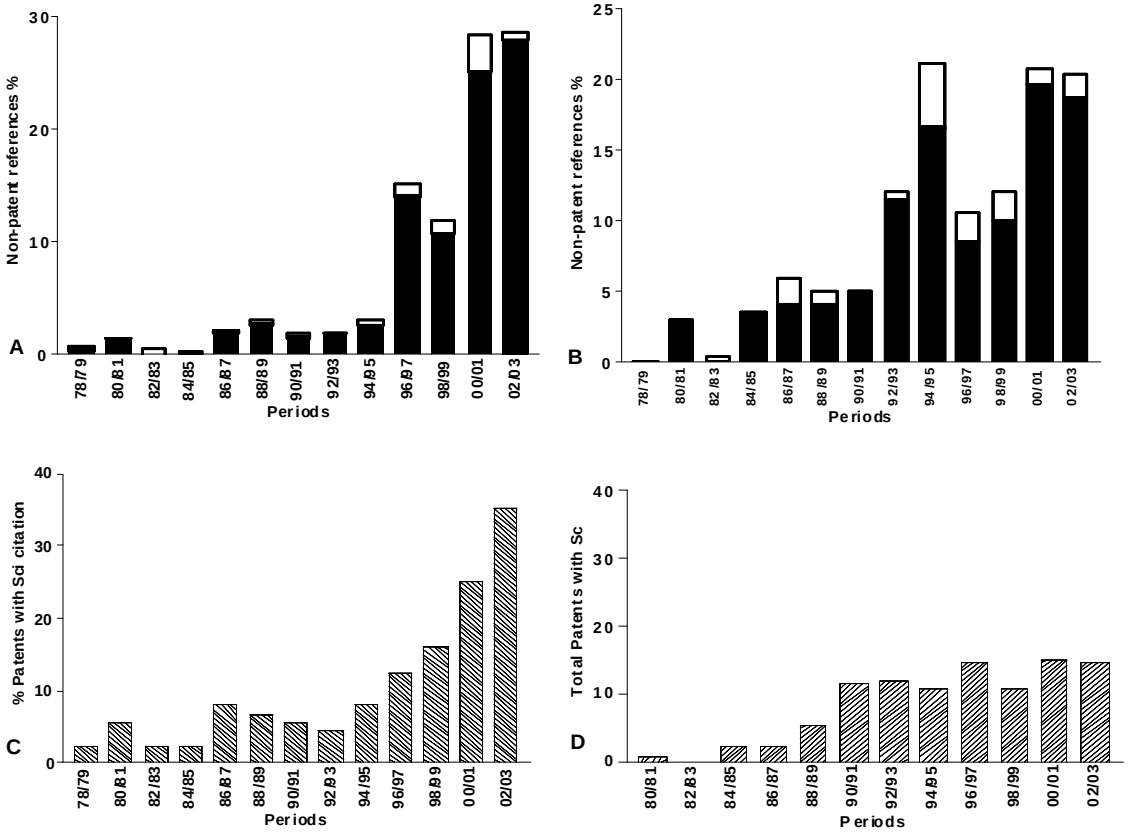

Figure 3: Percentage of non-patent references (NPRs) classified in references Science-based (Sc) (■) and Non Science-based (NSc) (□) in Brazilian patents (A), and in the Korean sample (B) in relation to total NPRs found from 1978 to 2003, arranged in two years period. Graphs (C) for Brazil and (D) for Korea show the increase in patents percentage that have science-based references in the same period. Source: USPTO database.

According to Verbeek *et al.* (2001), looking at the overall co-evolution of USPTO patent documents and NPRs found on their front-pages, it was observed that since 1988 onwards, the number of NPRs exceeds the number of patents. However, this was not caused by a general increase in the number of patents that cite non-patent literature, but it is due to the rise in the number of NPRs per patent, in certain technological areas. The rise in the average number of NPRs can be explained by a number of specificities related to USPTO. Due to a severe backlog in U.S. examination procedure, the number of patents granted has been marginal in a number of areas (e.g. biotechnology, agriculture). Therefore, NPRs are being cited before patent documents, which normally are cited first in order to describe prior art. It can be assumed that due to this backlog, patent examiners were stimulated to search for related research.

The skewed distribution of NPRs, with a majority of patents containing no references, while only a small fraction of all patents contains numerous references, was also found by Verbeek *et al*. (2001). From 1992 and 1996, the following distribution was noted in a sample of U.S. patents: 65% of all patents had no NPRs; 8% only 1 NPR; 19% between 2 and 4; 1% exactly 5; and, 7% more than 5. In all, 35% of patents contain one or more NPR cite. Authors also

noted that a major share of increase in the patents with high levels of NPRs occurs in science-based areas. They concluded that distribution of science references is field specific.
Using the same distribution, in Brazilian sample studied, patents that had no NPR's represented 84.1% (n=657) in the period studied. From patents that had NPRs (n=124), the following distribution was noted: 41.1% only one NPR (n=51); 28.2% between two and four NPRs (n=35); 5.7% with five NPRs (n=7); and, 25% of all patents with more than five NPRs (n=31). From all patents, almost 16% contained at least one NPR. It is interesting to note that this increase occurred together with a major incidence of Bioscience patents since 1995/96. In Korean sample, the distribution was 84.6% with no NPRs (n=1,452); from patents that had NPRs (n=264), 45.8% had only one NPR (n=121); 36.7% between two and four (n=97); 6.1% with five references (n=16); and 11.4% with more than five references (n=30).
Narin *et al.* (1997) showed that papers cited in U.S. patents granted to developed countries were published in prestigious and mainstream, basic research journals of scientific areas as biomedical and chemistry, and in applied research journals in physics and engineering. McMillan *et al.* (2000) demonstrated that in a sample of biotech patents granted to residents, 64.3% of cited papers were basic, from biomedical and clinical medical research journals.
Figure 4 shows the distribution of knowledge-based references (Sc), for both countries, classified as basic or applied, indexed or non-index journals and other sources of information as meetings, conferences proceedings and books, arranged in a two years periods. The increase in scientific and technological references detected in Figure 3A, since 1996, has the same pattern as the growth in basic and applied papers citations in Brazilian patents (Figure 4A). It is also important that the number of knowledge-based citations, in the last years is increasing for both countries, mainly in basic indexed journals, suggesting that for developing countries, this relation is not completely field-specific, different from expected.

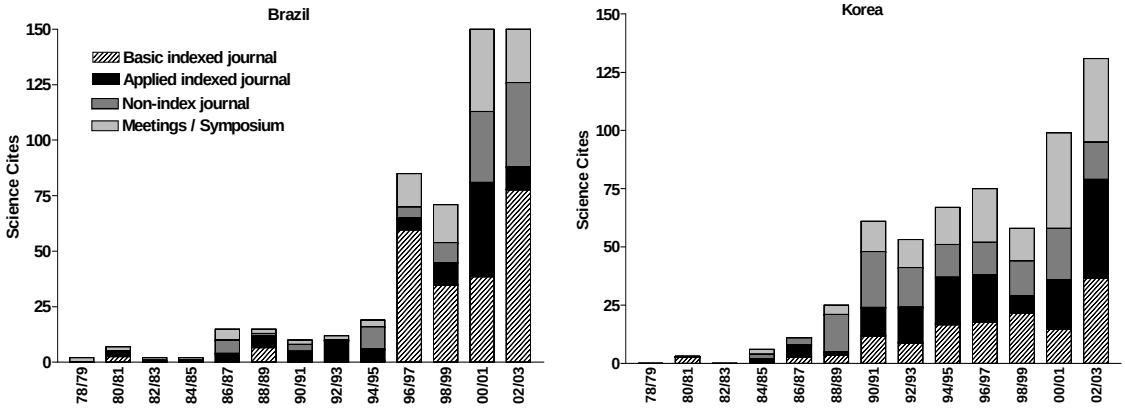

Figure 4: Comparison between different science-based references found in utility patents granted by USPTO to Brazil and Korea from 1976 to 2003, arranged in two years period. Source: USPTO database.

In Brazil, Bioscience showed an increasing relationship with scientific and technological knowledge, with a frequency of 8.6 cites per patent with NPRs for the whole period studied (data not shown). Citations were found, mainly, in two different IPC classifications: A61 related to medical science, veterinary science, and hygiene; and, C12 related to biochemistry, microbiology, enzymology and genetic engineering. Bioscience patents summoned 49.3% (n=283) of all Sc references (n=574) found in the Brazilian patents. It is important to note that engineering field had 29.4% (n=169) with an increase since 2000/01 periods. Bioscience is the most science-based field, but this tendency is very recent (since 1995); Engineering

showed linkage with scientific knowledge since 1980, representing 39.5% of (Sc) references found in the sample studied. It seems to be different from what happens in countries as United States and United Kingdom. According to NSF (2004), in 2002 US patents presented the following distribution in science citations: clinical medicine, biomedical and biology research combined represented 71.6%, chemistry 13.5% and the other fields (physics, engineering) shared 14.9%.

Korean sample showed a pattern similar to Brazilian case, the increasing linkage of technology with science is also a very recent event that started in the nineties. Major number of cites per patent was in Chemistry field, which presented 4.1 cites per patent with (Sc) references (data not shown), despite the fact that Figure 1 showed that majority of Korean utility patents was in physics and electricity technological fields.

According to NSF Science and Engineering Indicators 2006, from 1987 to 2004, the rate of scientific papers cites in US patents granted has increased 13 times (from 17,133 to 233,294 S&E cites) in citations' volume and more than six-times in S&E citations as an average per patent (from 0.21 to 1.42 citations/patent). The causes of this growth are complex, but they seem to include changes made in the Patent Law in 1995, enacted to comply with the General Agreement on Tariffs and Trade (GATT). The patent protection period changed from 17 to 20 years from filing date for applications received after June 1995. Previously rejected patents refilled after this date would also be subject to GATT rules. Applications submitted to USPTO more than doubled in May and June of 1995. These applications carried an unusually large number of references to scientific material. Patents applied for in June 1995 carried three times the number of scientific citations of those filed in March 1995 and six times the number of those filed in July 1995. This sudden increase in referencing occurred in all patents' technologies, not just in biotechnology and pharmaceuticals, in which referencing is most extensive.

Narin *et al.* (1997) found that in addition to the rapid increase in article citations on U.S. patents, there is a shortening interval between publication and citation. References tended to be to articles appearing in nationally and internationally recognized, peer-reviewed journals, including journals publishing basic and applied research results, and to be field and technology-specific. According to Verbeek *et al.* (2001), multidisciplinary journals as "*Nature*," "*Science*" and "*Proceedings of the National Academy of Sciences of the United States of America*" are frequently present in NPRs found in U.S. patents. The frequent presence of journals edited by IEEE (Institute of Electrical and Electronic Engineers, U.S.) is also of interest. Also strongly represented is the journal "*Applied Physical Letters*" which is the most cited journal over the years.

Figure 5 shows the distribution of the Brazilian (5A) and Korean citations (5B) to different scientific journal fields from 1978 to 2003, arranged in two years period; and the impact factor of index scientific journals cited in Brazilian patents (Figure 5C) and in Korean sample (5D). In Brazilian case, the increase in total citations (Figure 4A), mainly, in basic and applied indexed journals have relation with the growth of patents in life sciences field. Figure 5A shows that these citations are mostly from Bioscience journals, with an expressive number of citations to prestigious and mainstream journals, for example, "*Proceedings of the National Academy of Sciences of the United States of America*" with 12.5% of citations and "*Parasitology*" (12%), beside others. In total, there were 133 indexed journals cited in Brazilian patents, 62% basic and 38% applied research.

It is important to remember that there are more journals related to life sciences field (45%) than to others fields included in ISI database, and the majority of journals with high impact factor are from this same field.

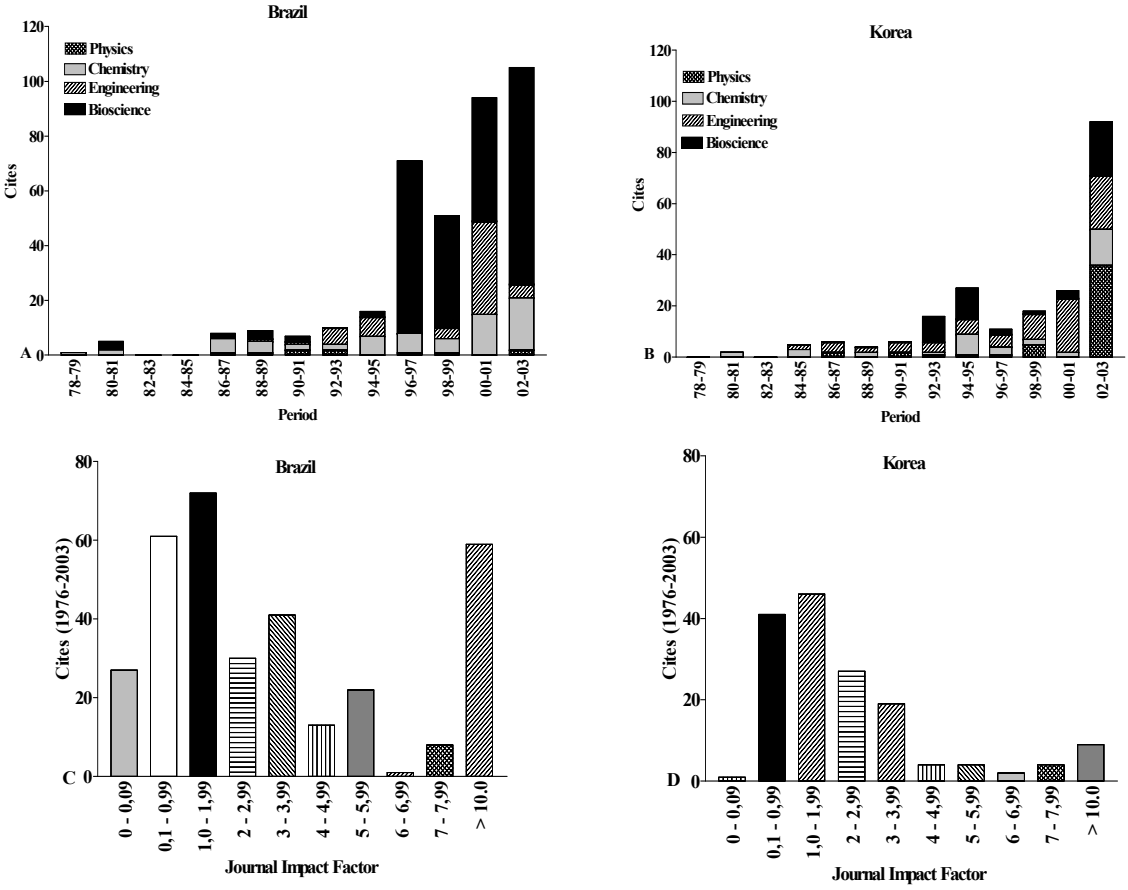

Figure 5: Distribution of Brazilian (A) and Korean (B) cites into the different scientific journal fields, from 1978 to 2003, arranged in two years period; and the impact factor of the scientific journals cited in utility patents granted by USPTO to Brazil (C) and in the Korean sample (D). Source: USPTO.

We also analyzed the NPRs of the Brazilian sample of utility patent applications from March/2001 to August/2003. During this period, Brazil applied for 435 new utility patents; 168 applications (39%) constitute our sample, 34 in 2001 representing total applications, 64 in 2002 (also, total applications), and 70 in 2003. Figure 6A shows total number of different journals and citations found in the text of applications, comparing data from Brazilian patents for the whole period studied (1978-2003) with the applications' sample from March 2001 and August 2003, classified by journal field. Figure 6B presents the distribution of science-based NPRs found in applications sample and the number of different journals cited in these applications, classified accordingly journal impact factor.

It is important to note that the number of citations from indexed journals of high impact increased in relation to data gathered from the patents profile (Figure 5C). According to data presented, there was an increment of eight-folds in the number of Bioscience research NPRs, and an increase of 3.7 folds in the number of different Bioscience journals used in the development of some new product or process. It is interesting that Engineering field concentrated a large fraction of Brazilian patents and showed an increasingly science-dependence in patents profile. It is worth noting that a less number of journals and scientific references was found (Figure 6A) in the engineering applications' in the sample studied.

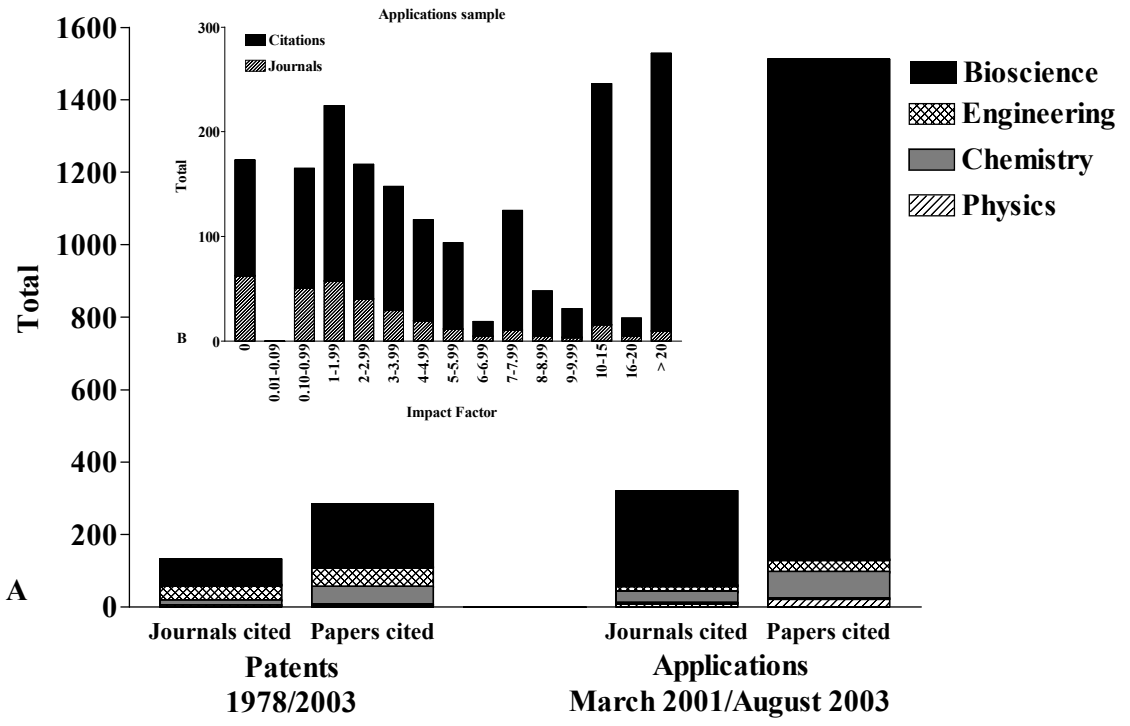

Figure 6: (A) Total number of scientific and technical journals cited and scientific references found in patents issued from 1976 to 2003 to Brazil, and in a Brazilian applications sample filed from March 2001 to August 2003; (B) Distribution of journals cited and references found in Brazilian applications, classified by journal impact factor. Source: USPTO database.

As mentioned previously, NPRs in U.S. patent front-page suffer interference from the inventor, the attorney, and the patent examiner. In the application case, there is no interference from patent examiner, because the exam only occurs 18 months after application date. Therefore, references found in the application sample could indicate the real knowledge and technology used by the inventor. Besides this, it is an indicator that brings a more dynamic and actual view of the science-technology linkage tendency in a country.

Final Comments

Scientific and engineering research conducted today will have an impact on economic success of corporations and countries in the future. However, despite living in such an increasingly knowledge-based society, the processes by which scientific/technical knowledge drive industrial competitiveness and economic development remains a difficult area to assess and understand. This lack of detailed understanding not only undermines the economic rationale for public and private investments in research – especially in risky exploratory academic research with long term objectives and uncertain payoffs – but also public confidence in societal benefits and rates of returns of academic research (Tijssen, 2001).

Technological advances have their origins in basic or applied scientific research, but the surge of science-generated technologies that conquered the market over the last 30 years have resulted in a large number of new commercial enterprises that now constitute a major fraction of the global economy. Lasers, semiconductors, fiber optics, mobile phones, medical imaging, and biotechnology all have resulted from fundamental discoveries from basic research, Internet being the most used high-profile example (Verbeek, 2001).

This study should be understood, primarily, as an exploratory effort contributing to a better understanding of tangible linkages between world scientific literature and Brazilian technology. As such, it should be seen as a step in an ongoing knowledge-creation process towards a more appropriate quantitative measure of linkages between science and technological development in the country.

Data shown suggest that, despite low numbers, in comparison with other studies done to identify science-technology linkage, the Brazilian patent profile and applications sample show an increasing science dependence tendency (Fig. 5 and 6), mainly, with Bioscience research, despite the fact that a great fraction of patents are from the Engineering field and related. Same situation was observed in Korean sample, but the relative frequency of scientific citations in the sample was two times less than in Brazilian patents. Probably, related with differences on technological fields of each country (Fig. 1).

Science cited in Brazilian patents and applications as in Korean sample are from prestigious mainstream scientific journals. Nevertheless, in Brazilian case, journals were mainly Bioscience basic research with high impact factor; in Korean sample, journals more cited (48%) were from engineering field. The number of scientific journals cited in Brazilian applications sample showed an increment of 3.7 folds in total Bioscience journals cited, and 8 folds in the number of scientific references (Fig. 6A).

Brazilian patents and Korean sample showed that independent of different technological fields of development, linkage between science and technology developed by national industry is quite recent in both countries, since the middle of nineties.

This increase is very important, because technological development of specific areas such as Bioscience, which is science-based, seems to be connected, mainly, with basic research that will attract investments to production of new products and processes. Technical application of knowledge creates new problems that basic research will solve, promoting a technology-pushed scenario.

Different studies mentioned the national characteristics of those scientific citations in the U.S. patents. Maybe this feature is related with the fact that the countries studied by other authors were all developed, with a mature system of innovation. In Brazilian patent profile and applications sample as in the Korean one, the number of self-citations and citations to national research was almost inexpressive, indicating that different from developed countries, in the developing world, technological development (independent of field) relies on world scientific literature. Therefore, it is possible that the main contribution of science from countries that are still in the development process is the increasing quality and quantity of human resources capabilities.

Albuquerque (2000) showed some signs of the immature character of Brazilian system of innovation, as a large share of individuals in patenting activities, little firm involvement in innovative activities, lack of continuity in patenting activity, beside others. It is possible that the suggested dependence with scientific knowledge in the development of new process and products of some technological fields is a sign of an innovation system that is in process of maturation.

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