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# Strategies to assure adequate scientific outputs by developing countries - a scientometric evaluation of Brazilian PADCT as a case study

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## Abstract

The main purpose of this article is to stimulate scientists and policy makers to ask the question: How reliable are scientific investments made by developing countries on a long term basis ? Strategies to assure adequate, long term, scientific outputs by developing countries must be enforced. Our experience in Brazil and in many other developing countries, particularly in Latin America, that successful scientific initiatives may be discontinued for non scientific reasons. Strategies in Brazil are discussed, as well as the results of a scientometric evaluation of the Brazilian PADCT as a case study. The methodology applied requires the availability of data bases listing all the active scientists, for performance comparisons amongst institution and countries. Financial investments by developing countries for S&T&I are limited when compared to developed countries but must be properly evaluated. Many developing countries have in addition difficulties to maintain consistent data bases on science and technology and as consequence fail to evaluate the outputs resulting from the investments in this area. This context weakens the position of the scientific academies, when the time to present the necessary demands of science to the highest decision making level bodies in the Country is offered.

## Keywords

Sc&T output evaluation , citation/paper , ISI Institute for Scientific Information, PADCT - Programa de Apoio ao Desenvolvimento Científico e Tecnológico

## Introduction and Background

### The Problems of Funding Science and Technology in Developing Countries

A peculiarity of most developing countries is their inability to protect the

sector of S&T from general socio economic as well as political interferences, This fact which differentiates less developed from developed countries is due in addition to the circumstance that in less developed countries the S&T&I sector competes for public funds with urgent social priorities which eventually take most of the budget. In order to understand the context leading to the limitations of funding science and technology in developing countries we invite a visit to the site of the Ministry of Planning and Finances of Brazil ( 1 ) where a statistical series for the last four years 2000/2004 demonstrate that from the General Union Budget ( 400 billion reais ; 1 US $ = 2.7 reais) 85 % goes to obligatory expenses ( welfare, other social obligations transfer of money to States and Counties and foreign obligations with the country debt ) and only 15 % is available for investment. Since the Law that governs the General Union Budget is named Directives for Budgetary Law, ( LDO ) the Executive is authorized but not obliged to operate the Law as approved by the Congress and sanctioned by the President of the Republic; except with respect to the obligatory expenses. In addition there is no mandatory chronological disbursement for the funds in the Law. Together these two legal circumstances allow for sectors of the Executive to block the disbursement of expenses approved by the LDO, using a contingence argument, which is related to a possible or unforeseen event within the social context, or to economical indicators which point to incomes for the exercise of the law, below what was previously estimated. The exercise of the LDO becomes as such a very dynamic and sometimes unpredictable process, amenable to continuous reevaluations for the reasons mentioned. (verify the number of decrees related to the exercise of the General Union Budget and versions of the Budget at **http://www.planejamento.gov.br/orçamento**) To exemplify Brazil established at Federal level private funds to finance the major areas related to S&T&I. These Funds integrate the Directives for the Budgetary Law approved by the Congress every year, but were never implemented as approved in the Law.

In the same site one can find the Budgetary and Financial Program for 2005 ( 2 ) . From the investment subtotal of 15 % more than 2/3 (68%) go to health, education and the Zero hunger program (6.2 billion reais). The Zero Hunger program in Brazil will need close to a billion $ /year, just to add 17 US $ /month /family to benefit 40.0 million people identified at poverty level in the country, ( 3 ). The investment for Science and Technology in 2005, including Agricultural Research is estimated to be 3.5 billion reais, approximately 5% of the investment subtotal mentioned.

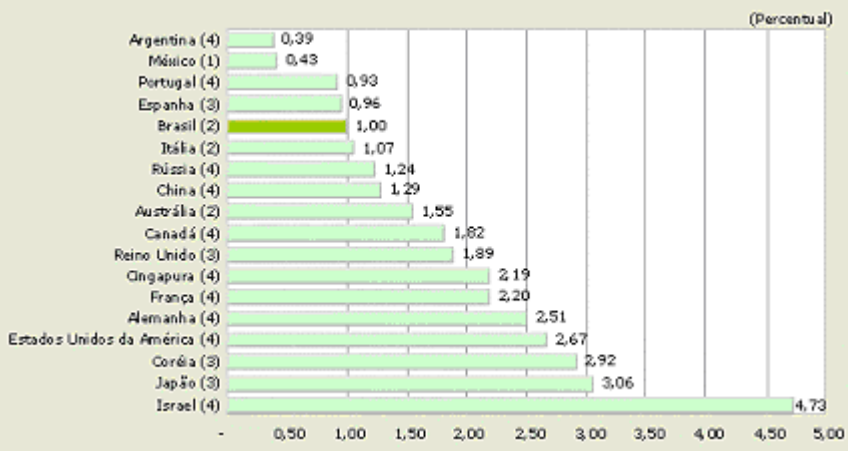
In addition it is not uncommon that social and political influences cause complete interruption of successful S&T projects and strategies. Brazil applied and received Loans from the World Bank to fund its Science and Technology sector for almost ten years from 1985 to 1995, through three versions of the so called PADCT, ( Programa de Apoio ao Desenvolvimento Científico e Tecnológico ) the largest science and technology funding program ever exercised in the country at federal level; that was the object of this scientometric evaluation. This strategy of applying for Loans from the World Bank for the development of Sc&T&I in Brazil was interrupted and is no longer exercised. Nevertheless even for the Loans that were approved by the Senate, when dealing with financial Executive agents, during eight years (from 1991 to 1999) as the Executive Secretary for PADCT, I had to face the exercise of contingence of funds, blocking of financial disbursements for the program, and frequently was told that no instruction from the Federal Government was put forward to treat science and technology differently from other areas.

Political influences prevented the development of Biotechnology and genetic engineering of plants in Brazil from 1998 till 2005 ( 4 ) . This overall scenario leads to discontinuity of investments in S&T and may differentiate our countries from developed countries that of course being less affected by social issues, have facilitated their mission to preserve S&T&I as a high priority. It should be said however that restrictions to investments in science and technology related to the genetic engineering of plants and other issues related to biotechnology is also prevalent in developed countries ,( 6 ),( 7 )

( 8 ) ( 9 ) (10).

Sustainable funding of S&T is for the reasons mentioned very difficult to be exercised in developing countries. In Brazil, long term funding for S&T&I is only exercised by the State of São Paulo. In this State, by law, FAPESP, (**fapesp@telegarget.com.br** ) a State Foundation established four decades ago to support science and technology, receives every year 1 % of the whole state tax income to apply in S&T&I , and executes its budget independently, without political interferences. The results are very positive and different from the rest of the country. The other States in Brazil include similar legal instruments to support S&T but do not enforce it as determined legally.

To summarize, Brazil spends inconsistently, federal and state public funds in the amount 1.0 % of the NGP /year in scientific research and technology development. The private sector does not invest an equivalent counterpart amount of money as this sector does in developed countries. (Figure1). Scientific initiatives sometimes exercised for decades are unexplainably discontinued, as for the PADCT program mentioned earlier; (for details of this Program see Implementation Completion Report- ICR, Brazil Science Research and Training Program – Loan 3269 BR World Bank and also SAR /PADCT III World Bank Loan Agreement 4268 – BR); **http://www.mct.gov.br** Programs (11) , (12 ) . After more than ten years of successful implementation and close to 1 billion US $ of investments in Brazil, PADCT in its third versions was discontinued as designed and previously negotiated with the World Bank, in the year of 1998.

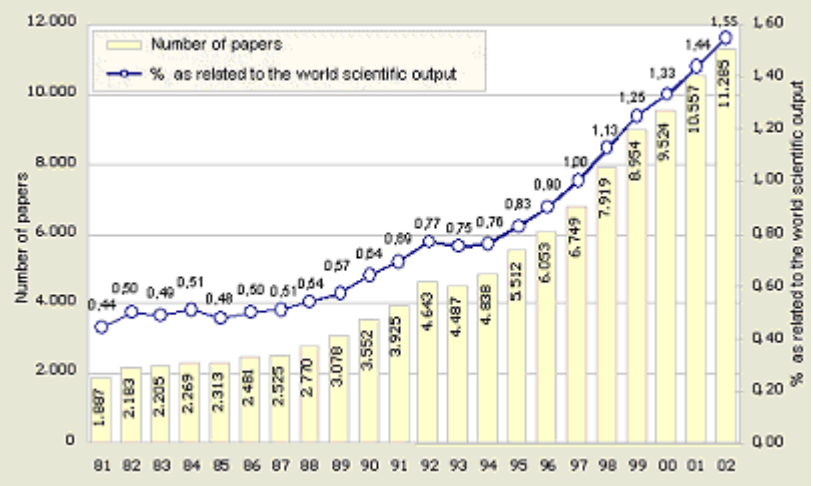



Source : The Ministry of Science and Technology/ Brazil - **http://www.mct.gov.br**

**Figure 1** - National expenditures in research and development by the private and public sectors by selected countries in the most recent years available expressed as % of the national gross income

**The Evolution of Scientific Outputs in Brazil**

Despite the limitations in funding for science and technology, the contribution of Brazilian scientists to the world's scientific outputs at least tripled during the last twenty five years and in many specific areas this contribution is way above the world average as shown in Figure 2 and Table 1 respectively. This performance results mainly from the investments made in human resource training during the last thirty years mostly by Agencies of the Federal Government (13 ),(14 ) linked to the Ministry of Education and of Science and Technology respectively. Brazil established a solid graduate program system which is yielding currently close to eight thousand Doctors




Source : The Ministry of Science and Technology/ Brazil - **http://www.mct.gov.br**

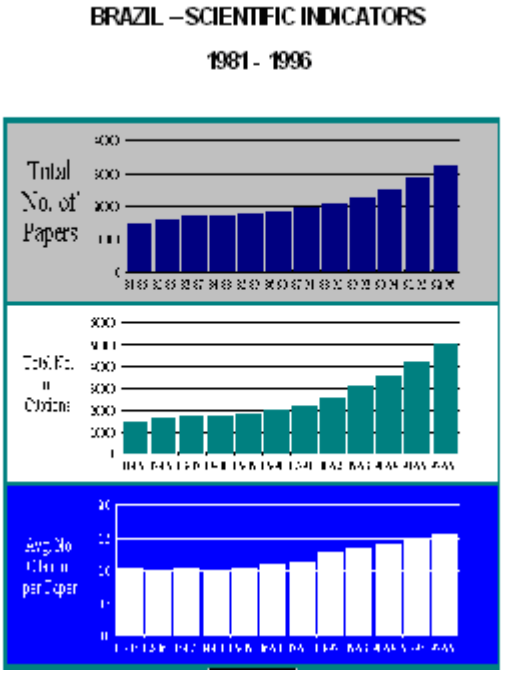
**Figure 2** - Institute for Scientific Information (ISI) indexed papers published by Brazilian residents as % of the world scientific output, 1981-2002

In addition, from the quality point of view the number of total citations increased by a factor of 3.3, and the number of citations per paper increased 1.60 fold .The total number of papers increased by a factor of 2.8, from 1981 to 1996 ( Figure 3 ). Table 2 shows that in 24 fields considered , during the same period , the number of indexed publications from Brazil increased by a factor of 2.12 whereas the number of publications in the World during the same period increased by a factor of 1.35. Table 3 shows more recent data ranking of 20 leading countries in terms of published papers in indexed international scientific journals during the period of 1997 to 2002 . Brazil ranks amongst the five best countries considering the slope of the growth curve.

**Table 1** - % ISI indexed papers published by Brazilian residents in selected areas in relation to the World

(%I)

| Áreas | 2000 | 2001 | 2002 |
|---|---|---|---|
| Agricultural Sciences | 3,06 | 3,08 | 3,00 |
| Physics | 2,04 | 2,36 | 2,30 |
| Microbiology | 1,89 | 2,08 | 2,18 |
| Animals & Plant Sciences | 1,86 | 1,99 | 2,10 |
| Air Space Sciences | 1,95 | 1,77 | 1,99 |
| Mathematics | 1,42 | 1,55 | 1,89 |
| Pharmacology | 1,70 | 1,56 | 1,76 |
| Biology & Biochemistry | 1,55 | 1,51 | 1,76 |
| Ecology and Environmental Sciences | 1,44 | 1,61 | 1,68 |
| Chemistry | 1,42 | 1,51 | 1,67 |




Source: ISI. National Science Indicators (NSI).
**Figure 3** - Brazil / Scientific Indicators

**Table 2** - Ratio of number of publication in 1981 to number of publications in 1995

| Áreas | Brazil | World | Brazil+World |
|---|---|---|---|
| Agricultural Sciences | 1.20 | 1.00 | 1.20 |
| Astrophysics | 3.10 | 1.40 | 2.21 |
| Biology &Biochemistry | 2.50 | 1.33 | 1.88 |
| Chemistry | 2.35 | 1.22 | 1.93 |
| Clinical Medicine | 1.86 | 1.35 | 1.38 |
| Computer Science | 2.23 | 1.60 | 1.39 |
| Economics & Business | 2.18 | 1.28 | 1.70 |
| Education | 2.90 | 1.00 | 2.90 |
| Engineering | 3.20 | 1.60 | 2.00 |
| Ecology/Environment | 3.34 | 1.43 | 2.34 |
| Geo- sciences | 2.36 | 1.34 | 1.76 |
| Immunology | 3.45 | 1.60 | 2.16 |
| Law | 3.00 | 1.18 | 2.54 |
| Molecular Biology | 1.69 | 1.89 | 0.89 |
| Microbiology | 2.66 | 1.30 | 2.05 |
| Materials Science | 3.96 | 1.61 | 2.46 |
| Mathematics | 1.79 | 1.23 | 1.46 |
| Neuroscience | 2.97 | 1.55 | 1.92 |
| Physics | 2.60 | 1.55 | 1.68 |
| Plant & Animal Science | 1.98 | 1.16 | 1.71 |
| Pharmacology | 2.53 | 1.23 | 2.06 |
| Psychology/Psychiatry | 1.35 | 1.18 | 1.14 |
| | | | |

| | | | |
|---|---|---|---|
| Social Science | 1.62 | 1.24 | 1.31 |
| **All Fields** | **2.12** | **1.35** | **1.57** |

Source: Implementation Completion Report - ICR, Brazil Science Research and Training Program – World Bank Loan 3269 BR Extracted from ISI Indicators

**Table 3** - Ranking of 20 leading countries in terms of published papers in indexed international scientific journals – 2002/1997 From ISI. National Science Indicators (NSI).

| Ranking | Country | 1997 | 2002 | 2002-1997 |
|---|---|---|---|---|
| 1 | People`s Republic of China | 17.888 | 33.561 | 15.673 |
| 2 | South Korea | 7.845 | 15.643 | 7.798 |
| 3 | Japan | 61.832 | 69.183 | 7.351 |
| 4 | Germany | 58.452 | 63.428 | 4.976 |
| 5 | Spain | 18.120 | 22.901 | 4.781 |
| 6 | Italy | 26.813 | 31.562 | 4.749 |
| 7 | Brazil | 6.749 | 11.285 | 4.536 |
| 8 | Turkey | 3.437 | 7.737 | 4.300 |
| 9 | India | 14.157 | 17.325 | 3.168 |
| 10 | Taiwan | 7.767 | 10.831 | 3.064 |
| 11 | England | 53.139 | 56.034 | 2.895 |
| 12 | USA | 242.686 | 245.578 | 2.892 |
| 13 | Poland | 7.351 | 10.046 | 2.695 |
| 14 | Singapoure | 2.232 | 4.301 | 2.069 |
| 15 | Australia | 19.036 | 21.078 | 2.042 |
| 16 | France | 43.018 | 44.999 | 1.981 |
| 17 | Greece | 3.784 | 5.335 | 1.551 |
| 18 | Mexico | 3.586 | 5.137 | 1.551 |
| 19 | Portugal | 2.040 | 3.567 | 1.527 |
| 20 | Belgium | 8.664 | 10.103 | 1.439 |

Source: The Ministry of Science and Technology/ Brazil - **http://www.mct.gov.br**

**Science and Technology Indicators and Databases - The Route to Sc&T Evaluation**

Brazil had no S&T indicators ten years ago. The first Science and Technology Indicators Hand Book was published in Brazil in January of 1996 (15 ) influenced by similar initiatives particularly by the RICYT ( 16 ) the most complete and reliable Sc&T indicators database published annually, that completed ten years in April of 2005; established under the initiative and leadership of CYTED ( 17 ) . When negotiations started with the World Bank for PADCT III in 1994 Brazilian representatives could not state to WB authorities how many scientific researchers were active in Brazil, and had no WEB database listing the CVs of the active scientific researchers in the Country. The first WEB data base listing the Brazilian scientists was elaborated in 1997 jointly by the PADCT staff and an institution named CESAR ( 18 ) housed at the Federal University of Pernambuco; and funded by the PADCT program of the MCT in Brazil .The database was embodied in the ReAACT (19) a WEB system to facilitate monitor and evaluation of Science and Technology

in operation since July of 1997 and still the best M&E system for science and technology available in Brazil; now adopted by FAPESP the State Foundation to fund Sc&T in the State of São Paulo. Three years later Brazil developed the Lattes CV Platform ( 19 ) housed at the National Council of Science and Technology in Brazil. In August of 2003 this platform had already listed 306.000 CVs of active scientific researchers and students in the Country. In the same site it is available the National Directory of Research Groups a step further to the Lattes CV data base, showing how the scientists are organized in groups and the research lines in progress. These component elements are essential for the evaluation of science and technology in any country and many developing countries do not have them available. However the databases by them selves do not provide an evaluation of the sector. Evaluation requires at least national and international peer comparisons. In addition not all areas are necessarily successful and the methodology presented in this Article indicate which areas are more competitive internationally and which are lagging behind. This information is essential to set priorities, strategies, and ultimately policies in SC&T. Setting priorities in Sc&T is incorporated in the funding agendas of all countries including the most developed ones ( 21 ). Other critical evaluations of Brazilian PADCT should be considered by the readers. ( 12), (22 ) and ( 23 ).

## Methods

### Sample Processing

It is important to mention that in this Article we essentially postulate that it is possible to evaluate a Sc&T program by the performance of the researchers funded by the program, compared to the same performance when they were not funded by said program. Equally one can compare the performance of scientists funded by a Sc&T program with the performance of scientists from other countries in the same fields they publish, to have a reference of the scientific output quality of the program funded researchers. If the method is applied to scientists of an institutions it is also possible to use the same strategy to verify in which areas the funded scientists are most competitive. The overall process of PADCT II evaluation was far more complex because it involved strategies to compare the performance of its Sub - Programs components mentioned below, and this will not be presented in this Article. When this method was conceived and designed to evaluate PADCT II , Brazil had not available CV databases as previously mentioned . That would have facilitated enormously the task of preparing the sample to exercise the inquire in the ISI system. We started from lists of all researchers involved in PADCT projects: available full names and institutional affiliation. To process this information into the name format used in the ISI database required the production of a new list with the last name of each individual followed by a space, followed by the initials representing the other names that appeared as part of the author`s name in the journal publication. This initiative elaborated by PADCT consultants ( see acknowledgements) generated a dictionary with all the names and variants affiliated to institutions and departments related to the six PADCT funded Sub Programs considered. It was of course a complex task to make sure that the outputs of homographs ( different individuals with identical ISI formatted names ) working in the same institution but in different fields than that funded by PADCT II are excluded . There is no way to eliminate this source of error completely when thousands of individuals are included in the sample as not including as a “hit“ a paper published by a homograph in a field completely unrelated to PADCT. On the other hand it is also possible that the analysis missed a “hit” paper because the author`s name was not included in the dictionary in the same format as it was in the ISI databases. In Brazil names such Castro can be shown in a paper as such or as de Castro or De Castro. Equally names ending with Junior and Filho must be carefully handled since these are family names common to hundreds of different names. The other initials in the proper order is the only resource to assure that the paper belongs to a PADCT funded scientist The dictionary had to include all these variants initially to compare to ISI variants. In short the methodology aimed to evaluate the performance of PADCT II based upon

the output quality of approximately 6500 scientists funded by the Program, distributed among six research sub programs, as shown below :

**Table 4** – Scientist funded by PADCT II sub programs during the period of 1991 -1996.

| Sub-Programs | # of scientists funded |
|---|---|
| Chemistry and Chemical Engineering | 2.356 |
| Biotechnology | 999 |
| Geo-sciences & Mineral Technology | 804 |
| Instrumentation | 1.074 |
| New Materials | 475 |
| Environmental Sciences | 872 |
| **TOTAL** | **6.580** |

The sample shown in Table 4 included the scientific personnel, (Technicians and Students were excluded) of all projects funded under the thematic Sub - Programs mentioned, without any selection for the experience of the groups or academic level of their members. This sample was sorted from the PADCT NET database which gathered around 12 000 staff people: scientists (10447) technicians (508) and graduate students (1339) for all sub-programs and project classes, (data not shown. PADCT NET is no longer available. (See also SAR /PADCT III World Bank Loan Agreement 4268 –Br and ICR Implementation Completion Report of PADCT II - Appendix A, Borrowers Report WB Loan 3269 –BR for details). The nominal scientific performance of the scientists funded by the PADCT II was followed during the period of 1981 to 1996. It is important to mention that the first version of the Program called PADCT I started in 1984 and included all Sub-Program areas mentioned above ( Table 4 ) except New Materials and Environmental Sciences which were included only in PADCT II which started in 1991. The analysis of publications by PADCT- funded researchers, included comparisons of their impact to that of Brazilian and world overall publications. The analysis was based upon the publication data appearing in the citation index databases of the Institute for Scientific Information (ISI), the most widely used database for bibliometric analysis. ISI indexes individual papers appearing in more than 6,000 journals in all disciplines drawn from all over the world.( see ISI Journal Abbreviation Index – Caltech Library System ) While this is a relatively small proportion of the estimated 50,000 journals being published, the coverage includes the most widely cited peer-reviewed journals, both national and international, and represents a very high proportion of scientific papers that are referred to by other publications.

**Methodology for the Bibliometric Analysis : Scientific Field Analysis**

For the purpose of this study and for future use by the Ministry of Science and Technology in other studies, a data set was purchased from ISI that included the following elements:

1) A full bibliographic listing (all authors, paper title, journal of publication with volume, initial page, and year) for all papers indexed in the ISI databases from 1981 to 1996 a total of 70,258 publications;
2) All address information appearing with the publication, which ISI includes in its databases;
3) A scientific (sub) field classification for each article based on a system devised by ISI and based on the journal of publication;
4) Records of all citations to each Brazilian paper in the database by year of the citation;
5) Records of expected number of citations to each Brazilian

paper, calculated by ISI on the basis of the average number of citations to papers in the journal of publication during a given year.

Additional data was acquired from ISI in the form of its deluxe version of National Science Indicators on Diskette, 1981-1996. This version includes international data on the sub-fields used to classify the Brazilian articles, making it possible to develop comparative analyses. Searches of the Brazil database were done for researchers funded in each of the six PADCT Sub-Programs mentioned previously matching the ISI-formatted version of the MCT`s input names against the all-author table in the ISI Brazil database. An estimate of the prospective error rate derived from the implementation of the methodology described was considered to be on the order of 10 percent or less.

The scientific field analysis compared the productivity and impact of three groups of researchers by field. PADCT-funded researchers comprise the primary group. The complete set of publications of all six fields of researchers funded by the program was combined into a single file, which was then sorted into individual scientific fields as classified by ISI. These field classifications are based on the journal in which the paper was published, and it is possible for a paper to appear in more than one field if ISI places the journal in more than one category. The file was restricted to papers that ISI classifies as Articles (normal research papers), Reviews (extended review articles), and Proceedings (self explanatory), eliminating things such as book reviews, notes, and letters-to-the-editor because the ISI journal impact factors are based only on the first three types of publications. Since the researchers funded by PADCT published in a variety of ISI-defined fields (e.g., chemists published in polymer chemistry, catalysis, physical chemistry, etc), this provided a mixed set of PADCT fields within each ISI-defined field. Publications by PADCT-funded researchers appeared in more than sixty of the ISI-defined (sub) fields[1] of science. For roughly the forty most significant fields (in terms of cited papers), as well as a few smaller fields closely related to PADCT program themes, data was compiled from an analysis produced by both the ISI Xcite and National Science Indicators on Diskette programs that provide a rolling five-year window showing the impact of a collection of papers. The collections used were PADCT researchers, Brazilian researchers overall, and world researchers in each of the fields. The results were tabulated in spreadsheet format and used to generate composite comparative. Twenty one of the ISI defined fields account for more than eighty percent of the total number of publications produced by PADCT funded researchers. Arbitrarily it was conceived that fields were PADCT scientists published the most, were the ones were the impact consequences of the program could be mostly relevant nationally. Among all the fields 19 accumulated at least 100 cited publications and 32 accumulated at least 40 cited publications during the period analyzed. Five year window Figures corresponding to the Citation/Paper of PADCT II funded researchers, Brazil and the World in 18 fields are shown in the proper section of this article to illustrated the methodology.

The nineteen mentioned fields which correspond to 82 % of the citation were investigated further by comparing the Brazil overall citations in these fields to seven selected countries: Spain, Peoples Republic of China, India, South Korea, Mexico, Argentina, and Egypt arbitrarily chosen. The selection included countries of the so called emergent economies and Spain to have a reference of a developed country. In addition all the countries selected have either economic or social similarities with the Brazilian developmental process. South Korea , India and Peoples Republic of China are Asian countries experiencing acute transformations in recent decades with success in many respects but also with similar difficulties being faced by Brazil. India has a long tradition in scientific research and is capitalizing this experience to promote technological development although under the pressure of enormous social problems. Argentina and Mexico are two of the most important Latin American economies going through a parallel developmental process particularly Mexico which recently surpassed Brazil economically if the NGP is considered as a

parameter; although both countries bear strong similarities in terms of difficulties to compete internationally. Egypt and Brazil have similar vocations particularly in the agribusiness area. Spain represents the G7 countries and is the best reference to be looked upon in terms of Sc&T for Innovation. The experience of Spain is of paramount importance for countries like Brazil to set goals that can be reached on a medium term basis.The nineteen fields allowed a classification in six more general areas :

**Physics** - (Material Sciences and Engineering, Applied Physics ,Spectroscopy, Instrumentation and Analytical Sciences)
**Chemistry** - (Analytical Chemistry, Physical Chemistry/Chemical Physics, Inorganic and Nuclear Chemistry, Organic Chemistry and Polymer Sciences, Biochemistry and Biochemistry)
**Medical Research** - (General Topics, Pharmacology & Toxicology)
**Earth Science** - (Environment Ecology)
**Biology** - (Molecular Biology and Genetics, Microbiology)
**Agriculture** - (Animal & Plant Sciences, Agricultural Sciences)

This comparison of course cannot be related to the previous one since Citations / Paper is a measure of quality and Total Citations compares in this case countries which have much different critical masses of scientists working in the different fields considered. The objective was essentially to verify the overall quality trend of the scientific outputs in the Country for the related areas previously analyzed and refer it to the performance of other countries.

## Results

Of 49 fields for which Figures were produced, ( Figures 4 to 21 corresponding to the Citation/Paper of PADCT II funded researchers, Brazil and the World in 18 fields are shown in this Article ), a remarkable 44 show an up-trend in the final three to five years. Many show an up trend over a longer period, but there are oscillations and down periods in others. There are 25 fields in which the PADCT-funded researchers' papers consistently have a higher impact than papers in the field from Brazil overall for the entire sixteen year period, while seven are consistently higher in impact than the world overall in the field. Four are higher than both Brazil and the world — Electrical and Electronics Engineering, Instrumentation/Measurement, Metallurgy, and Optics/ Acoustics. In general, the data suggest that the performance of PADCT funded researchers is of generally high quality in the Brazilian context and that the support generally increased the impact and visibility of their work in the international context. When compared to the World however, only six out the seventeen fields shown exhibit the mentioned behavior: Chemistry, Earth Science, Environmental Ecology, Inorganic and Nuclear Chemistry, Material Science and Physics. There are fields however where the presence of PADCT is modest, (considering the number of cited papers < 50), but the performance is extremely positive, being consistently above the World`s performance, such as: Electrical and Electronics Engineering, Entomology, Instrumentation/Measurement, Optics and Acoustic ( data not shown) . It is not assessed in this article whether the modest presence of PADCT II in these successful fields result from a small critical mass of scientists involved in the field or rather because just the very best ones are funded by the program, or both.

The next section that includes comparative Total Citation Figures for the eight previously mentioned countries, (Figures 22 to 39 ). Amongst all mentioned areas **Physics** shows the best relative performance. The total citations in Physics for the most recent five year period considered corresponds to more the 10 % of the total citations of the country overall. Brazil lags behind Spain, India and Peoples Republic of China in Physics and all related fields mentioned, and is a close fourth to South Korea in the areas of Spectroscopy, Instrumentation, Analytical Sciences Applied Physics and Material Sciences.

**Medical Research** is the second best relative performance, (close to 5000 citations in the sub-fields considered). Brazil is second to Spain and way above all the other countries in the mentioned field and also second to Spain in the related areas of Pharmacology and Toxicology practically with the same number of citations as India and Peoples Republic of China. **Chemistry** included many sub-fields. Among them the best performance of Brazil is in the area of Biochemistry and Biophysics, third to Spain and India. In the related area of Physical Chemistry/Chemical Physics Brazil lags behind Spain, India and Peoples Republic of China and very close to South Korea. In the other related sub –fields the performance of Brazil is less relevant. In the Area of **Biology** although the number of citations is smaller than the three previously mentioned areas, the relative position of Brazil compared to the other countries in the sub–fields considered is very positive: second to Spain in Molecular Biology & Genetics, (critical areas for Biotechnology) and third to Spain and India in Microbiology with a number of citation very close to India in the last five year period (1992-1996). The relative performance of Brazil compared to the other countries in **Earth Science** and related fields is similar to that of Biology although the number of citations is smaller than that of Biology: Third to Spain and India in Environment and Ecology, (very close to South Korea and Peoples Republic of China), and fourth to Spain, India and Peoples Republic of China in Earth Science itself. Brazil lags behind Spain, China and India in **Agriculture** related sub-fields.

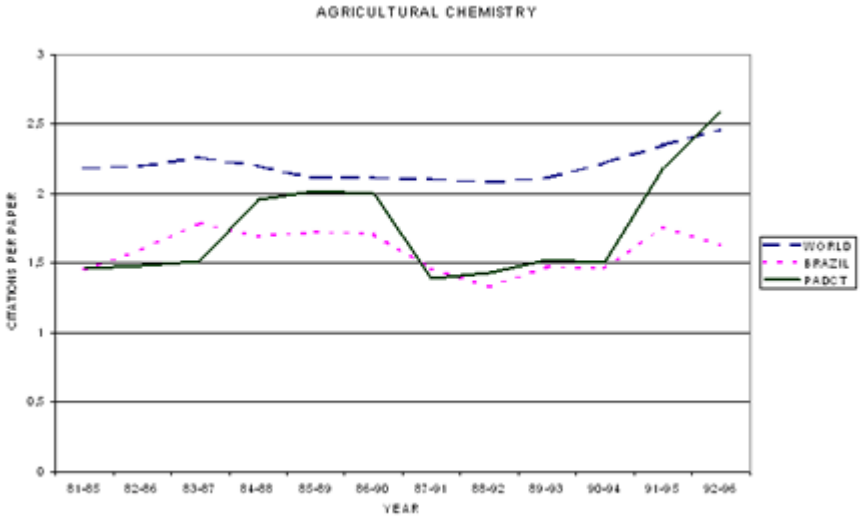



**Figure 4**

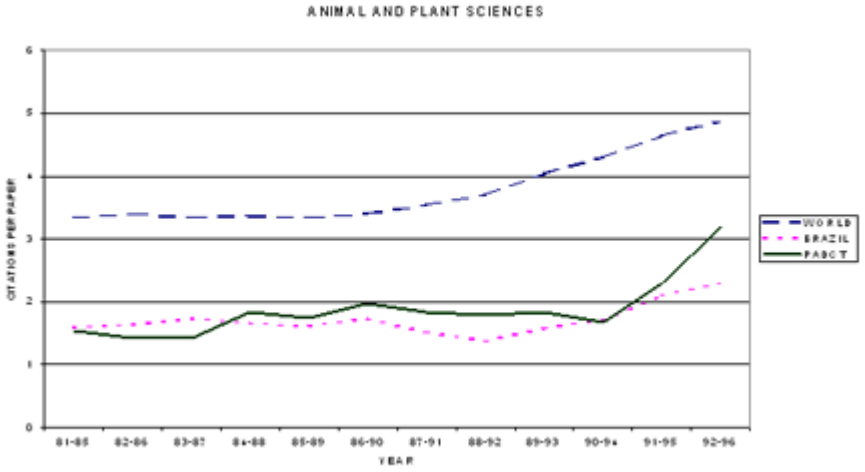



**Figure 5**

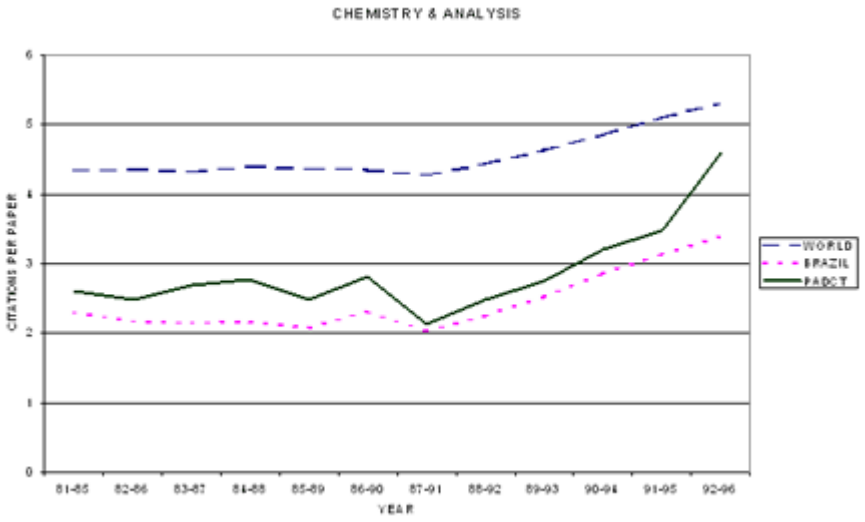



**Figure 6**

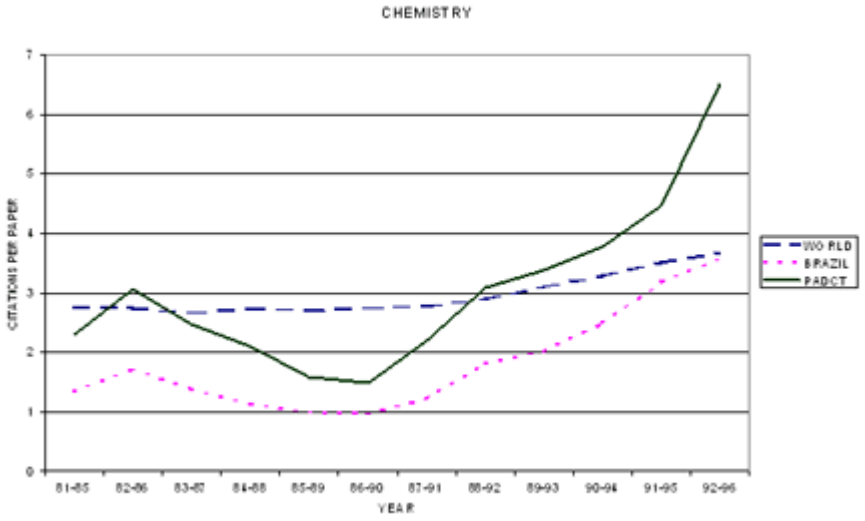
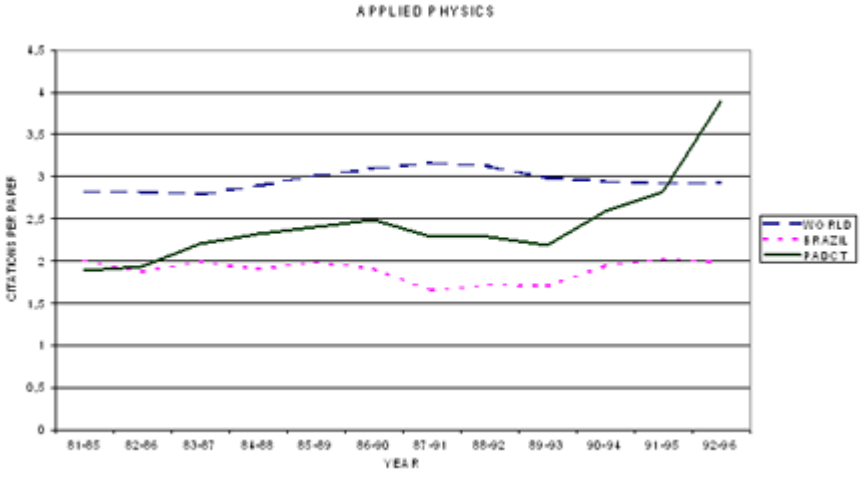



**Figure 7**

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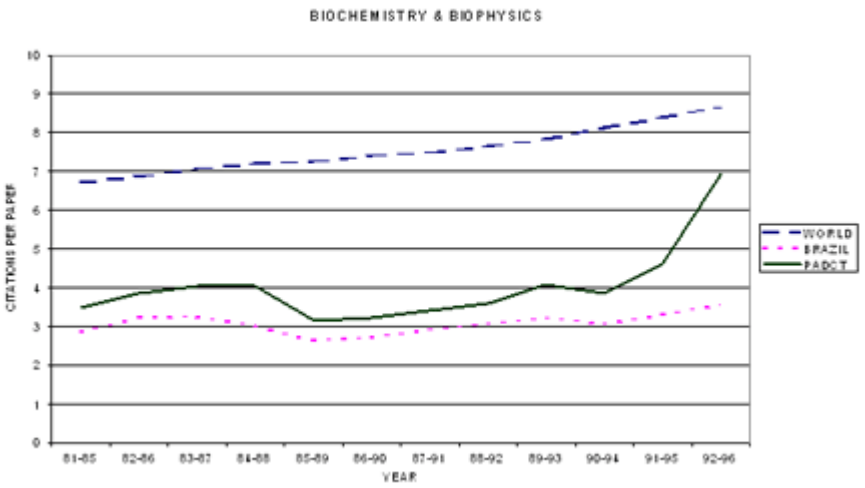


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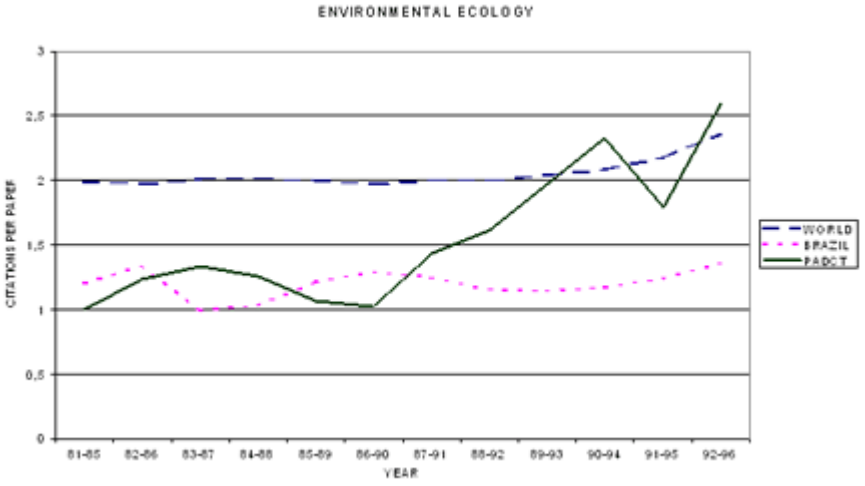


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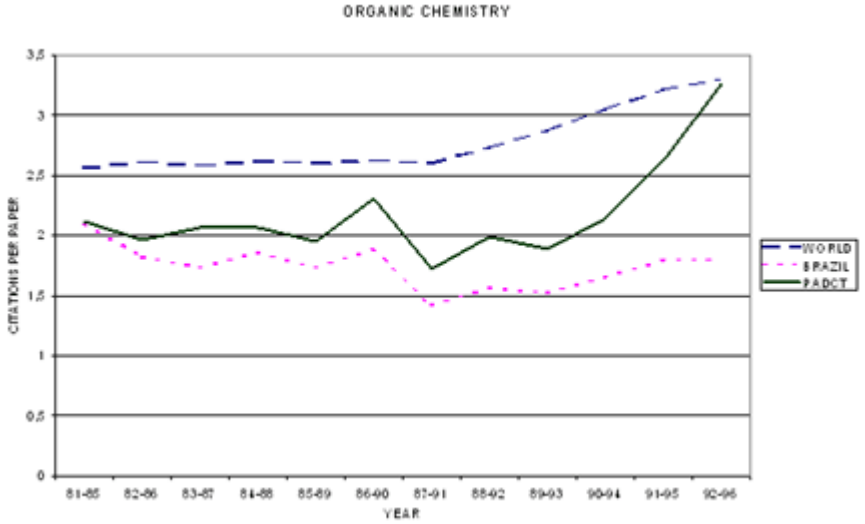


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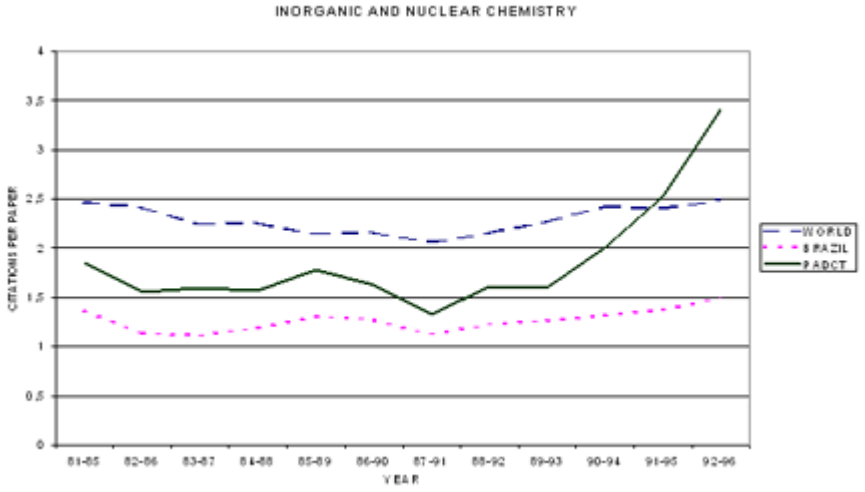


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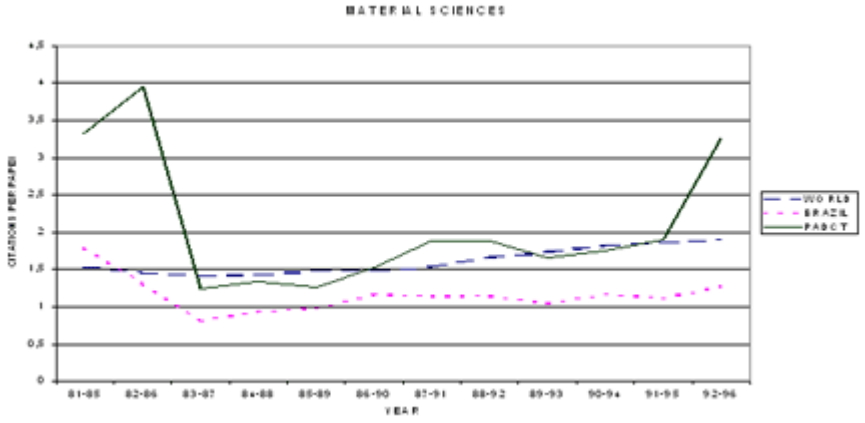


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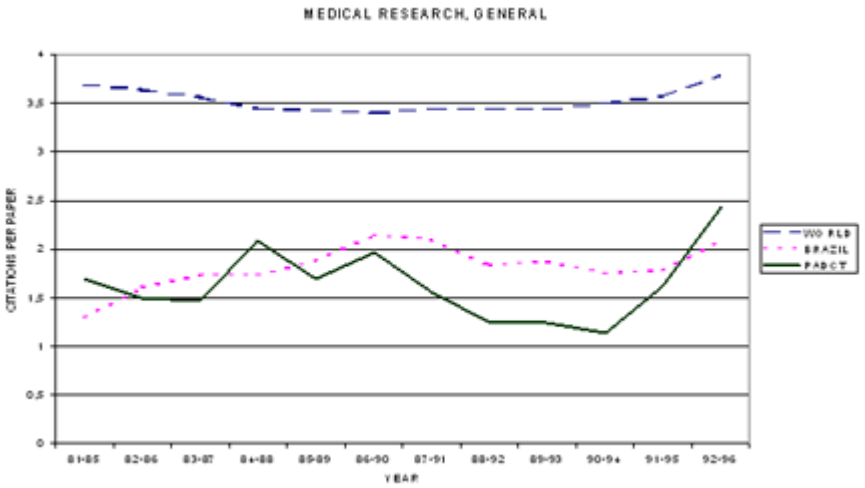


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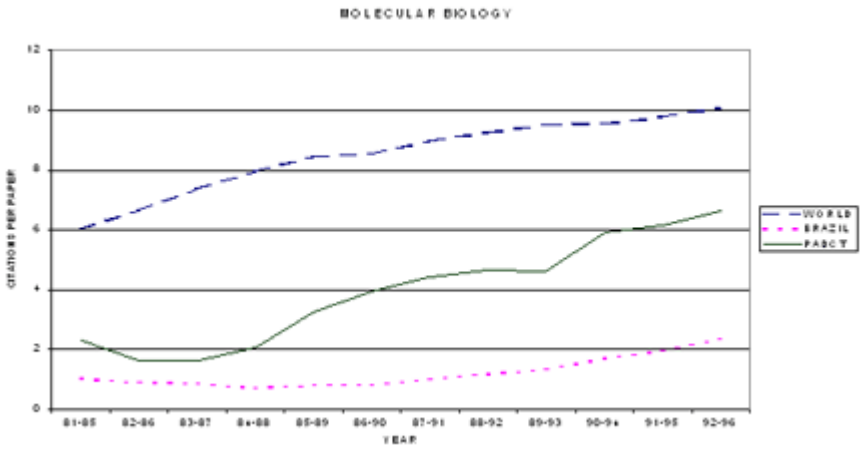


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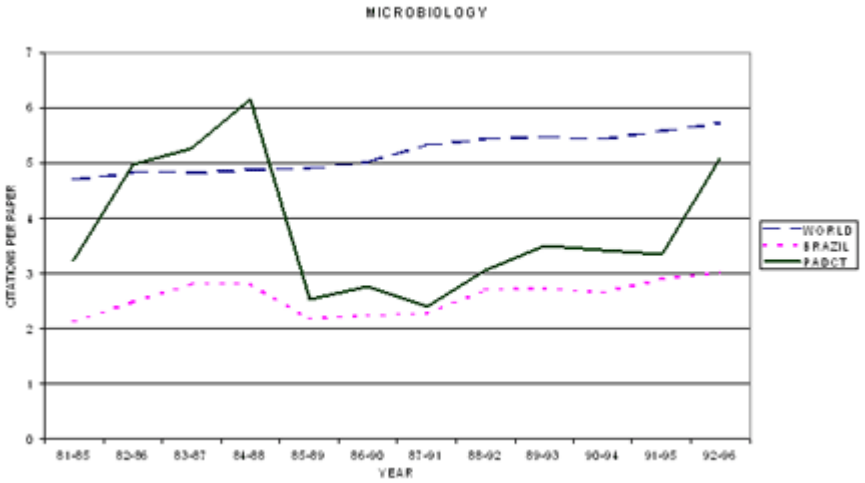


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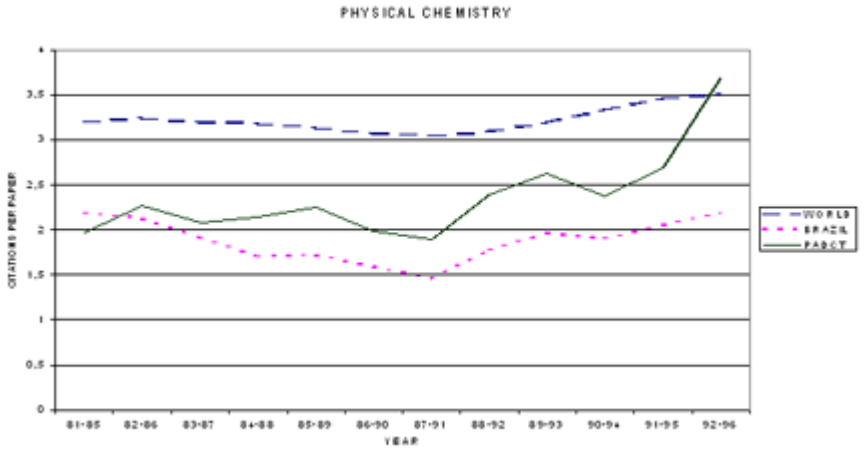


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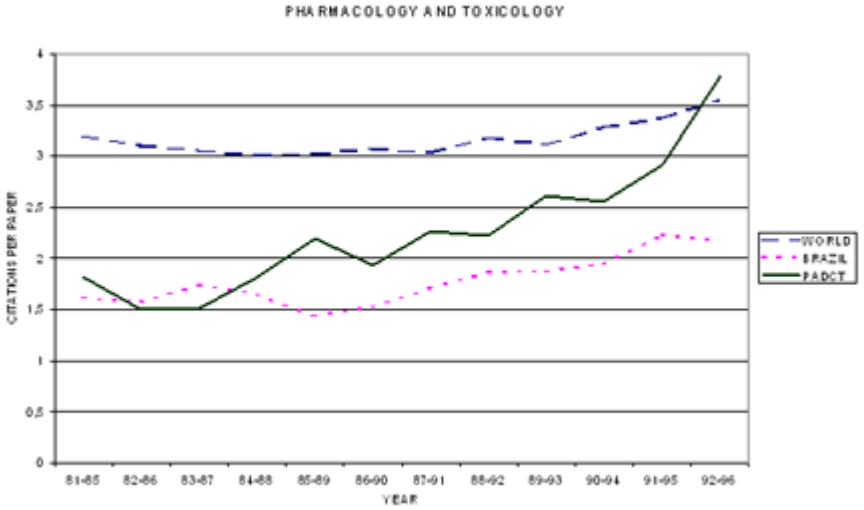


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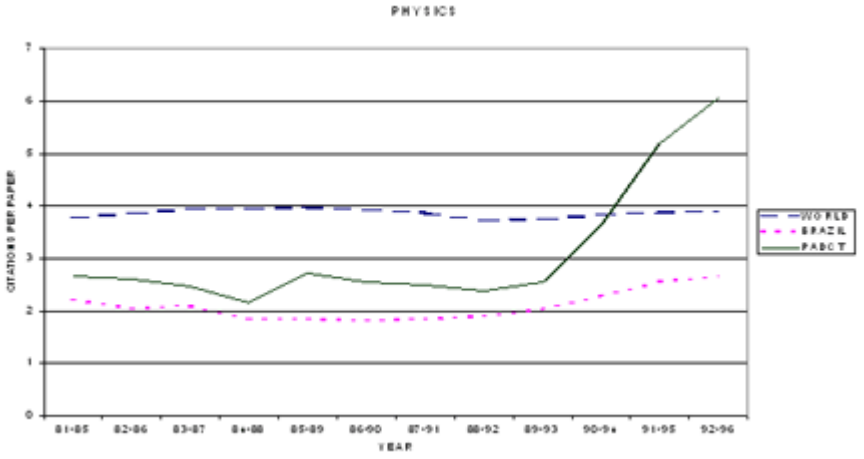


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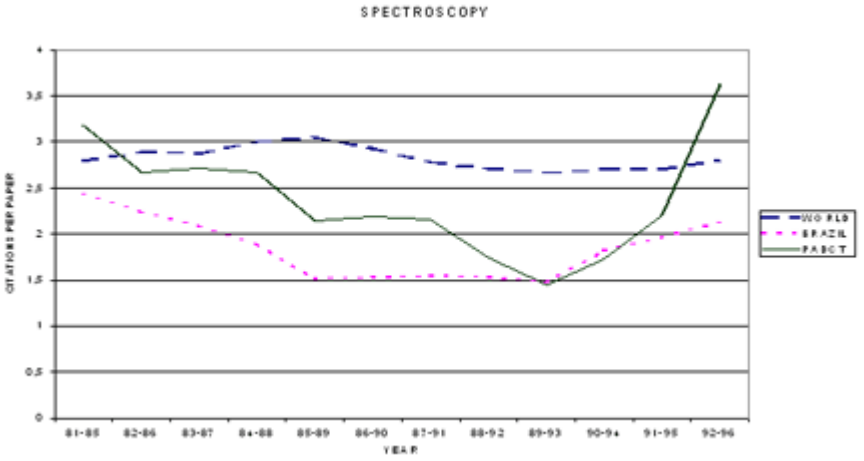


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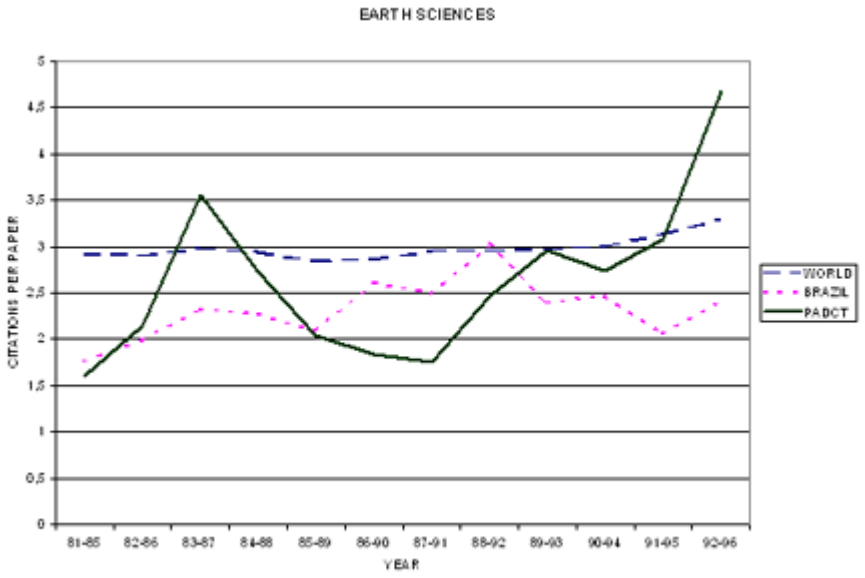


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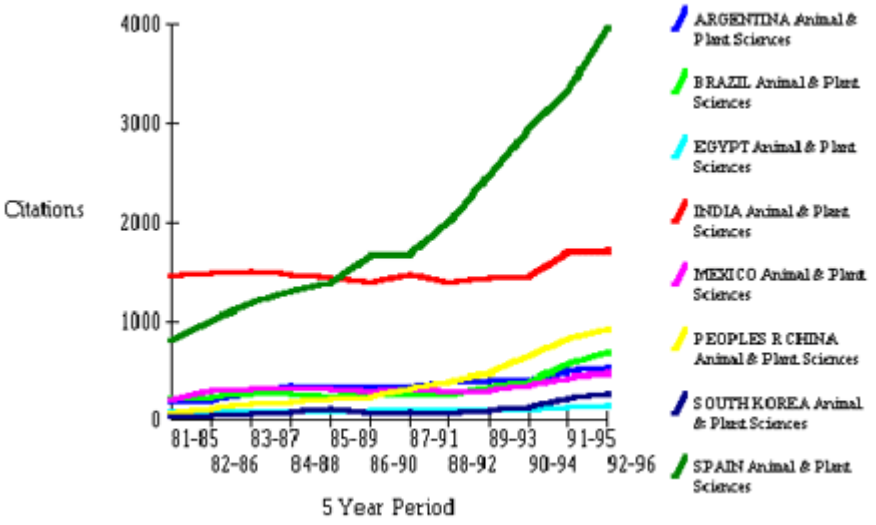


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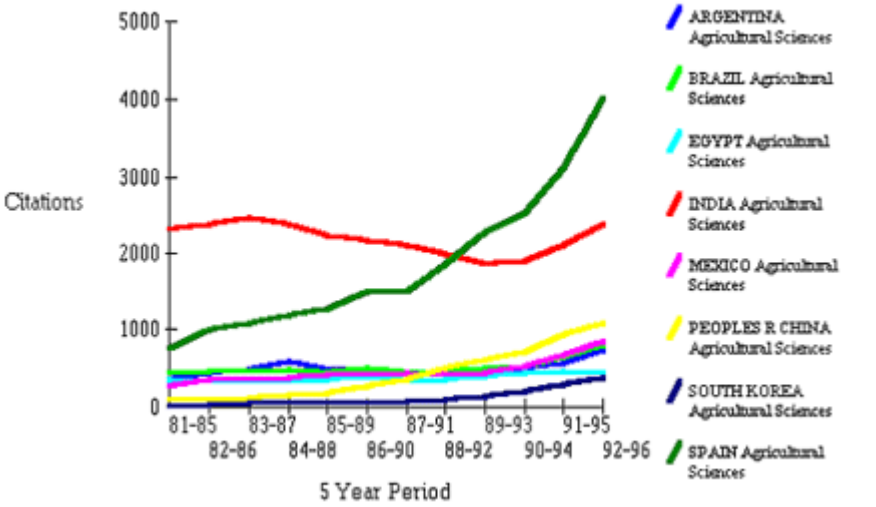

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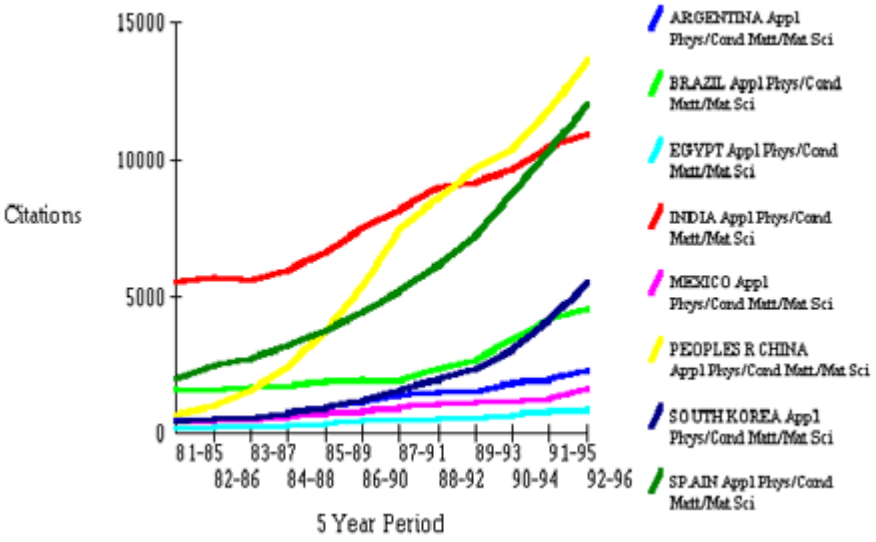


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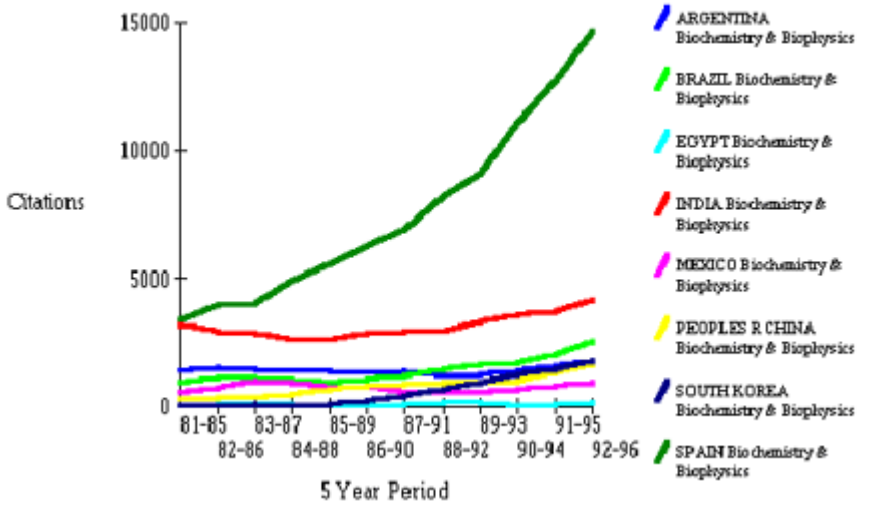


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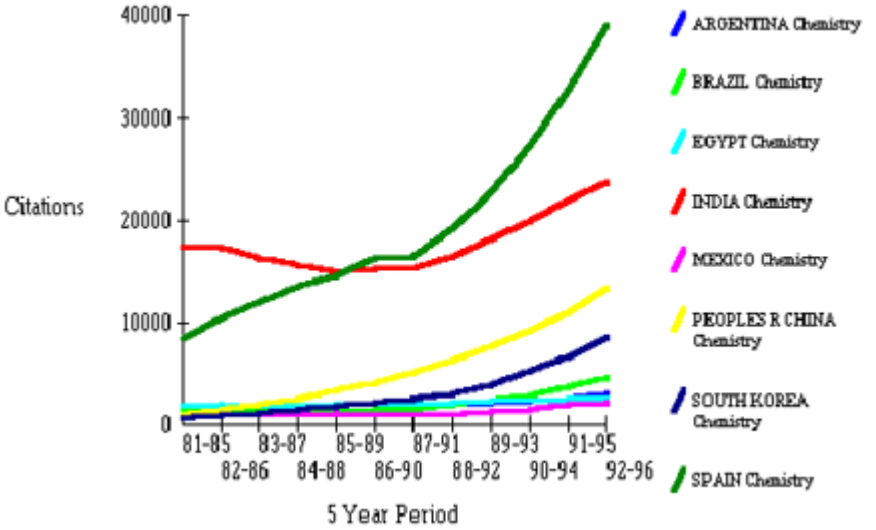

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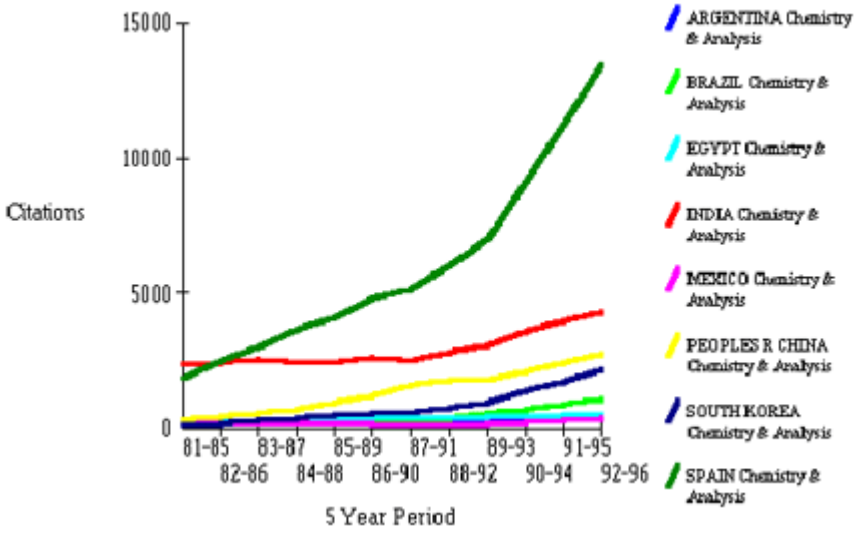


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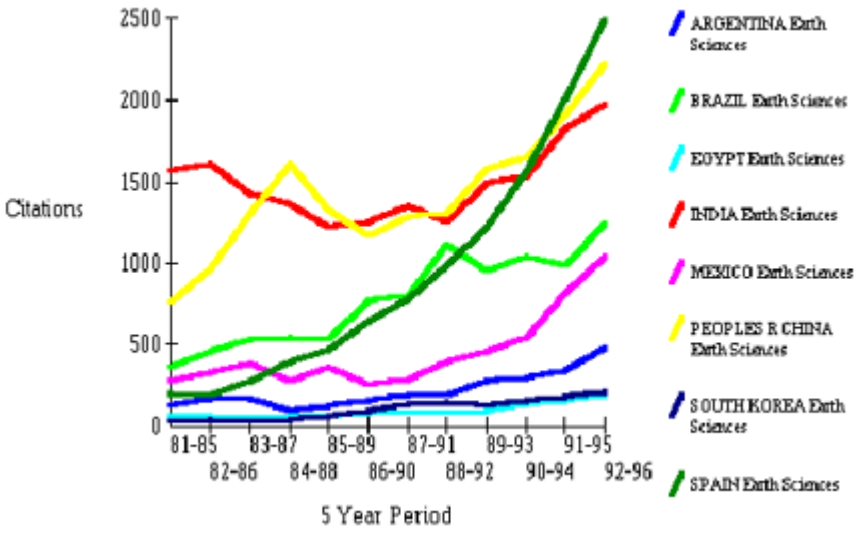


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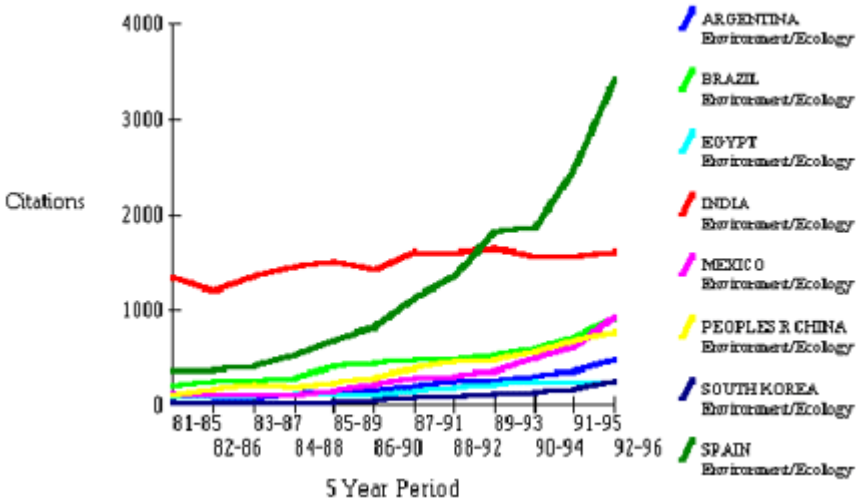

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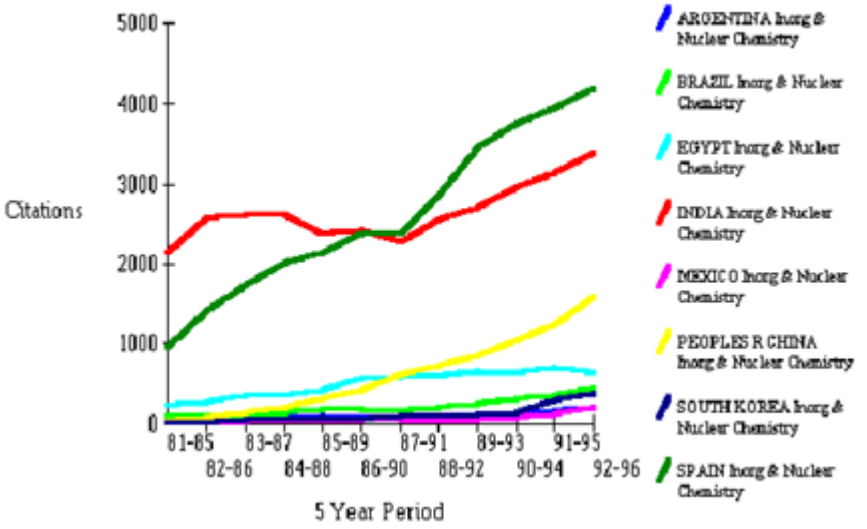


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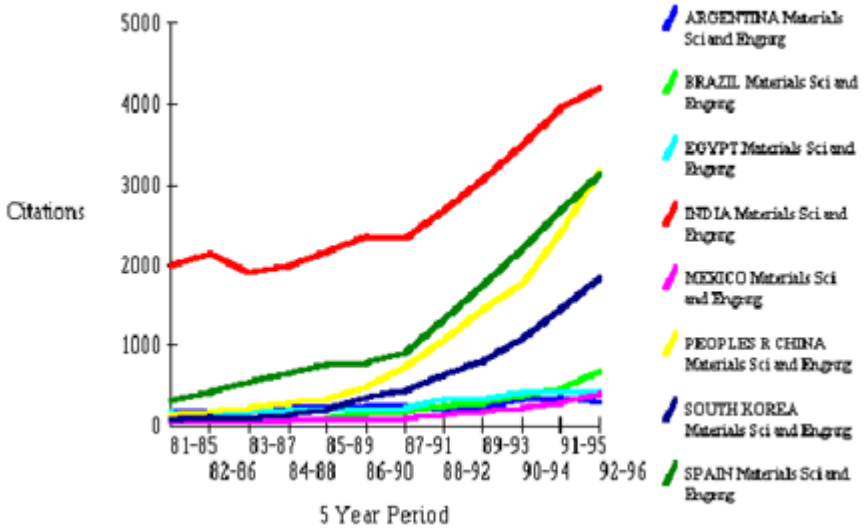


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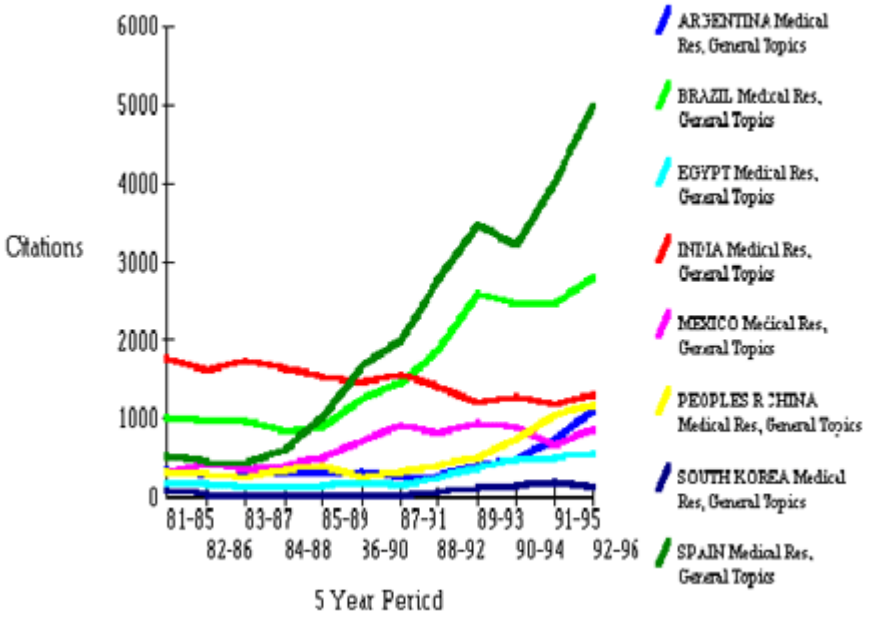


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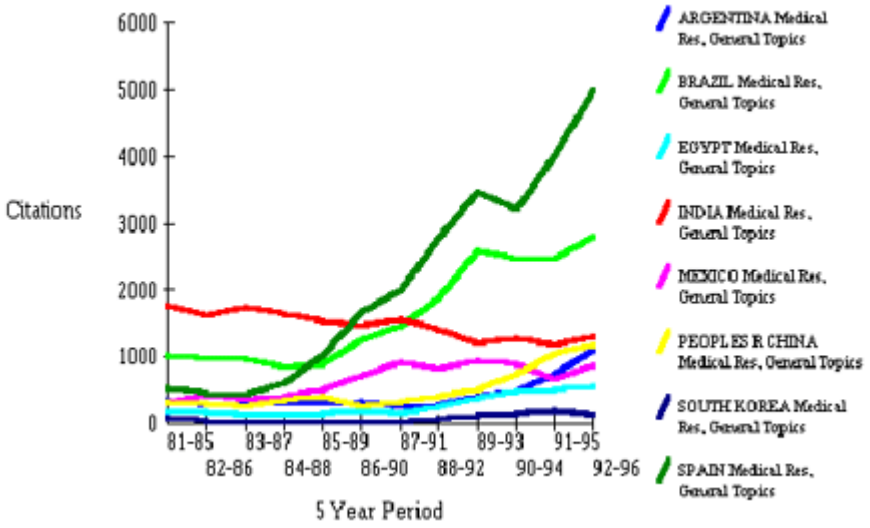


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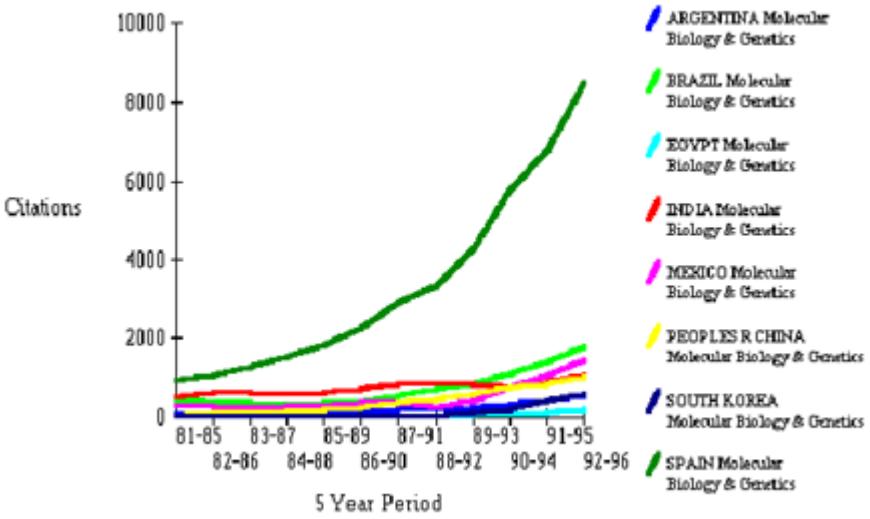

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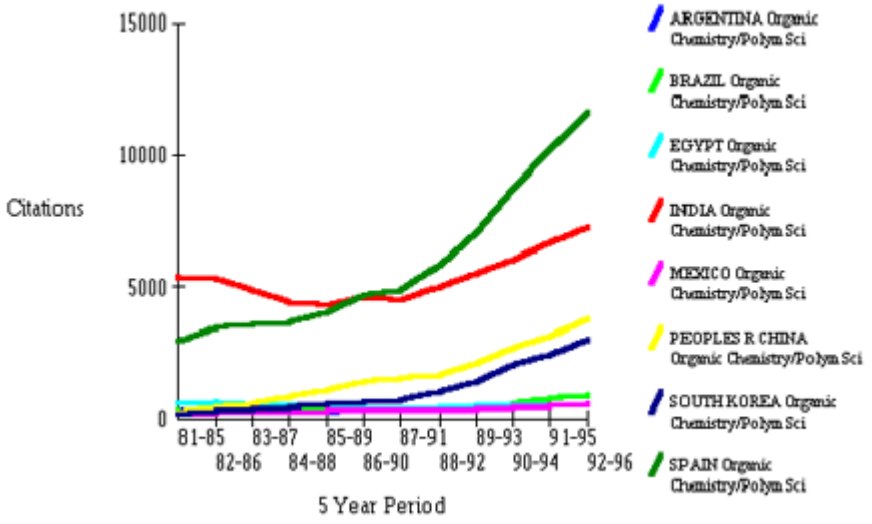


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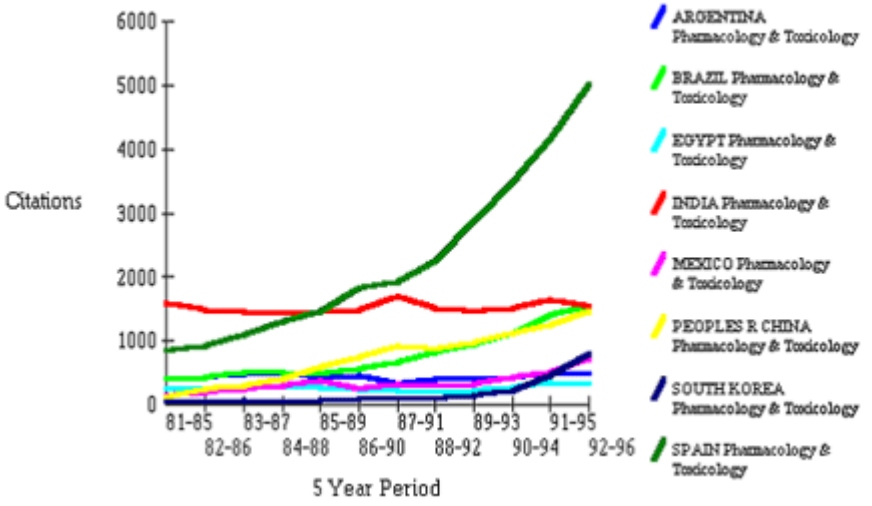


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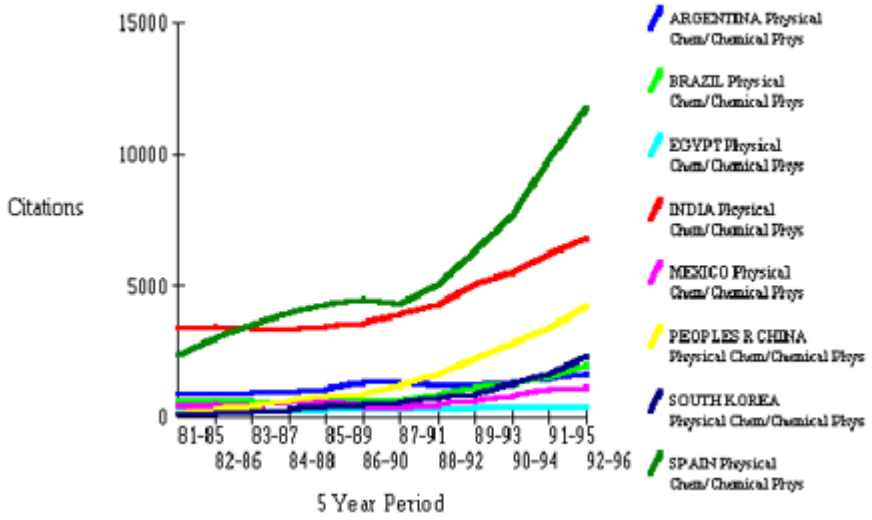


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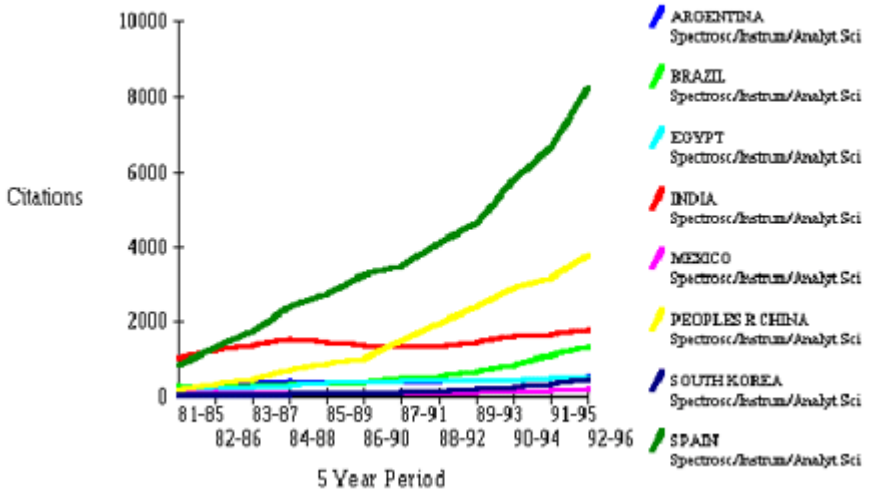


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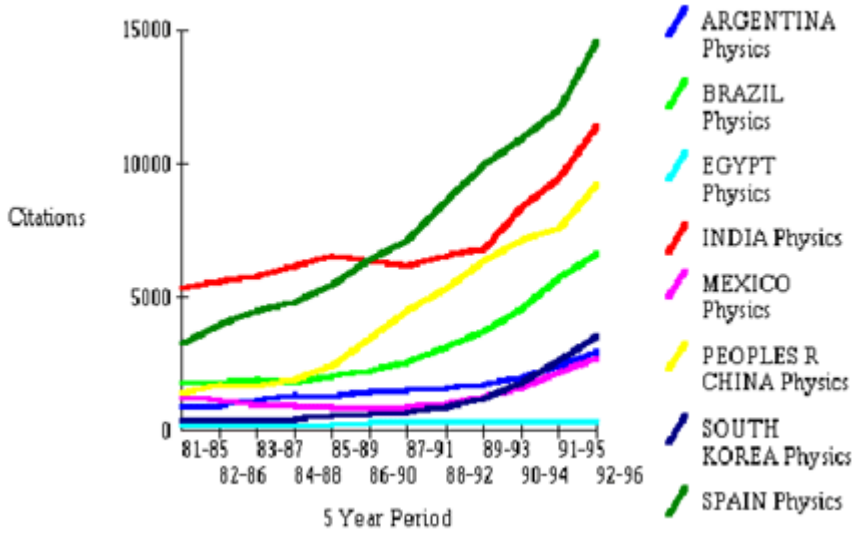


**Figure 39**

## Discussion

### The PADCT Program in Brazil

The purpose of this article is to show a scientometric evaluation of the outputs of PADCT II . During its exercise strict peer evaluation, a common procedure in most developed countries, almost completely eliminated conflicts of interest and was a key instrument to fund projects. Nowadays, except by the State Foundations , particularly FAPESP in the State of São Paulo this instrument encounters difficulties to be exercised by Federal Programs, and often the same problem is faced by other developing countries. ( See also External Evaluation of Project - WB Loan 4572 –VE, Scientific Millennium Initiative ( PICM ) Progress Report , Caracas April ,2004 External Evaluators : Claudio Wernli , Luiz Antonio Barreto de Castro and Norma Nuñez). It is demonstrated in this Article that positive consequences for the quality of science result from the exercise of this instrument. PADCT II was designed in Brazil as an ambitious program whose main objectives were to strengthen human resource development in specific scientific areas through support for science research and graduate training. The program also aimed to improve management and decision-making processes which were established under its previous version, through open competition for funding of research grants, strengthening

transparency, optimizing peer review in the allocation of these financial resources, for greater continuity and integration in the financing of research projects. Other objectives were to improve infrastructure support and equipment needed for high quality research, inter-Agency cooperation and interaction between these government agencies and the scientific community, and to modernize management of Brazilian S&T. The program objectives were to be achieved through competitive grants for research and training in six thematic research areas considered as sub-programs : Biotechnology - SBIO, Chemisty and Chemical Engineering - QEQ - Geology and Mineral Technology-GTM, Instrumentation-SINST, New Materials- SNM and Environmental Sciences - CIAMB ; and six support or horizontal sub-programs in areas of: Science Education-SPEC, Science Planning and Management-PGCT, Metrology and Basic Industrial Technology-TIB, Science Technology Information-ICT, Provision of Consumables-SPIN, and Maintenance of Scientific Equipment-SPM. The project was also to help increase public understanding of issues affecting the management of the publicly supported system of scientific research and the environment for technological innovation in the private sector, by supporting the preparation of two studies on science and technology policies and on issues related to the international competitiveness of the Brazilian industry.

One of the evidences shown in this Article is upward trend of scientific performance by scientists funded by PADCT II compared to the positive overall performance of Brazil previously described. We postulate that the strong competition introduced by the rigorous peer review system of PADCT II may have stimulated the general scientific quality of the groups competing for funds, as to be responsible for the better scientific outputs in fields were PADCT was mostly influential. We support this point of view by the fact the PADCT II funded only 18 % of the projects submitted by the groups registered at the National Council of Research Groups Directory Database, (see Project Implementation Plan/Table 7 page 31 and See also SAR /PADCT III World Bank Loan Agreement 4268 –Br and ICR Implementation Completion Report of PADCT II - Appendix A , Borrowers Report WB Loan 3269 –BR for details).The relation between PADCT funded researchers and Country performance is extremely indirect and it is not the purpose of this paper to infer that areas where PADCT funded researchers where successful influenced successful country performances. However it is evident that in all Chemistry and Physics related areas where an upward output performance of PADCT funded researchers can be seen, the same upward country trend was observed . When the slope of the curve representing PADCT funded researchers exceeds by far that of the country, this can merely mean that the best scientists where funded which is a positive indication of project management. There is not however a down ward country tendency in areas where the PADCT trend was upward meaning that PADCT was relevant for country performance and perhaps indicating that if the magnitude of the investments by the program were higher the slope of the country curve would follow close that of PADCT funded researchers; which would signify that all the very best scientists were being funded by the program.

Citations per paper is generally accepted as a parameter to measure scientific quality. The method presented in this paper measures the scientific quality outputs of discrete populations of scientists. These population can be scientists from a given institution or from a given department within an institution or from a funded program such was the case study here or from a specific state within a country. The method requires essentially a reliable data base were this discrete population of funded scientists is gathered. Once it is available it can and should be used on a long term basis. In Brazil these WEB databases fortunately are available now. One can follow the presence and performance of researchers and research groups in these data bases. The WEB databases are essential in the process of understanding trends derived from this methodology since from them the scientific output of the researchers in specific areas is obtained by means of assessing the National Scientific Indicators Database available world wide. Other developing countries where these databases are not organized must move in the same

direction to be able to evaluate science in a long term base. It is not expensive to sustain a long term evaluation of scientific outputs using this method which in addition preserves a high degree of confidentiality treating performances by scientific areas although conveying data from individuals to assemble the performance of these areas. For developing countries it is essential to verify if limited funding applied to science, results in scientific performances in specific areas comparable to other countries, at least of the same level of development of their own. Additionally this method provides elements for analysis as to indicate why certain areas do not respond to scientific investments or perform comparatively better than others, given the same level of funding support.

Investments made by developing countries for the development of their S&T sectors must be evaluated. This is not exercised by many developing countries, which in addition are often unable to keep consistent data on science and technology on a long term basis. This context weakens the position of the scientific academies, often empty handed, when the time to present the necessary demands of science to the highest decision making level bodies in the Country is offered.

## Conclusions

Scientific Indicators data presented in this article show that Brazil increased significantly its overall performance in science during the last fifteen years, as measured by all indicators considered. The main purpose of this Article was to show a scientometric evaluation of PADCT II . We hopefully demonstrated in this Article that scientists funded by PADCT II, achieved high levels of scientific performance, during the period of 1992 – 1996, compared to previous periods when funds of PADCT were not available particularly for some areas as New Materials . This method can be applied to qualitatively evaluate scientific outputs of programs and institutions, and will be useful particularly for developing countries for all the reasons mentioned previously. To yield the needed outputs the method must be applied on a long term basis.

## Acknowledgments

I want to acknowledge the work performed by H. Robert Coward then at the SRI International whom as a consultant for the Brazilian Government produced an unpublished Report on PADCT for the Ministry of Science and Technology and that of Roland Bardon who exercised the methodology at the ISI Databank.

## Notes

1. The regular version of ISI's National Science Indicators on Diskette is limited to data on major fields or disciplines of science, while the deluxe version breaks these down into sub -fields. For convenience, we will refer to the sub - fields analyzed here generically as fields.

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