SCIENTOMETRIC INDICATORS AS A MEANS TO ASSESS THE PERFORMANCE OF STATE SUPPORTED UNIVERSITIES IN DEVELOPING COUNTRIES: THE CHILEAN CASE

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ABSTRACT

Chilean universities are responsible for more than 80% of the science produced in the country, which in the last 20 years with some periods of great difficulties, has grown more than 600%. One of the underlying problems of the governments of developing countries to delineate suitable strategies to allocate efficiently the few funds available, has been the absence of clarity to distinguish the individuals and centers committed with competitive scientific research. As a consequence, the scarce state funds, do not always reach to the right people and to the right places, amplifying the already existing problems for the good scientists that resist to emigrate. To evaluate the corresponding situation in Chile, and to follow the results of substantial actions to support the scientific activity in the country, we have examined the performance of state financed universities.

RESUME

Les universités chiliennes fournissent plus de 80% de la production scientifique du pays, laquelle a augmenté de plus de 600% durant les 20 dernières années, et cela malgré quelques périodes de grandes difficultés. Un des problèmes que rencontrent les gouvernements des pays en développement pour déterminer une stratégie pertinente d'attribution de leurs quelques fonds disponibles, réside dans l'absence de discernement entre le soutien à apporter aux individus et aux centres qui sont engagés de façon concurrentielle dans la recherche. En conséquence, les financements publics, qui par ailleurs sont rares, n'atteignent ni les personnes ni les lieux qu'il faudrait, renforçant ainsi les problèmes des bons scientifiques qui résistent aux tentations de l'émigration. Afin d'évaluer cette situation au Chili et pour suivre les résultats des actions substantielles menées pour soutenir l'activité scientifique dans le pays, nous avons examiné les performances des universités financées par l'Etat.

INTRODUCTION

With about 8% of the population of the world, the Latin American and Caribbean region hardly contributes with 1.3% of the world's total output of mainstream publications (1,2). As in most developing countries, the region's scientific research is being performed mainly within the framework of universities. Thus, in addition to the intrinsic responsibilities which characterizes higher education and in which original scientific research plays an important role, in general, the universities in Latin America and the Caribbean, provide the main source from which local and not imported knowledge is produced to nourish the society needs and the development of the country.

The higher education scenery of the region is very heterogeneous. The same is true within each country. A peculiar feature in Latin America is that the faculty engaged in active research determine in a high degree the true possibilities of stable and competitive country progress. This is not the case in industrialized countries where universities share this obligation from a primary academic perspective. The reality is not the result of explicit policies. In a way, it has been generated as the result of the absence of adequate policies, matter that deserves further comments. However, the fact that scientific research appears as one of the most valued constituents of contemporary university life in many Latin American countries, responds to important debates and definitions which took place in the sixties.

The search for an identity involving conceptions of social mobility, democratization and capacity to answer to the requirements of the productive apparatus which slowly underwent a trend towards modernization, strengthens the needs for special efforts to train professionals with profound scientific knowledge and capacity to solve the problems of underdevelopment and dependence (3).

During the last three decades higher education in Latin America experienced an immeasurable growth regarding student population, number and kind of institutions involved, and faculty (4). While in 1960 the number of students in the region was 630,000, in 1970 it reached 1.5 million and grew to 5 million by 1980 (4). Furthermore faculty involved in higher education in Latin America comprised in 1965 about 100,000 persons and 600,000 in 1980 (4). The explosive growth of the higher educational system occurred, in general, under precarious economical and political situation which determined in part, that the universities instead of being a model for society, turned into a mirror of the current turmoils.

Chile was not an exception on this rather peculiar kind of growth. Enrollment in universities rose from 24,000 in 1960 to 39,000 in 1984 (4). In the late sixties, graduate programs at Ph.D.'s level began to be offered, but it was not until the eighties that programs towards M.Sc.and Ph.D. degrees covered many areas and reached higher standards with an increasing number of students. From 1981 to 1984 the number of graduate students doubled to 2800 (5). These

programs expressed the existing research capacity and the will to proceed with a formal fourth cycle to prepare the scientists that the country needs.

As a consequence of new laws regarding higher education in Chile, the number of state supported universities grew from 8 to 20. In fact, the new universities were derived from campuses of mainly two big state universities. In addition, new truly private (without direct financing from the state) universities were founded. The latter, although to soon to judge, have shown to be teaching oriented and in general, with no interest towards competitive research.

In Chile, from 1965 to 1970, the state invested in higher education about 1% of the GNP; the fiscal support to universities increased to 2% by 1974 and then gradually diminished to 0.87% of the GNP (6). As stated by Sanfuentes (6) some signs revealed that the incidence of the state expenditure in universities would not recover the levels attained between 1971-1974, and that scantily could be maintained around 1% of the GNP. According to Lavados and Lemaitre (7), the restriction emerged when the priority criteria were changed at the time that it started to be corroborated that the expectancies associated to the development of the higher education sector were exaggerated and unrealistic.

The strengthening of scientific research in Chilean universities began almost concurrently with the rapid growth that these institutions experienced. Also with movements involving both students and faculty members who searching for clearer social commitments and in-house democracy, distracted the universities from their primary functions. Excessive ideologization ended with intervention which, --when concluded--, returned the university government to its own members. Time will tell if the identity crisis which denatured the leading role of universities, --as truly intellectual and hierarchical organizations encompassing the integral progress of the society--, will be overcome. One could say that the main current problem of universities is that they are running behind the times.

Examining the many perturbations, --whether originated in the campuses or outside them--, that lead to the present crisis of many universities in the region and in particular in Chile, is beyond the scope of this work and requires a profound study. Nevertheless, there is in Chile a consensus with respect to the preeminent role that these institutions play in the cultural, productive and social processes. Thus both, government and universities have been and are searching ways to define policies to allocate the funds within the frame of the responsibilities that the state has to undertake and, to assure an in-house autonomous and functional organization, to efficiently respond to the demands of a modern society.

As mentioned before, the scientific capacity in Chile is to a large extent embodied in the state supported universities. Thus, their functional organization affects not only their performance with respect to their undergraduate and graduate programs, but also the most important scientific endeavour that the country has. In regard to this matter, it is not irrelevant to keep in mind that because in many countries of the region, the active scientific community is small and a stringent academic hierarchy does not exist, it is frequent that people find

(political) ways to anchor themselves in university positions from which they can influence on matters that require more intellectual competence than they can offer (2). According to Sagasti (8) the present situation suggests that during the next years the region will experiment a process of rapid obsolescence which will increase the gap between the productive and social needs. The lack of a sufficient highly qualified human resource seriously limits the progress of the region, especially in those countries where the university system is in crisis.

Developing countries have to deal with a variety of problems affecting the very basis of their development. When comprehension with respect to the role of science and technology exists, suitable and coherent policies to support research are established. When most of the research is performed in the state supported universities, as is the case in Chile, financing higher education becomes a matter of greater complexity. In this paper it is shown that scientometric indicators can contribute to delineate the performance of universities, and also to evaluate their efficiency and efficacy in the use of the public money they receive.

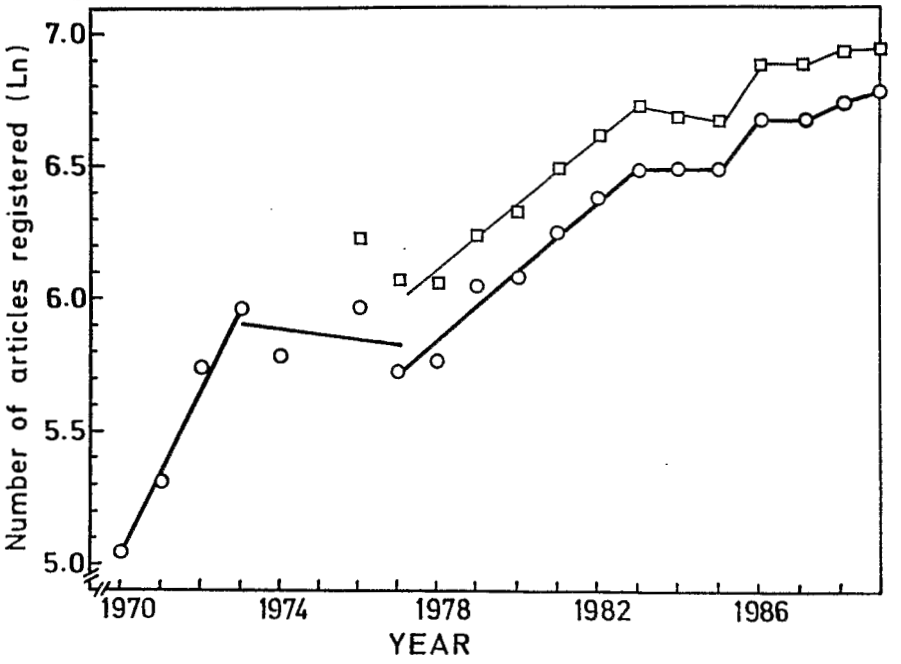
SCIENTIFIC OUTPUT IN CHILE

Scientific activity was studied quantifying the publications registered every year by the Institute for Scientific Information (ISI) and which identified Chile in their address (9-13). For the period 1970-1974 the information was obtained from the corresponding Corporate Index of the Science Citation Index. The articles registered in 1976 and 1977, were obtained through a Scisearch from ISI and the information starting in 1978 through ASCA, also from ISI. During the last few years a bank containing the full references and information regarding the field covered by the publication and the degree of collaborative work involved, is being constructed. Abstracts have not been considered as publications.

The dynamic of scientific output in Chile is shown in Figure 1. When the Ln of the number of mainstream papers registered per year is plotted, it is possible to draw linear regression lines and calculate the slopes representing average annual growth. It is also possible to obtain a plot with the changing trends through a period of time. Knowing turning points helps the analysis of a country's scientific performance specially in the Third World, where most of the time, a true political support towards scientific research does not exist. This means, that specific actions which favor scientific development rarely prevail and are subjected to changes together with government changes. Thus, the trends reveal discrete periods of time in which conditions affected positively or negatively the scientific activity.

It is difficult to ascertain the number of years that mediates between the time that research is executed and the date in which the corresponding publication is registered in the mainstream indexes. In Chile, a rough approximation is 3 to 4 years. This has to be taken into account to analyze patterns as the one of Figure 1. As seen, in spite of the unsteadiness of Chilean universities during the last

Figure n°1. Growth of the number of scientific articles in Chile



□ = total output
O = output corresponding to universities

decades, with the exception of a distinctive period of time, competitive research grew steadily. The fraction (around 85%) of mainstream papers originated in universities with respect to the total output, remains almost constant since its quantification began. Again, this feature is far for being trivial, because universities' performance determines the existing capacity of the country. The changing trends observed in Figure 1 can be correlated with well defined periods of time in contemporary Chilean history in that not only specific policies for scientific research can be clearly perceived, but also government changes and priorities, economical fluctuations and recession periods, and surely important, the government of universities and their permanent debate in search for an identity to satisfy the needs of a society in a developing country aspiring modernization.

Growth rates in numbers of publishing authors have been determined for Chile and for other Latin American countries (2) following Kowach's approach (14). The indicators comparing the decade examined by Kowach (14) and the following five years are shown in Table I. If the 1967-1976 decade is

reexamined in 2 periods of five years, during 1967 to 1971 growth rate was significant while from 1972 to 1976, the increment of scientific output stopped (15). The profile is consistent with that obtained when the number of articles were measured (Figure 1).

Table n°1. Growth rates in number of publishing scientists

	1967-1976a		1978-1982	
	Growth rate b	rc	Growth rate b	rc
Argentina	0,143	0,946	0,145	0,984
Brazil	0,211	0,986	0,136	0,985
Chile	0,131	0,860	0,267	0,987
Mexico	0,184	0,983	0,118	0,894
Venezuela	0,090	0,488	-0,007	-0,030

Growth rates in number of publishing scientists in Chile (periods of five years)		
1967-1971	1972-1976	1978-1982
0,257 b	-0,01 b	0,267 b

(a) Data from ref. 14; (b) Trend line slope, obtained from plots of the Ln of the number of publishing scientists per year. (c) Correlation coefficient. SOURCE. refs. 2,15.

The climate for science demands state financial investment. One of the big differences between industrialized and developing countries, is the percentage of GNP dedicated to scientific and technological research. If difficulties exist to calculate the exact percentage of the GNP utilized in each country each year, they grow when it comes to ascertain the efficiency with which the money has been used. This is particularly valid for developing countries where the exchange value of currency fluctuates notoriously.

It appears of interest to correlate the information attained with Figure and Table I and with the tendency of the investment in terms of percentage of GNP. Figure 2 shows investment of Chile in R&D according to Dellacasa & Güell (16). Despite the lack of knowledge of the many variables which determine research output, rationalizing resources is for policy makers one of the main targets in their strategies. In Chile this aspect encompasses the financial support to the state university system so as to assure the suitable resources to the faculty involved in competitive research. Thus, scientific output indicators for each university provide valuable information on the existing capacity, the efficiency with which the resources are used and the needs.

Figure n°2. Percentage of GNP invested in R&D in Chile (1965-87)

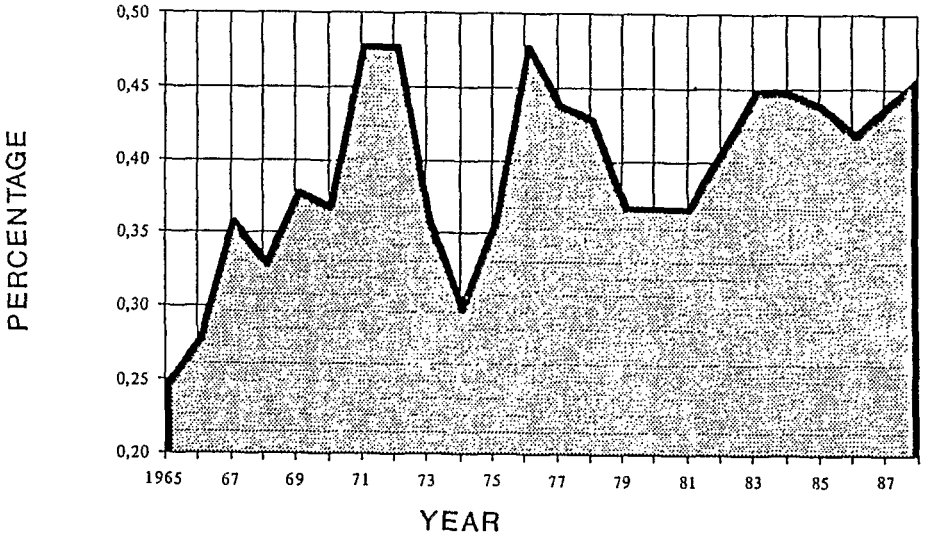


Table II shows the number of mainstream papers originated during the last 3 years in Chilean state supported universities. Clearly the scenario is highly heterogeneous. Furthermore, most of the research output corresponds to 4 of the 20 universities analized.

Because Third World countries are inadequately represented in the international databases, it is clear that the true scientific capacity of the country, and as derivative the one existing in each university, can not be inferred from the scientometric indicators used in this study. Articles from Journals not considered as mainstream, books, patents and royalties, research contracts, success in obtaining competitive grants and Ph.D.'s theses among others, have to be taken into account to delineate a more realistic picture of the available strength and productivity. In Latin America there are many good and competitive Journals which have not succeeded in their attempts to enter the mainstream literature. Needless to say, that in addition, there are also Journals which respond more to personal or institutional interests, and that do not warrant rigorous peer review and frequency of publication and also lack appropriate channels of distribution (17). This is also the case in Chile where efforts have been made to distill an editorial policy (17) to favor the publication of high quality Journals. The concern includes the scientific community and government agencies such as the Chilean Commission for Scientific and Technological Research (CONICYT) which in 1988 started to subsidize the 7 Journals indexed by ISI.

TABLE n°2. Number of mainstream papers published by chilean universities

UNIVERSITY	1987		1988		1989	
UCH	390	(49,9)	398	(45,6)	407	(46,3)
PUC	171	(21,9)	214	(24,4)	195	(22,2)
U.de C.	54	(6,9)	69	(7,9)	65	(7,4)
UCV	14	(1,8)	16	(1,8)	29	(3,3)
UTFSM	32	(4,1)	24	(2,7)	19	(2,2)
USACH	22	(2,8)	26	(3,0)	47	(5,3)
UACH	62	(7,9)	69	(7,2)	69	(7,8)
UN	3	(0,4)	8	(0,9)	3	(0,3)
UV	5	(0,6)	6	(0,7)	8	(0,9)
UA	5	(0,6)	6	(0,7)	6	(0,7)
ULS	2	(0,3)	1	(0,1)	8	(0,9)
UBB	2	(0,3)	0		2	(0,2)
UFRO	7	(0,9)	15	(1,7)	10	(1,1)
UMAG	2	(0,3)	1	(0,1)	1	(0,1)
U TALCA	1	(0,1)	3	(0,3)	4	(0,5)
UAT	0		1	(0,1)	0	
UTA	2	(0,3)	3	(0,3)	3	(0,3)
UMCE	6	(0,8)	3	(0,3)	0	
UPACE	2	(0,3)	4	(0,5)	1	(0,1)
IPO	0		7	(O,8)	2	(0,2)
U.A.IBANEZ	-		-		1	(0,1)
TOTAL U (a)	782		874		880	
OTHER	192	(20,0) (b)	183	(17,7) (b)	182	(17,6) (b)
TOTAL PAPERS	961		1032		1035	

N.B. The numbers in parenthesis indicate % with respect to the total output of universities (Total U). (a): if an article had two or more universities in the author's address it was added to each research center. The actual total number of papers can be easily deducted from the total number of papers which indicate the effective output registered every year. (b): % with respect to the total articles registered in the corresponding year.

Despite the aforementioned limitations and that it is urgent to correct the bias against competitive Journals from Third World countries, scientometric indicators arising from mainstream databases are helpful in developing countries.As stated by Cori (18) counting mainstream papers and ascertaining citation patterns can be useful to compare a country, an institution, or an individual with itself but not with other categories; in chemical languages ISI's

databases are useful kinetic indicators. Towards this end the kind of bibliometric data contained in Table II contributes to examine the progress of each university with regard to their scientific activity, and in addition to detect where the most productive research centers are. The database which is been constructed allows the identification of the university departments involved. As shown in Table II there are other institutions which also contribute to the scientific and technological output in Chile. The most relevant area investigated outside de universities is Astronomy. Around 75% of the 1987-90 articles registered in this field originated in the international observatories located in the north of Chile (9). However in the period 1976-79, with a lower output, they reached 91% (13). The fraction of publications in the fields of Medical (clinical) Sciences (30%) and Social Sciences & Humanities (30%) produced outside the university system is also significant (13).

In general the nature of the scientific work performed in Latin America has been largely concentrated in the life sciences with less emphasis on disciplines which have direct influence on industries (2,19,20). Thus the changes attained during the last decade in Chile are relevant. As shown in Figure 3 concurrently with the growth of Chilean scientific output, the field pattern of the publications changed, showing a tendency towards a distribution characteristic of advanced countries (20). Figure 4 depicts the field profile of the publications produced by the universities that follow the same changes which occurred with the whole country's scientific output, except in Astronomy, where their relative contribution increased.

Recent studies have led to the conclusion that in Chile there are between 2400 and 4000 active scientists (21), which beyond any doubt are insufficient for the country's need. Upon mainstream bibliometric studies (2,22) quantitatively, Chilean science occupies the fourth place in Latin America. Scientometric indicators (13) reported by Braun et al. (23-26) reveal that among the first 100 countries, quantitatively Chile ranks 34 in Life Sciences, 38 in Physics, 38 in Chemistry, and 46 in Mathematics. However, when the qualitative impact is measured in the same period (1981-1985) Physics ranks 8, Mathematics 16, Chemistry 35 and Life Sciences 49.

To examine the performance of state financed universities, three distinctive products were measured: (a) The number of individuals which obtained their degrees in Undergraduate and Professional Schools; (b) the number of individuals which reached their Master and Ph.D. degrees, and, (c) the number of mainstream publications. It is clear that the genuine meaning of an university can be hardly reduced to mere quantities of teaching and research products. Nevertheless, their assessment provides valuable information. The problem arises when one compares universities which notorious differences in the amount of public funds they receive. In Chile, an important fraction of the total state funds correspond to what is known as historical antecedents. Thus, there are some universities which consistently receive more state funds than others.

Figure n°3. Percentage of scientific publications in each field registered during 1976-79 and 1987-88

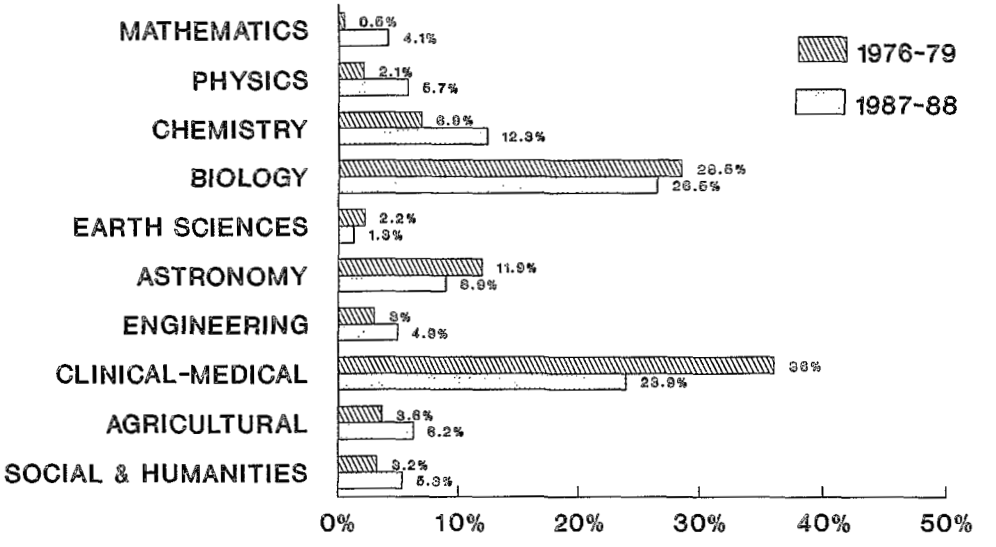
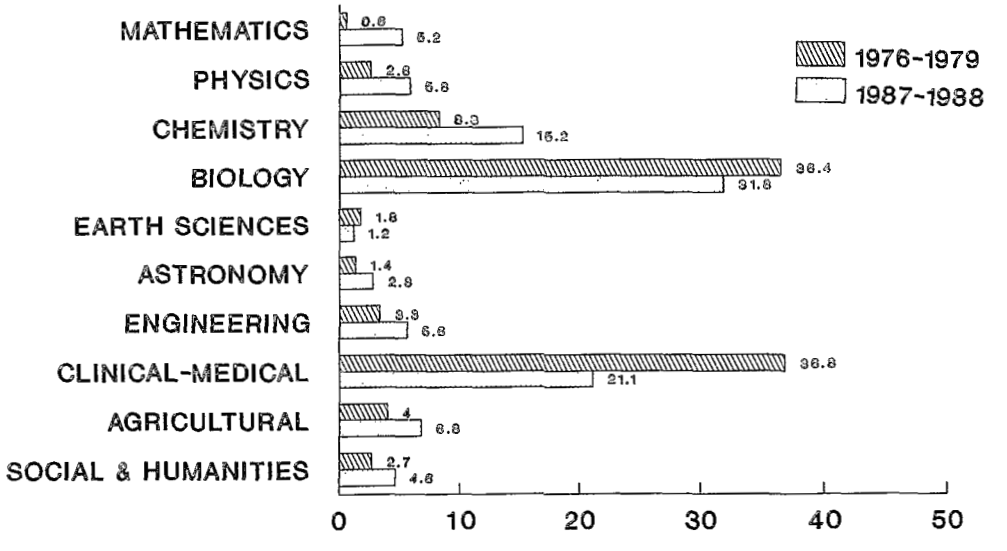


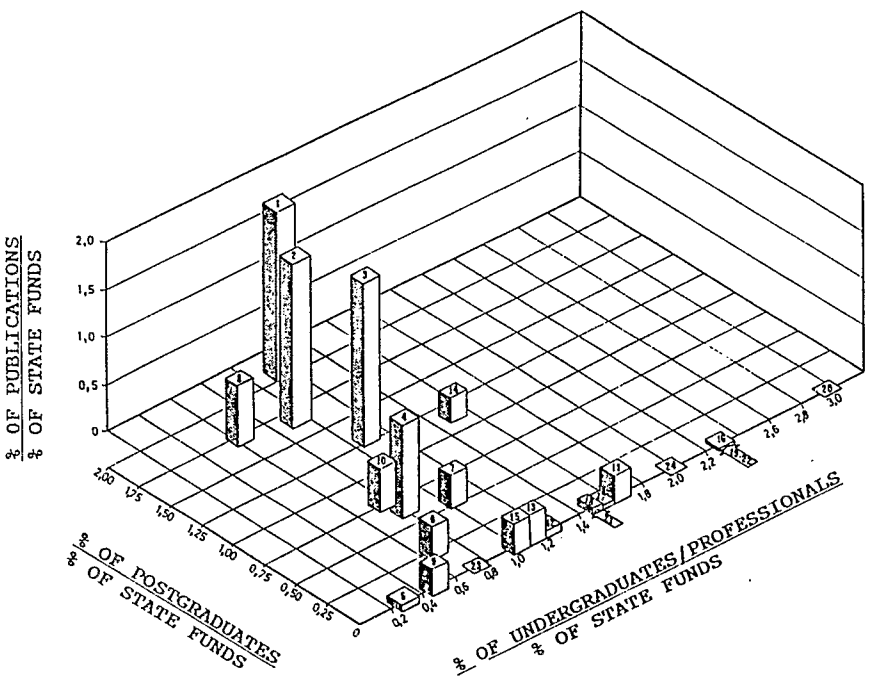
Figure n°4. Percentage of scientific publications originated in Chilean universities in each field during 1976-79 and 1987-88



Because the aim of the approach is to approximate the efficiency and efficacy with which universities use public funds within country resource constrains, it is imperative to standardize the indicators to a common denominator.

Accordingly the percentage of mainstream scientific articles of a given university with respect to the total output of the system, was divided by the percentage of money that the given university received from the total state funds which were allocated to the universities. Similar procedures were followed to compare the relative contribution of each university in regard to undergraduate/professionaldegrees or titles, and postgraduate Master and Ph.D. degrees. Thus, to evaluate the performance of public financed universities, the percentage of individuals graduated in 1985-86 in each university with respect to the total output of graduates in the corresponding category was divided by the fraction of state funds received in 1983 by the given university. This rendered two standardized indicators: undergraduate/professional and postgraduate degrees/titles yield. Scientific production was attained by dividing the percentage of mainstream articles produced by each university and registered in 1985-86, by the fraction of state funds received in 1983 by the given university. The three aforementioned indicators were plotted as depicted in Figure 5.

Figure n°5. Academic productivity of Chilean state financed universities (Each column represents a university)



The plot represents the academic productivity of a group of Chilean universities and reveals, that indeed the scenario is highly heterogeneous. In the search for efficiency and efficacy it is difficult to asses theoretical optimums. However, the 3-D plot displays a cluster conformed by about 60% of the universities with respect to their undergraduate/professional yield. This is more difficult to distinguish when scientific performance and postgraduate activity is analyzed. Efficacy can be inferred from the correlation that results between scientific output and postgraduate activity. With few exceptions, as seen in Figure 5, the universities with higher indicators in scientific work contribute more to postgraduate training.

The results presented herein, indicate that the use of indicators related to a "unit of state financial support" can provide academic productivity maps which permit to compare the performance of the universities, and might help the design of government policies to rationalize funding and strengthen the scientific capacity so scarce in developing countries. In addition, they can provide valuable in-house information to adjust academic policies and management.

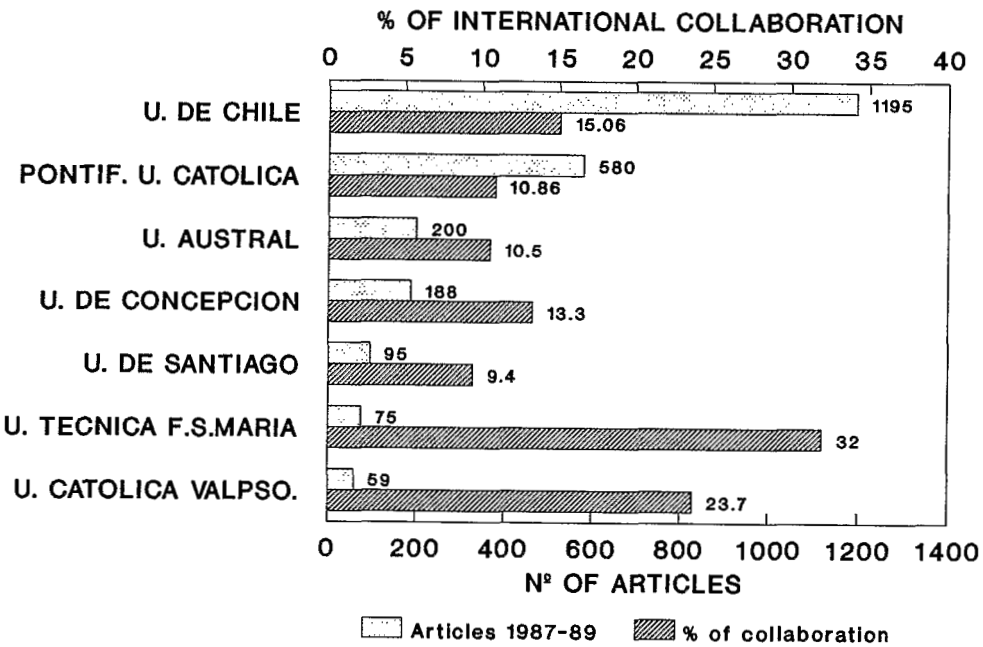
The maps can not provide insights on the quality of the graduates and scientific work performed, matter which is of enormous relevance. However, publishing in mainstream Journals is not an easy task in Third World countries. Peer review is more strict because of distrust in the capacity of developing countries to do science. Furthermore there are natural limitations regarding the English language used in the international scientific literature. Therefore, although not directly, the scientific indicators based in mainstream literature analyses reveal a degree of quality. Accordingly, the use of mainstream literature indicators in developing countries can have a meaning, despite the limitation discussed before.

Postgraduate studies underwent during the last decade a considerable development in Chile. Apart from offering advanced knowledge within a highly creative environment they raised the intellectual capacity that the universities hold. Thus, it is not irrelevant to undergraduate studies that take place in an university, the lack or presence of postgraduate programs (27). This attracts more universities to start such programs. To ensure excellence in the postgraduate programs it is deemed of importance to play public attention on them (28) and to reach as soon as possible the necessary consensus for a proper way to ascribe them public credit (5). Government authorities and faculty are aware of existing risks with respect to the generation of Master and Ph.D. programs not fulfilling the quality standards reached by the existing ones in Chile, and efforts are being made to keep the higher standards possible. It is well established that doctorates demand intensive and competitive scientific research. Scientometric indicators allow the mapping of the most competitive centers.

From the database containing the publications in which Chile is named in the address, it is possible to extract relevant information regarding collaborative work between a Chilean university and a foreign research center. Postgraduate programs require an open window to the world. Competitive scientists too.

During the last decade collaborative research has increased significantly. In fact in 1988 about 18% of all mainstream publications born in Chile shared a foreign address. As for the universities, the percentages reached between 1987 and 1989 are indicated in Figure 6. Interestingly, universities that show lower productivity in number of articles published, exhibit a higher percentage of collaboration with foreign scientists. Although clearly beneficial, it might also show that in-house research capacity is insufficient to cope with the demands of their own challenges. However, because all the universities need to back their needs and weaknesses and avoid inbreeding in their postgraduate training, international collaboration appears to be a must in developing countries. Again, scientometric indicators can contribute to the identification of those centers which fulfill suitable conditions for specific Ph.D. programs.

Figure n°6. International collaborative research.: Percentage of articles published by some Chilean universities in conjunction with foreign centers.



For developing countries which seriously think of attaining progress and international competition, science and technology is a must. In Chile, a National Plan of Science and Technology for Development was started in 1988. Conforming the Plan are actions discussed by the scientific community, the government, universities and the private sector. The Plan serves as backbone for a body of supportive means toward specific ends covering the training for young scientists, support to postgraduate students, research grants to individuals, acquisition of institutional major instrumentation, public acquaintance about the

cultural and practical value of knowledge, etc. As the science and technology scenario evolves, the political will has to be expressed by strengthening and increasing mechanisms to support research by means of coherent governmental actions which have to take into account the existing reality. Once more, scientometric studies contribute to evaluate the yield that certain actions produce and the capacity which prevails.

As a recurrent motif in Chile, as in many other Third World countries, any Plan that does not take into account the conditions affecting the overall performance of their universities would be incomplete.

In his already classic essay on *The Mission of the University* (29), Ortega y Gasset stated in 1930 that universities were becoming *a tropical forest of teaching*, meaning by this that information prevailed over formative instruction. Sixty years later this condition predominates in the undergraduate and professional programs of Chilean universities. Most probably they are not an exception, yet an important obstacle for progress. "Universities generally have, as organizations, rather conservative habits of reaction. They shelter many inventive and creative minds and many people capable of reflecting in a free and bold manner on all kinds of problems. But as soon as a really profound and unexpected change is suggested in the curriculum or in the pedagogical or administrative structure of a department or faculty, the professors who see some improvement in this are few indeed". The latter are words of Rev. Alphonse-Marie Parent cited by Goma (30). University in-house conservative attitudes can be also a real problem for science. According to Brunner (31) less than 20% of the total academic staff working in Chile, is actively involved in research. Furthermore, the capacities are concentrated in a few universities. This is consistent with the maps that the scientometric indicators yield. Needless to say that this reality seriously influences in-house decisions.

The task and challenge of the present is to strengthen the scientific capacity of Chile, while preserving the legitimate and invaluable autonomy of the state financed universities which lodge most of the available research abilities of the country. Knowledge of their performance through scientometric analyses can indeed contribute to devise mechanisms for an efficient allocation of the always limited public funds.

ACKNOWLEDGMENTS. My thanks to Professor Oriana Gonzalez for critical reading of the manuscript. Scientometric studies were supported by a Grant (C-17) from Fundacion Andes.

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