Arch. Biol. Med. Exp. 24: 37-47 (1991)
Printed in Chile

Assessing the scientific strength of Chile

Estimación de la capacidad científica de Chile

CAROLE GANZ BROWN, H. ROBERTS COWARD and ROBERT C. STOWE

Division of International Programs, National Science Foundation, Washington, D.C. 20550, USA.

We use analysis of co-citation and relative citation rates to assess the scientific strength of Chile as compared with other developing countries and to evaluate the potential for increased international collaboration between Chile and the United States in science and engineering.

Co-citation is the citation of two scientific papers by a third paper. By examining frequency and patterns of co-citation, the intellectual structure and evolution of scientific disciplines and research specialties can be traced. Chile is especially "strong", as defined by the co-citation model we employ, in biomedicine and clinical medicine, and in astronomy.

A relative citation rate is the ratio of the number of citations a paper receives to the average number of citations for all papers published in the same journal over time. Analysis of relative citation rates of papers published by authors with Chilean addresses show that Chilean physics, including earth and space sciences, is of unusually high quality, considerably higher than any other developing country and comparable to several industrialized countries.

We conclude that Chile's scientific capacity is advanced enough to absorb and benefit significantly from strategic additions to the country's resources and capabilities for research. These would include increases in: exchanges of researchers in specific fields with U.S. and other Latin American academic, industrial, and government scientists and engineers; training at outstanding U.S. and Latin American institutions; laboratory equipment, computer time, communications links, and library materials; and funding from U.S. and international organizations. It is also apparent that Chile is strong enough in certain fields to cooperate with the U.S. in mutually benefical international efforts.

INTRODUCTION

Scientists usually communicate and accumulate new scientific knowledge by means of published papers. Bibliometric indicators, based upon numbers of published papers and citations to these papers, are commonly taken to provide insight into the quality of the research performed by individual scientists, laboratories, or entire nations. This paper uses bibliometric indicators to assess the scientific strength of Chile as compared with other developing countries and to evaluate the potential for increased international collaboration between Chile and the United States in science and engineering.

Our analysis[1] draws upon a recent National Science Foundation (NSF) project for the U.S. Congress, the objective of which was to help develop an agenda for

Carole Ganz Brown holds a Ph.D. in Logic and the Philosophy of Science from Stanford University. She is Senior Program Manager for Studies and Assessments, Division of International Programs, National Science Foundation, Washington, D.C.

H. Roberts Coward holds a Ph.D. in Political Science from the Massachusetts Institute of Technology. He is Senior Science Policy Analyst with SRI International in Arlington, Virginia.

Robert C. Stowe holds a Ph.D. in Political Science from the Massachusetts Institute of Technology. He is Assistant Professor of Public Affairs at Maharishi International University in Fairfield, Iowa.

[1] An earlier version of this paper was presented at the Annual Meeting of the American Association for the Advancement of Science (AAAS), Boston, February 1988. The authors are grateful to James W. Rowe for inspiring the project and providing the opportunity to prepare and present the paper, and to Tibor Braun of the Hungarian Academy of Sciences, who provided the authors with unpublished data on relative citation rates. Damian Saccocio, while a Science Policy analyst with SRI International, contributed significantly to the paper. The findings of this paper represent solely the views of the authors and not the organizations with which the authors are affiliated.

enhanced U.S.-Latin American scientific and technological cooperation in the 1990s (Ailes, 1988). This study of Chile is intended as an example of how the results of the NSF project, when integrated with nonquantitative assessments of Latin American research capabilities and potential (e.g., through peer review), might be used for the mutual advantage in science and technology of both Latin America and the U.S.

Background on Bibliometrics

Although bibliometric indicators can instruct us about the quality of scientific research, their validity must be qualified. Almost all bibliometric work is based on the database developed and maintained by the Institute for Scientific Information (ISI). A number of biases are built into this database. For example, only the first authors of cited scientific papers are reported by ISI. It has been suggested that this omission might systematically discriminate against younger scientists and those with last names beginning with a letter near the end of the alphabet (Chubin, 1973; Lindsey, 1980; Long, *et al.*, 1980).

More germane to the topic of this paper, ISI's bibliometric database may under-represent scientific papers from non-English language journals (Martin, *et al.*, 1987). Many scientists from developing countries, including those in Latin America, publish in such journals[2]. We partially control for this distortion by comparing developing countries with one another.

In addition to these qualifications on ISI's database, the question is often raised of why scientists cite other papers. That scientists cite papers for reasons at least partially unrelated to quality may call into question assumptions upon which citation analysis is based (Bavelas, 1978; Brooks, 1985; Gilbert, 1977; Moravcsik and Murugesan, 1975). In addition, because citing behavior of scientists in different disciplines or even sub-disciplines varies, comparison of citation counts across fields may be problematic (Lange, 1985). Finally, citation rates may be more a measure of the "impact" than the "quality" of scientific papers. For example, papers describing new laboratory techniques are among the most highly cited. While having a major impact upon subsequent scientific research, these papers in themselves may not substantively advance science.

In response to such critiques, bibliometric analysis has become increasingly refined. The pioneers of bibliometric analysis relied on simple publication and citation counts (Price, 1962; Cole, 1970). More recent bibliometric techniques emphasize co-citation counts, relative citation rates, contextual citation analysis, and the convergence of bibliometric indicators with other measures.

John Irvine and Ben R. Martin use "converging partial indicators" to assess the performance of research groups, or centers (as contrasted with individuals or countries). Agreement among various indicators, including systematic peer review and citations, is used by Irvine and Martin to evaluate performance (Martin and Irvine, 1983). Daryl Chubin, Henry Small, and others analyze the textual context of the citation to reveal more about the cited paper than citation counts alone could (Chubin and Moitra, 1975; Small, 1982).

Both converging partial indicators and citation context analysis are highly labor-intensive techniques. Neither have been used to evaluate the state of science and engineering in entire countries or to assess the potential for international scientific collaboration. In contrast, computerization of co-citation and relative citation rate analysis has encouraged such applications. Co-citation indicators are the primary focus of this paper, with results selectively compared to those reached through the analysis of relative citation rates.

Center for Research Planning (CRP) Co-citation Model

The Center for Research Planning (CRP) has developed a model of world science

[2] Compounding this problem is the fact that much Third World science, which may otherwise be of high quality, involves applied problems of relatively local interest in medicine, agriculture, and energy. Many scientists in developing countries do not try to publish the results of such work in international journals. If they do try, editorial boards may determine that, while perhaps of sufficient calibre, the work is not of enough interest to the majority of their readers to accept it for publication.

by applying co-citation techniques to the ISI database. The CRP model is well suited to studying and comparing countries' scientific activity and strength[3].

Co-citation is the citation of two scientific papers by a third paper. By examining frequency and patterns of co-citation, the intellectual structure and evolution of scientific disciplines, sub-disciplines, and research specialties can be traced (Small and Griffith, 1974; Mullins, *et al.*, 1977). As do all co-citation models, CRP specifies an "intellectual base" and a current set of citing papers. In the 1984 model used here, intellectual base papers are those published prior to 1984 which are cited by 1984 papers. Linkages among base-papers are identified through an algorithm for analyzing co-citation of base-papers by current papers. Base-papers are thereby assigned to one or another node, or "scientific specialty"[4]. Current papers are assigned to specialties as well, according to the patterns of their citation to base-papers. In every case, current (1984) papers in a specialty cite at least one paper from the intellectual base of that specialty.

Once specialties have been developed in the model, various characteristics of specialties can be determined for a specific country. These characteristics include: (1) activity level; (2) strength (both "national" and "international"); (3) size; and (4) intellectual age. The first two properties pertain to 1984 literature; the others to the intellectual base.

Activity level refers simply to the number of papers in a given specialty which scientists from a particular country published in 1984. "Strength" is somewhat more complex. A particular country can be "internationally" or "nationally" strong in a specialty. A country's international strength in a specialty is relative to the country's strength in world science as a whole. For example, if scientists in Country X are responsible for 1% of *all* of the current world literature in the model, and if biomedical researchers in Country X are responsible for, say, 20% of the world's papers in biomedicine, then Country X's "international ratio" for biomedicine is 20 and biomedicine is internationally strong for Country X.[5, 6].

A country's national strength in a specialty is a country's activity in the specialty relative to the country's total activity in the model. For example, if scientists in Country X published 10 papers in microlithography in 1984 and published 1000 papers in total, the "national ratio" for microlithography is .01, and Country X is nationally strong in microlithography. Thus, national strength is a measure of the priority given to specialties within a country[7].

Size and intellectual age pertain to the intellectual base of a specialty. "Size" is the number of papers in the intellectual base of a given specialty. The intellectual age of a specialty is the mean number of years elapsed between publication of papers in that specialty's intellectual base (the co-cit*ed* papers) and the publication of current papers in the model –1984 in this case (the cit*ing* papers). "Younger" specialties are those which are more dynamic– progressing more rapidly. They may also have more intellectual ano

[3] Such study is made possible by the inclusion in the ISI database of the institutional addresses of authors. In the cases of developing countries with prominent international research facilities, it is advisable to examine the names of authors of papers in the appropriate disciplines. A significant number of astronomers with Chilean addresses, for example, may in fact be visiting scientists from other countries.

[4] "Specialties" in the CRP model are quite narrow. In many cases, "specialties" might better be labelled "research topics". There are 28,128 specialties in the 1984 CRP model used in this paper. Specialties can be aggregated by lowering co-citation thresholds to form broader research areas or "regions". These are roughly equivalent to sub-disciplines or, in some cases, what scientists ordinarily term "specialties".

[5] In certain cases, "internationally strong" specialties for Country X will be those in which few scientists from other countries are interested. These "parochial" specialties are likely to exist in applied fields such as agriculture or clinical medicine, which tend to address local problems.

[6] In the CRP model, raw values for both national and international strength, such as the examples given in the text, are converted to standard scores by means of the formula: Standard Score = (Value-Mean)/(Standard Deviation).

[7] For each of the four properties discussed, the CRP model defines three levels of intensity. Boundaries between levels (e.g., between international ratios which are "strong", "average", or "weak") are maxima in the second derivative of the distribution curve of the parameter in question.

economic interest to scientists and policy-makers.

Co-Citation Analysis: Results and Conclusions

Table I summarizes data and analysis from the CRP model for Chile and other developing countries.

of the active specialties (Table I), Brazil demonstrates a smaller percentage than the norm for the five larger South American countries, and Venezuela a considerably larger percentage. Chile's percentage is about average for these countries.

TABLE I

Developing Countries Ranked by Number of Specialties in which Active

Rank	Country	Number of Active Specialties[1]	Active Specs. as Percent of Total Model	Number of Int'l'ly Strong Specialties	Strong Specs. as Percent of Active
1	India	5419	19.3	62	1.14
2	Brazil	1988	7.1	27	1.36
3	China	1830	6.5	23	1.26
4	Argentina	1465	5.2	34	2.32
5	Mexico	1216	4.3	23	1.89
6	Chile	1075	3.8	25	2.33
7	Taiwan	687	2.4	22	3.20
8	Egypt	618	2.2	16	2.59
9	Nigeria	586	2.1	14	2.39
10	Venezuela	582	2.1	31	5.33
11	Hong Kong	555	2.0	18	3.24
12	South Korea	482	1.7	23	4.77
13	Turkey	392	1.4	23	5.87
14	Singapore	346	1.2	18	5.20
15	Saudi Arabia	331	1.2	17	5.14

1/ Active specialties are those in which at least one paper was published by authors in the country in 1984.

Among the developing countries, India, China, and the larger South American countries of Brazil, Argentina, Venezuela, Mexico, and Chile have the most active scientific communities in the CRP model. Table I indicates that Chilean scientists and engineers are active in about 1000 scientific specialties. (An active specialty is one in which at least one paper was published in 1984). This a level of activity roughly equivalent to that of Mexico and Argentina, about half that of Brazil and China, and about one-fifth that of India. Venezuela and the Pacific rim countries of South Korea and Taiwan display a level of scientific activity somewhat lower than Chile.

Chile is internationally strong in 25 specialties (Table I). This level of strength is approximately equivalent to that of Brazil, China, Mexico, South Korea, Turkey, and Taiwan. India has 62 internationally strong specialties and Argentina 34. When considering the number of internationally strong specialties as a percentage

Slightly less than half of Chile's internationally strong specialties are also "young", or progressing rapidly, as defined by the CRP model. The ratio for the other large South American countries, as well as for those along the Pacific Rim, is similar.

Many developing countries with stronger scientific communities tend to focus on more applied problems in medicine and agriculture (Garfield, 1983). Chile is not unusual in this regard, as suggested by Figure 1, which presents CRP analysis of active specialties in Chile[8].

Chile, however, is unique among the larger Latin American countries in the degree to which its "internationally strong" specialties (as defined by the CRP model) are concentrated in biomedicine or clinical medicine. All of the other larger Latin American countries display more scientific

[8] Krauskopf, *et al.* (1986) and Krauskopf and Pessot (1985) present comparative data on publications activity for Chile and other Latin American countries.

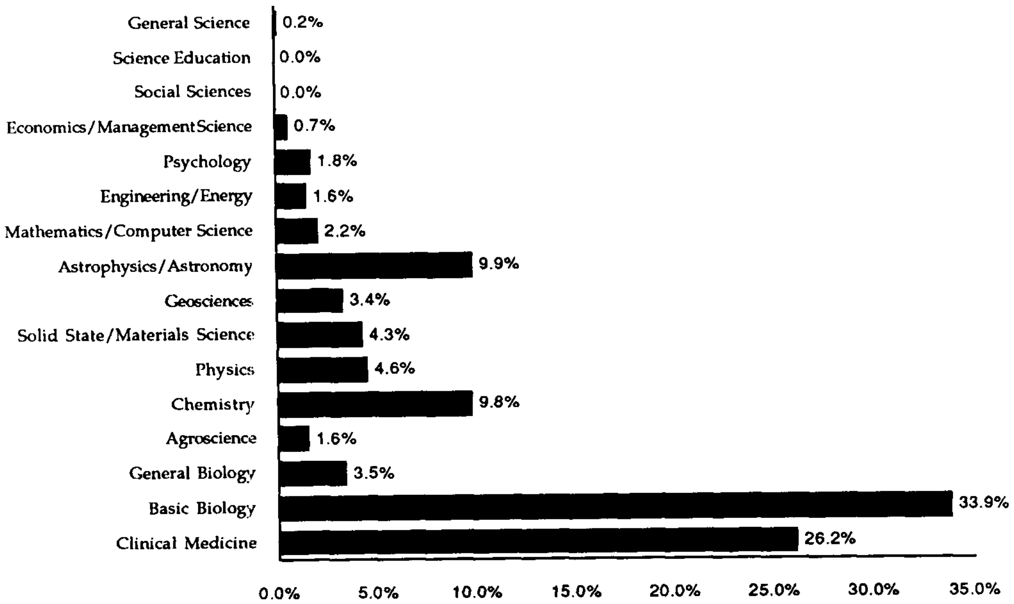

Figure 1: Field specialties in which Chile is active as a percentage of total field specialties in the 1984 model. *Source:* Ailes, 1988.

diversification among their internationally strong specialties. Mexico's and Argentina's internationally strong specialties, for example, are less concentrated in clinical medicine. In Argentina, physics and chemistry are more heavily represented among the internationally strong specialties. Brazil and Venezuela are balanced between clinical medicine, on the one hand, and solid state physics and materials science, on the other.

In addition to measures of Chile's international strength in particular specialties, the CRP model provides measures of Chile's strength in specialties relative to the other specialties in which the country is active. *National* strength is one measure of the priority given to specialties within a country. All of Chile's nationally strong specialties, according to the model are in astronomy. CRP analysis of active specialties, presented in Figure 2, confirms the importance of astronomy in Chile.

Relative Citation Rates as a Measure of Scientific Strength

Using the ISI database, Tibor Braun has developed an indicator known as the relative citation rate that has proven valuable in comparing the quality of scientific research between countries. A relative citation rate, in its simplest form, is the ratio of the number of citations a paper receives to the average number of citations for all papers published in the same journal over time. (Papers having a relative citation rate of over 1.0 are considered to be highly-cited or, by extension, of above-average quality). Thus, relative citation rate partially controls for the variable citing practices of scientists in different disciplines.

Relative citation rates for papers can be aggregated across countries and disciplines. For example, to ascertain the relative citation rate for Chile in physics, one must first identify a set of journals "composing" physics, and then all papers in those journals written by scientists with Chilean addresses. The relative citation rate for each of these papers is then individually determined and the mean computed.

In Figure 3, developing countries are shown with their relative citation rates for all scientific and engineering disciplines for papers published by their authors during the years 1981-1985. In subsequent figures, relative citation rates are shown for che-

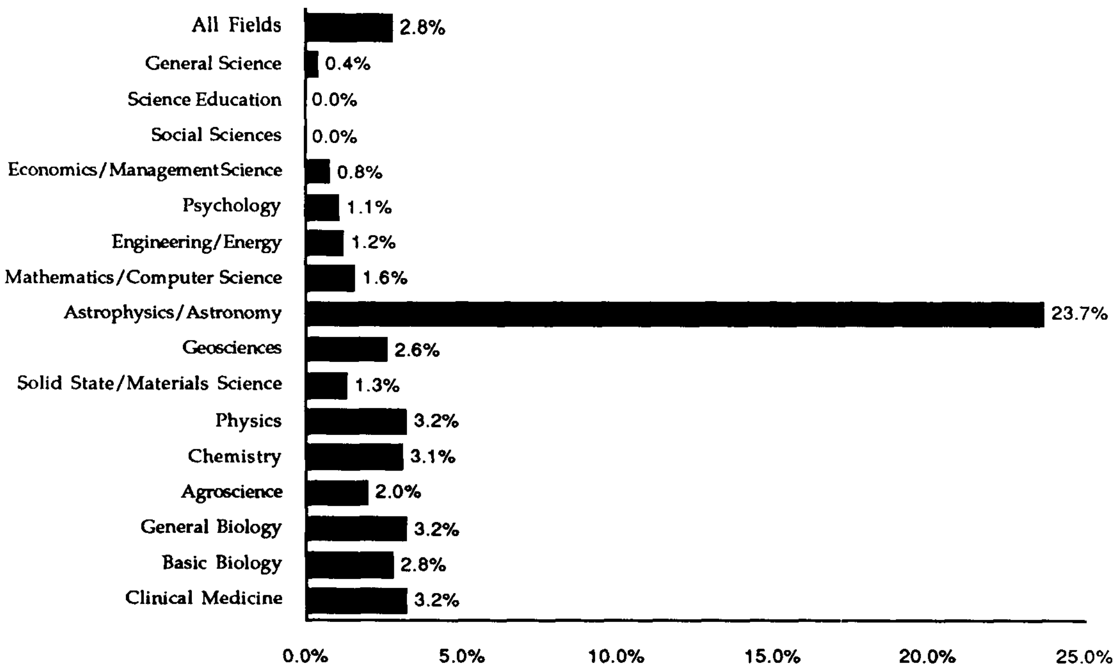

Figure 2: Field specialties in which Chile is active as a percentage of all specialties in which Chile is active (1984 model).
Source: Ailes, 1988.

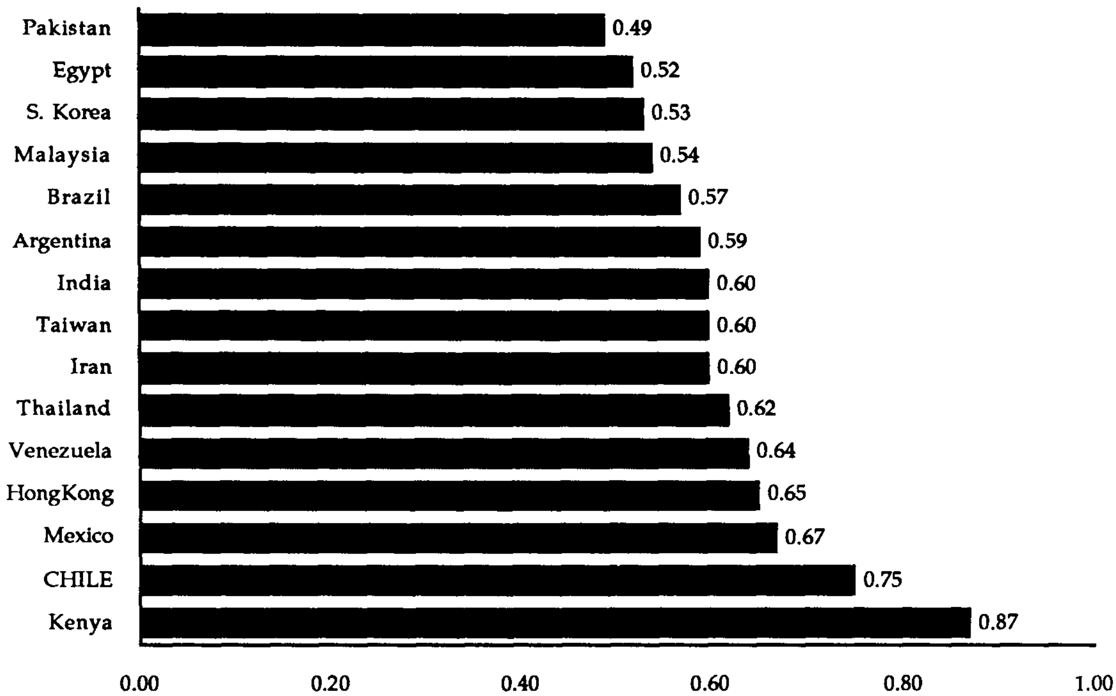

Figure 3: Relative citation rates, all specialties.
Source: Braun *et al.*, 1988a.

mistry, the life sciences, physics, mathematics, and engineering[9].

Conclusions From the Analysis of Relative Citation Rates

A number of conclusions may be drawn from the data presented here. First, Figure 3, which presents aggregate data, confirms the overall quality of Chile's science and engineering. Especially striking is the quality of Chile's physics (Figure 6). Chile's relative citation rate for physics is much higher than that of Mexico, which has the next highest rate among the developing countries (though Mexico published twice as many papers: 899 vs. 410 for Chile). In

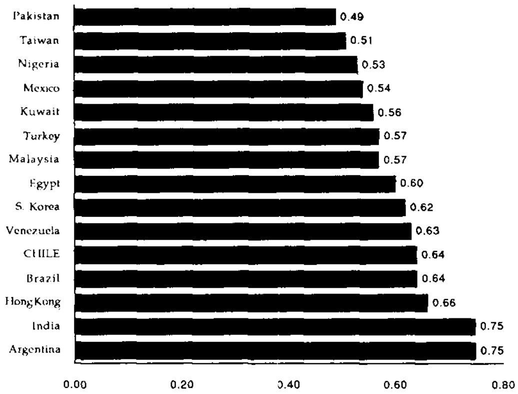

Figure 4: Relative citation rates, chemistry.
Source: Braun *et al.*, 1988b.

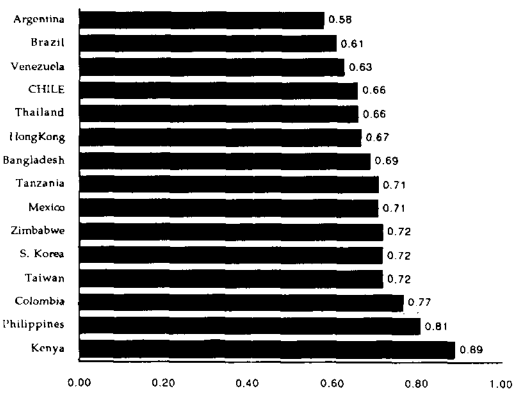

Figure 6: Relative citation rates, physics.
Source: Braun *et al.*, 1988c.

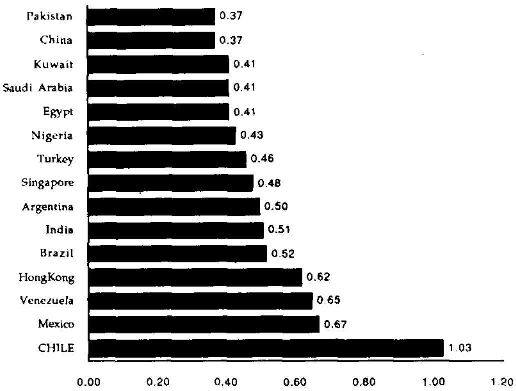

Figure 5: Relative citation rates, life sciences.
Source: Braun *et al.*, 1988b.

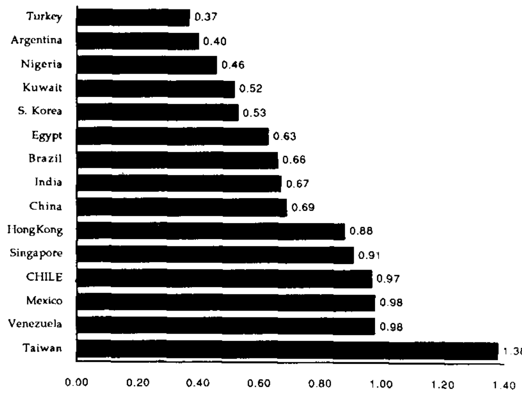

Figure 7: Relative citation rates, mathematics.
Source: Braun *et al.*, 1988c.

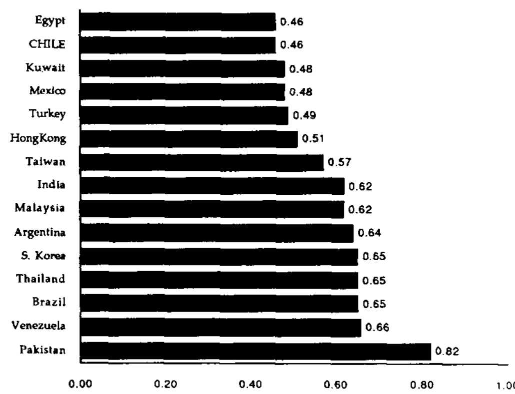

Figure 8: Relative citation rates, engineering.
Source: Braun *et al.*, 1988c.

[9] In the bar charts, countries are listed in rank order of their relative citation rates. However, small differences in relative citation rates are probably not statistically significant, even for countries whose authors publish large numbers of papers. We have not performed statistical tests to determine the significance of the differences between Chile's relative citation rates and those of other countries. Here we wish only to give an impression of Chile's standing in various fields of science. The statistical procedure for performing such analysis is given in Braun (1988e).

fact, Chile's physics is in the same class as a number of industrialized countries. "Physics" here includes the earth and space sciences (Braun, 1988d). Chile has world-class international centers in both fields at which scientists from Chile and many other countries work. It is likely that these centers are largely responsible for Chile's high relative citation rate in physics.

Equally important, given Chile's high activity level in the life sciences, is the country's mediocre relative citation rate in these disciplines (Figure 5). Kenya, the Philippines, Colombia, and Taiwan, which have the highest relative citation rates in the life sciences, all have international research centers in one or another of these fields. Life sciences as a whole constitute about 65% of Chile's total publication output (Figure 1), and it is clear that the quality is not commensurate with the quantity of publications in these disciplines.

Chile's chemistry and mathematics (Figures 4, 7) are clearly in the same range as the other large Latin American countries. The quality of Chile's work in engineering, however (Figure 8), is at the lower end of the scale for these disciplines.

Recommendations

Based on these analyses, two tentative recommendations concerning efforts to advance Chilean science and engineering are put forth to receive critical evaluation by appropriate science and engineering communities. First, in attempting to promote needed scientific diversification and develop its strong fields of research, Chile should be selective, not attempting to expand in a wide variety of new directions. Promising approaches to the development of new fields of research include: making more use of existing Latin American, as well as U.S., research and educational facilities in those fields, and offering incentives for the return of Chilean scientists from abroad in disciplines targeted for expansion.

In particular, the bibliometric data suggest that Chile should consider building on its existing strengths in biomedicine and clinical medicine, as an alternative to expanding into new medical specialties. While Chile shows much international strength in clinical medicine specialties, many of these specialties tend to be very small. Some of them are also old and lack international competition. The worst case, involving study of viral hepatitis, has a 20 year old intellectual base composed entirely of U.S. papers. Overall, about 40% of Chile's clinical medicine specialties are young. With respect to Brazil, 90% of these specialties are young; Venezuela (67%); and Argentina (50%). Mexico ranks below Chile with 33% being young. Clearly, therefore, Chile should encourage advanced training and sabbaticals abroad for its mature faculty, and foster the integration of newer trends in biomedicine into existing research.

For example, in attempting to develop Chilean biotechnology, it may be wise to focus on applications in biomedicine. By proceeding in this manner, Chile would both improve its already significant abilities in the biomedical fields and also accelerate the incorporation of advanced biotechnological knowledge and techniques into the national scientific community. Agricultural and energy-related biotechnology efforts would appear to have less impact on existing research. Introduction of more modern instrumentation and biomedical engineering skills should also be explored to internationalize and update the biomedical community.

Remaining with the theme of building upon existing scientific strengths, Chilean scientists should make more and better use of the country's international astronomy facilities, especially the Interamerican Observatory at Cerro Tololo. All of Chile's nationally strong specialties in the 1984 CRP model are in astronomy. While institutional data for the 1984 model is not available, inspection of 1982 specialties strongly suggests that Cerro Tololo is an important Chilean institutional address for many important 1984 astronomy specialties. These specialties tend to be young, large, and highly competitive internationally.

Countries as scientifically diverse as France, the Netherlands, Great Britain, China, Canada, Japan, West Germany, Mexico, Australia, the Soviet Union, Turkey, and Sweden as well as the United States participate in these specialties. U.S. institutions participating in astronomy specialties included all the major U.S. astronomical facilities and universities, as well as IBM and Bell Labs. Certainly further opportunities exist for Chileans to take advantage of this international scientific presence to strengthen Chilean astronomy and related fields such as mathematics and theoretical physics. Considering these potential advantages from international institutes, Chile should perhaps more aggressively compete for establishment of international facilities in areas such as earthquake engineering, and advance more local participation in these facilities.

Finally, Chile must be discriminating in support of research to advance technology. High-technology areas have become popular throughout the developing world and, among donor agencies, as a means to strengthening capacity for research in fields with economic impact. Microelectronics stands out in this regard as the most frequently discussed and most energetically pursued set of disciplines. Chile, however, shows less strength in the applied physical sciences which support microelectronics than in its overall capabilities. This is in contrast to, say, Venezuela or Brazil. If it wishes to pursue research with high economic impact, Chile might do better to develop more science and engineering expertise in technology related to its basic industries, including copper mining, metallurgical extraction, and collateral activities.

Our second major recommendation is that Chile and the United States must together develop criteria for international cooperation that work for both sides. In recent years, industrial countries generally have become more cautious about international cooperation. Budget limitations and pressures arising from international competition have encouraged industrial countries to monitor science abroad more carefully, to emphasize more clearly that cooperative efforts should be mutually beneficial, and even in some cases to limit foreign access to domestic research centers.

While the idea of mutually beneficial collaboration is clear in the minds of both Chilean and U.S. scientists and policymakers, the increasing reticence of industrialized countries to collaborate internationally has made the idea difficult to implement. Concerned parties in both countries must work to develop better criteria for mutually beneficial research if the goal of increased collaboration is to be met.

Bibliometric data indicate that the U.S. is dominant in global research across most scientific fields. If mutual international strength is a U.S. criterion for international cooperation, *only one specialty* (out of about 28,000) in the 1984 CRP model passes the test: a "nuclear reactor safety" specialty in which both the U.S. and Japan are internationally strong.

As an alternative, Chile and the U.S. might agree to collaborate in a set of specialties, in some of which Chile is internationally strong and the U.S. weak, and in others the U.S. is strong and Chile weak. A difficulty with this approach is that there are few specialties in which Chile is internationally strong and the U.S. weak. Table II lists the numbers of specialties in the CRP model for which the U.S. is internationally weak and other countries, including Chile, are strong. In addition, Table II indicates how many of the specialties which satisfy both of these conditions are also young.

Table II implies that Latin American countries, especially Chile and Venezuela, offer limited opportunities for bilateral cooperation in young specialties. However, even in the case of France, less than 0.5 percent of the specialties in which France is active pass the test, with the corresponding figure for Japan being significantly lower.

This argues for more consideration of multilateral approaches which will aggregate the benefits of research in such a way that all individual partners benefit significantly. Participation by several individual industrial or Latin American countries and by consortia of small countries on Chile's

TABLE II

Young Specialties in which the U.S. is Internationally Weak and Selected Other Countries are Internationally Strong

Country	Active Specialties	Int'l'y Strong Specialties	In which U.S. is Int'l'y Weak	Of which Young
France	15,114	106	81 (76%)	59
Japan	14,545	98	65 (66%)	45
Argentina	1,465	36	20 (56%)	7
Mexico	1,216	23	11 (48%)	7
Brazil	1,988	27	12 (44%)	6
Chile	1,075	25	8 (32%)	3
Venezuela	582	31	14 (45%)	3

behalf could increase benefits to the United States. The Organization of American States is one existing channel through which such multilateral collaboration could occur. On the U.S. side, multi-agency funded international programs have the potential to offset the often limited benefits realized by highly specialized individual agencies.

Concluding Remarks

This paper used recently developed bibliometric measures of national and international research capabilities to assess the scientific strengths of Chile. We compared science and engineering in Chile with other countries in Latin America and with nations such as India, China, and Taiwan. The paper did not attempt to achieve exactitude in rating and ranking Chile's scientific strengths. Rather, its goal was an improved basis for identifying windows of opportunity for cooperation in international research, especially between Chile and the U.S. This paper is an example of how bibliometric indicators can contribute significantly to setting the agenda for mutually beneficial collaboration in science and engineering between Latin America and the U.S. over the next decade.

REFERENCES

AILES, C.P. (1988) *New Directions for U.S.-Latin American Cooperation in Science and Technology.* Arlington, Virginia: SRI International.

BEVELAS, J.B. (1978): The social psychology of citations. *Canadian Psychological Review 19:* 158-163.

BRAUN, T.; GLANZEL, W.; SCHUBERT, A. (1988a) The newest version of the facts and figures on publication output and relative citation impact of 100 countries, 1981-1985. *Scientometrics 13:* 181-188.

BRAUN, T.; GLANZEL, W.; SCHUBERT, A. (1988b) The newest version of the facts and figures on publication output and relative citation impact in the life sciences and chemistry, 1981-1985. *Scientometrics 14:* 3-15.

BRAUN, T.; GLANZEL, W.; SCHUBERT, A. (1988c) The newest version of the facts and figures on publication output and relative citation impact in physics, engineering, and mathematics, 1981-1985. *Scientometrics 14:* 365-382.

BRAUN, T.; GLANZEL, W.; SCHUBERT, A. (1988d) The newest version of the facts and figures on publication output and relative citation impact: a collection of relational charts, 1981-1985. *Scientometrics 15:* 13-20.

BRAUN, T.; GLANZEL, W.; SCHUBERT, A. (1988e) An alternative quantitative approach to the assessment of national performance in basic research. Presented at the Ciba symposium, The Evaluation of Scientific Research, London (June 1988).

BROOKS, T.A. (1985) Private acts and public objects: an investigation of citer motivations. *Journal of the American Society for Information Science 36:* 223-229.

CHUBIN, D. (1973): On the use of the *Science Citation Index* in sociology. *American Sociologist 8:* 187-191.

CHUBIN, D. and MOITRA, S.D. (1975) Content analysis of references: adjunct or alternative to citation counting? *Social Studies of Science 5:* 423-441.

COLE, J.R. (1970) Patterns of intellectual influence in scientific research. *Sociology of Education 43:* 377-403.

GARFIELD, E. (1983) Third World research: where it is published and how often it is cited. *Current Comments* (August 15 & 22).

GILBERT, G.N. (1977) Referencing as persuasion. *Social Studies of Science 7:* 113-122.

KRAUSKOPF, M. and PESSOT, R. (1985) Science in Chile: Where is it going? An analysis of the present activity. *Archivos de Biologia y Medicina experimentales 18:* 225-239.

KRAUSKOPF, M.; PESSOT, R. and VICUÑA, R. (1986): Science in Latin America: How much and along what lines? *Scientometrics 10:* 199-206.

LANGE, L. (1985) Effects of disciplines and countries on citation habits: an analysis of empirical papers in behavioural sciences. *Scientometrics 8:* 205-215.

LINDSEY, D. (1980) Production and citation measures in the sociology of science: the problem of multiple authorship. *Social Studies of Science 10:* 145-162.

LONG, J.S.; McGINNIS, R. and ALLISON, P.D. (1980) The problem of junior-authored papers in constructing citation counts. *Social Studies of Science 10:* 127-143.

MARTIN, B.R.; IRVINE, J.; NARIN, F.; STERRITT, C. (1987) The continuing decline of British science. *Nature 330:* 123-126.

MARTIN, B.R. and IRVINE, J. (1983) Assessing basic research: some partial indicators of scientific progress in radio astronomy. *Research Policy 12:* 61-90.

MORAVCSIK, M.J. and MURUGESAN, P. (1975) Some results on the function and quality of citations. *Social Studies of Science 5:* 86-92.

MULLINS, N.C.; HARGENS, L.L.; HECHT, P.K.; KICK, E.L. (1977) The group structure of cocitation clusters: a comparative study. *American Sociological Review 42:* 552-562.

PRICE, D.J. (1962) *Little Science, Big Science.* N.Y.: Columbia University Press.

SMALL, H. (1982) Citation context analysis. In *Progress in Communication Sciences,* Vol. III. Dervin, B. and Voigt, M.J. (eds.) Norwood, N.J.: ABLEX, p. 287-310.

SMALL, H. and GRIFFITH, B.C. (1974) The structure of scientific literatures I: identifying and graphing specialties. *Science Studies 4:* 17-40.