Jointly published by Elsevier Science B. V., Amsterdam and Akadémiai Kiadó, Budapest

Scientometrics, Vol. 34, No. 1 (1995) 45–61

THE INCREASING ROLE OF INTERNATIONAL COOPERATION IN SCIENCE AND TECHNOLOGY RESEARCH IN MEXICO

JANE M. RUSSELL*

Centro de Información Científica y Humanística, Universidad Nacional Autónoma de México, 04510 México, DF (México)

(Received December 14, 1994)

Increasing importance is being given to international scientific activities, especially with regard to developing countries. In the present paper, an analysis is made of the studies published by Mexican institutions in coauthorship with foreign colleagues between 1980 and 1990, as registered in mainstream journals. Different characteristics of the collaboration are described, such as research areas, countries and institutions involved, of interest to Mexican policy makers and scientists, as well as to foreign governments and international organizations sponsoring cooperative agreements with Mexico.

Introduction

The integration of scientists from developing countries into the global scientific community is seen today as a necessary condition for the advancement of science at national level. It is suggested that the problems caused by smallness in terms of a country's scientific effort, can be overcome by the integration of the country's research into the international scientific environment, especially the scientific centre. According to *Schott*,[1] international integration refers to the participation of scientists in international networks of informal communication about the problems, procedures and results of research. In this way, scientists from peripheral countries do not confine their intellectual intercourse to a few local colleagues but extend this to foreign scientists. The exchange of ideas through correspondence and visits leads to improved research methods and the possible submission of results to the scrutiny of the major international scientific journals. In many cases, this exchange will lead to

* Postal address: Apartado Postal 70–392, 04510 México, DF, México

0138–9130/95/US $ 9.50

formal or informal research collaborations with foreign scientists and institutions resulting in the publication of coauthored papers.

One of the ways, therefore, to measure the degree of international integration of a small research community is through an analysis of its internationally coauthored articles. In this context, *Frame* and *Carpenter*[2] consider that international cooperation has taken place when institutional addresses from two or more countries are credited on a single paper.

International scientific cooperation is understandably one of the major and recurrent themes in national science policy today.[3] Science policy makers need to have insights into the patterns of international integration of their national scientific communities, and, particularly, into the factors influencing this integration.[4]

Mexico appears to be no exception in the search for international integration and recognition of its scientific activities. Preliminary studies at our institution have indicated a trend towards a higher international profile, as reflected in an increasing level of international coauthorship in recent years.[5]

Objective

The present study aims to shed light on the degree and nature of Mexico's international scientific activity which has resulted in a joint publication in one of the mainstream journals.

Methodology

Records containing addresses within the Mexican Republic were downloaded from the annual Science Citation Index (SCI) CD-ROMs 1980-1990 and converted into the MINI-ISIS format. Individual records were checked for errors or anomalies in the assignation of Mexican institutions. Studies carried out in collaboration with a foreign partner were identified and coded for the following variables: Mexican institution, location of the institution according to Mexican state, major field and subfield of the journal titles, foreign country, main activity of the Mexican and foreign institutions (higher education, research, government, private sector, international, or unclassified).

Mexican institutions were coded using a classification scheme developed at our Centre.[6] Journal classification was carried out using the nine categories developed by Computers Horizons, Inc. in 1986 [Clinical Medicine (CLI); Biomedical Research

(BIM); Biology (BIO); Chemistry (CHM); Physics (PHY); Earth and Space Sciences (EAS); Engineering and Technology (ENT); Mathematics (MAT); Psychology (PSI)].[7] A further category (Multidisciplinary) was added to identify those studies published in multidisciplinary journals such as *Nature*. Journal impact factors were noted for those journals frequently publishing Mexican papers written in international collaboration.[8]

Results

A total of 3660 documents were registered in the SCI which were published between 1980 and 1990 as a result of activities of international collaboration by institutions within the Mexican Republic. Articles, letters, notes and reviews accounted for 89.1% of the total. Document types with the highest percentages of internationalization were discussion papers, reviews, articles and notes (Table 1).

Table 1
Documents types publishing Mexican studies in international cooperation

Documents	Total of Mexican studies	Mexican studies int. cooperation	Percentage
Article	9300	2884	31.0
Biographical item	6	1	16.7
Book review	2	0	0
Discussion	47	19	40.4
Editorial	53	9	17.0
Letter	401	63	15.7
Meeting abstracts	2110	369	17.5
Note	964	268	27.8
Review	137	47	34.3
Software review	3	0	0

The great majority of studies, 86.9% (n = 3182) were carried out by Mexican researchers in combination with specialists from one foreign country only, 10.4% (n = 379) involved two foreign countries, 1.6% (n = 60), three, and 1.1% (n = 39) with four or more. In the case of 298 studies resulting from Latin American cooperation (not including Puerto Rico), 178 involved only Latin American countries while 120 also involved a non-Latin American country.

A steady rise was seen in the number of Mexican documents written in international collaboration. The number more than doubled from 203 in 1980 to 453

in 1990 (Fig. 1). An increase was also apparent in the percentage of documents coauthored internationally which rose from 18.5% in 1980 to 34.0% in 1990, ndicating a marked increase in the international scientific activity of Mexico during :se years (Fig. 2).

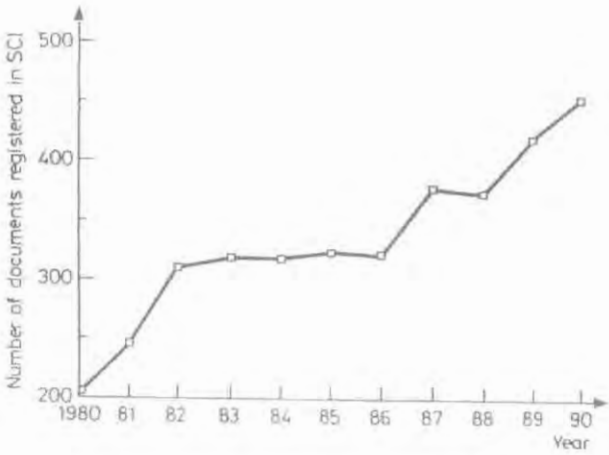

Fig. 1. International scientific cooperation with Mexico

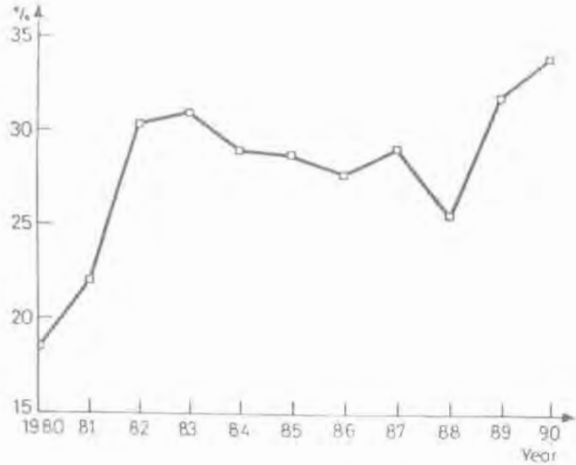

Fig. 2. Percentage of Mexican documents in international cooperation

This international activity was concentrated in Clinical Medicine (19.8%), Physics (17.3%) and Biology (15.7%). The Life Sciences accounted for 47.3% of documents in international cooperation (Fig. 3). However, the percentage of Mexican studies in Clinical Medicine which were the result of cooperation with foreign institutions was low compared to other fields, only 17.0% compared to Earth and Space Sciences with 44.7%, Engineering and Technology with 38.9%, Biology with 35.9% and Mathematics with 38.2%. The highest figure was found in the multidisciplinary journals where half of the 139 Mexican studies were internationally coauthored (Fig. 4).

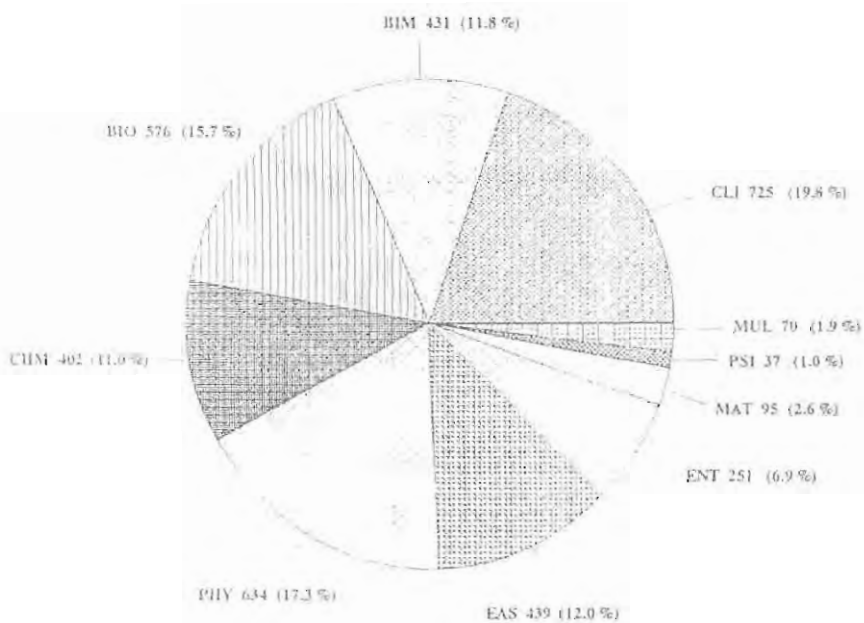

Fig. 3. Fields of international scientific cooperation with Mexico

Although an increase in the number of internationally authored Mexican studies was found in the Life Sciences fields and Chemistry, this was more marked in the case of Biology and, to a lesser extent, Biomedicine (Fig. 5). In respect to other fields, a gradual rise in international cooperation was seen in both Earth and Space

Sciences, and Engineering and Technology while little overall change occurred in Physics and Mathematics (Fig. 6).

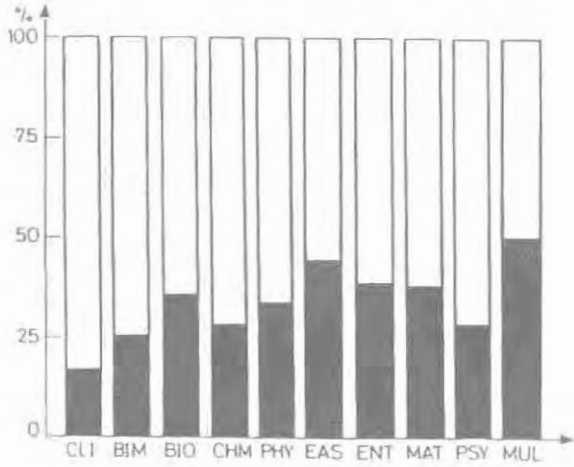

Fig. 4. Percentage of Mexican documents in international cooperation according to major field

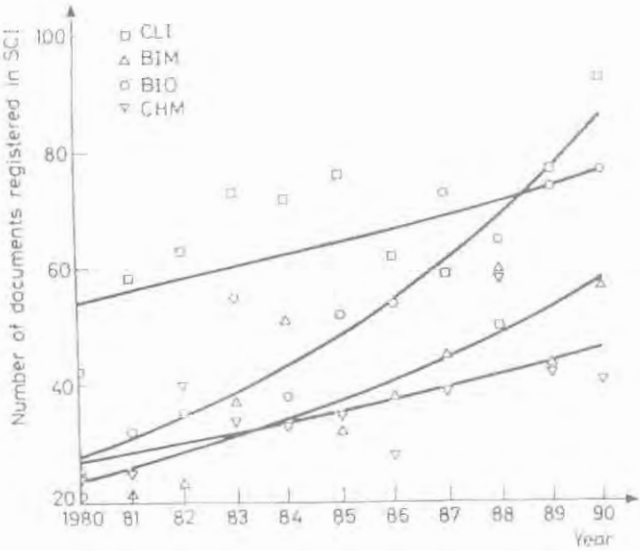

Fig. 5. International scientific cooperation with Mexico in Chemistry and the Life Sciences

The main international partners were the United States with a total of 2122 collaborations, France with 308, United Kingdom with 262, Canada with 231, West Germany with 215, and Spain with 192. The number of coauthored studies with all other countries was less than 100. Of Mexico's Latin American partners Brazil was the most frequent (n = 96) followed by Chile with 51 and Argentina with 42. In all cases there was a marked tendency for an increase in the frequency of published collaborations from 1980 to 1990.

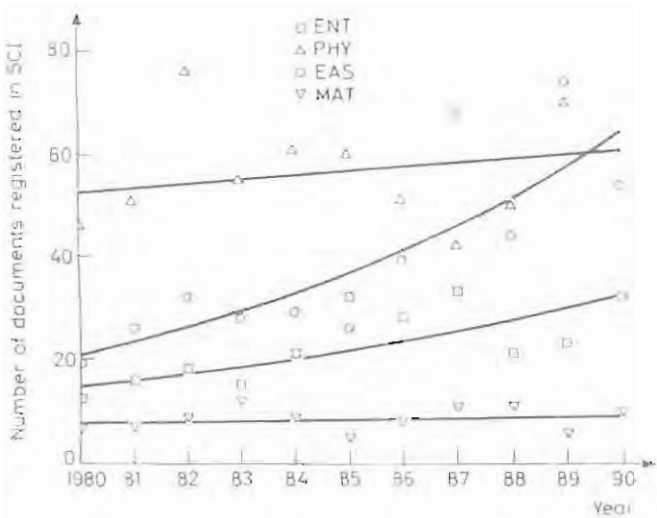

Fig. 6. International scientific cooperation with Mexico in Engineering and Technology; Earth, Space and the Exact Sciences

Figure 7 shows the trends in international cooperation of Mexican institutes with different regions of the world. The total number of collaborations with the USA or Canada was 2353, with European Community (EC) countries, 1154, and with Latin America (LA), 319. Although collaboration with Mexico increased from 1980 to 1990 in all cases, this was more marked with respect to USA and Canada, and the EC than with other LA countries in terms of absolute numbers. However, collaboration with LA increased 4.5 fold, while that with the EC increased by 3.2 and with the USA and Canada by 1.9.

The fields of cooperation (excluding Psychology and Multidisciplinary) with the most frequent partners varied considerably with respect to country. Clinical Medicine was a popular field of research collaboration with the USA and, to a lesser extent with Canada. The Life Sciences accounted for 56.4% of studies with the USA, 40.1%

with the UK, and 32.9% with Canada. Other European partners showed a lesser preference for collaboration in the life sciences. Physics was an important field for cooperation with Germany and Spain, 27.6% and 29.2%, respectively, as were the Earth and Space Sciences, 21.1% and 18.8%, respectively. There was also significant coauthorship in these two fields and in Chemistry with French scientists. Engineering and Technology was a field of few international partnerships except with Canada where it accounted for 16% of studies (Fig. 8).

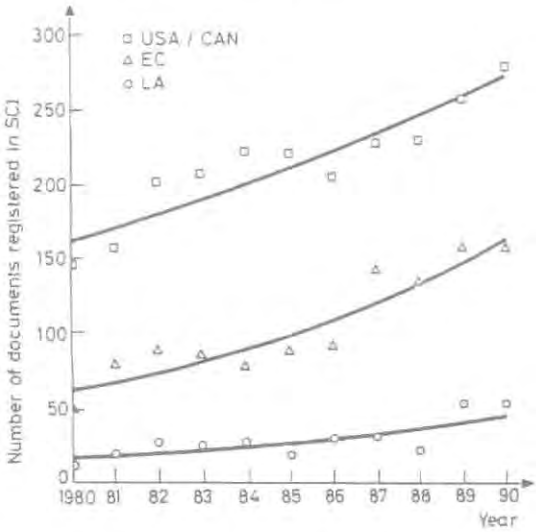

Fig. 7. Cooperation with North America, the European Community and Latin America. Note: Figures refer to sum of collaborations with individual countries within each entity

The general difference in coauthorship patterns of Mexican scientists with their European colleagues, and that with the rest of the American continent is further illustrated in Fig. 9. Cooperation with the USA and Canada, and with LA was heavily biased towards the Life Sciences, 54.1% and 58%, respectively. With the EC, this represented only 31.3%, while Physics, Earth and Space Sciences, and Chemistry occupy more important positions that any one of the three Life Sciences fields, 21.3%, 18.9% and 13.9%, respectively.

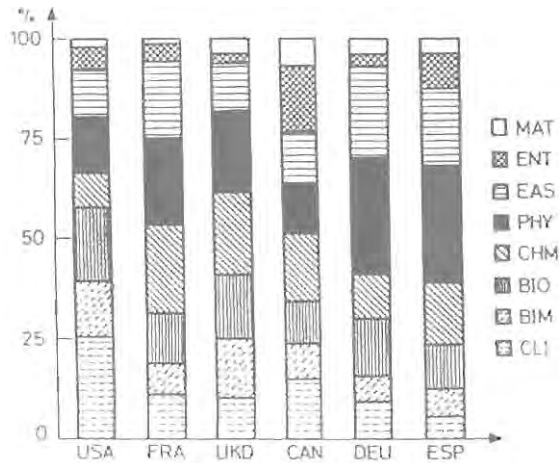

Fig. 8. Fields of international cooperation with the 6 most frequent partners

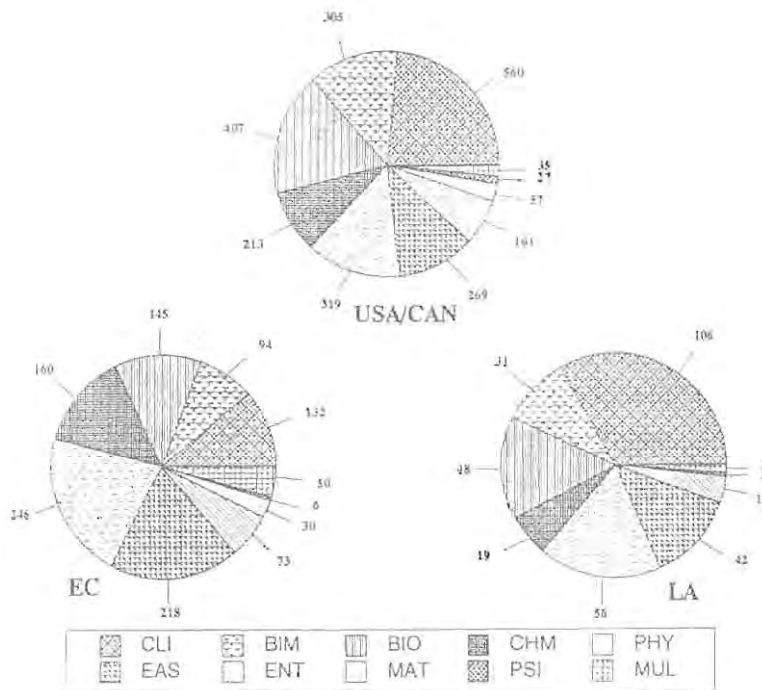

Fig. 9. Fields of international cooperation with North America (USA/CAN), the European Community (EC) and Latin America (LA). Note: Figures refer to the number of documents in the different subject categories published in collaboration with the three groups of countries

The majority of Mexican and foreign institutions taking part in bilateral or multilateral studies are the universities and other institutes of higher education. This situation is more marked with respect to cooperation with the USA and Canada and less marked, with the exception of the UK, with respect to the European countries, particularly France where slightly more participation was found with research institutes than with higher education establishments. Very little collaboration was found with the private sector, particularly on the Mexican side (Fig. 10).

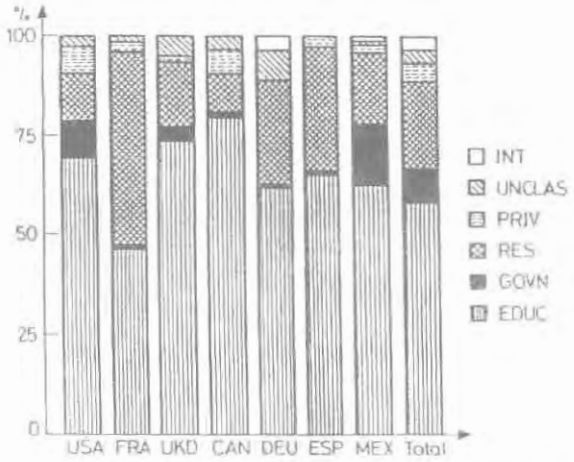

Fig. 10. Types of Mexican and foreign institutions (6 most frequent partners + total participating in international cooperation with Mexico). Note: CAN = Canada; DEU = Federal Republic of Germany; ESP = Spain; FRA = France; MEX = Mexico; UKD = United Kingdom; USA = United States of America

The 12 Mexican institutions with more than 100 international collaborations are shown in Fig. 11. The National Autonomous University of Mexico (UNAM Universidad Nacional Autónoma de México) published a total of 1616 studies with foreign institutions which represented 29.5% of its total output, followed by the National Polytechnic Institute (Instituto Politécnico Nacional) with 515 (28.4% of its total output) and the Autonomous Metropolitan University (Universidad Autónoma Metropolitana) with 128 collaborative studies (22.6% of its total output).

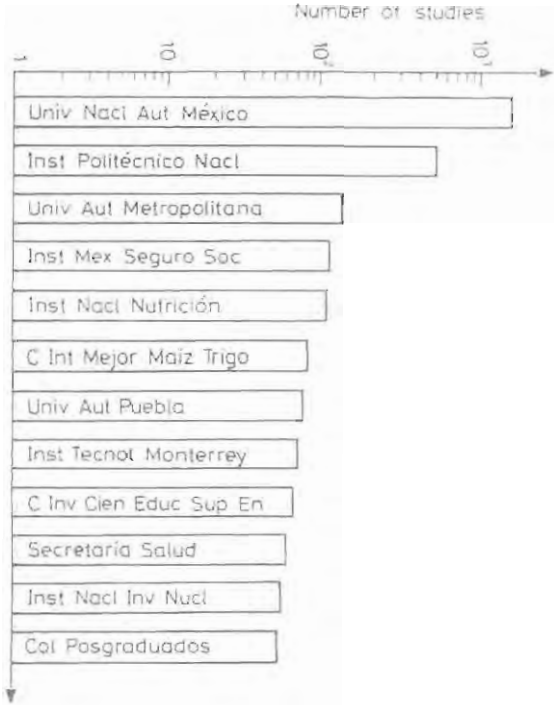

Fig. 11. Mexican institutions with the highest number of studies in international scientific cooperation

Table 2 shows the journal titles publishing more than 20 Mexican papers coauthored internationally from 1980 to 1990. Three of the top five places were occupied by Astronomy journals. *Physical Review B* published 64 of these articles, the *Astrophysical Journal* and the Mexican journal of astronomy and astrophysics (*Revista Mexicana de Astronomía y Astrofísica*) edited by the Institute of Astronomy at the UNAM, both publishing 63. The impact factors of these journals were varied ranging from 7.59 to 0.50.

The importance of international cooperation for the different geographic zones of the Mexican Republic is shown in Fig. 12. With the exception of the South, which showed the highest level of international partnership, the most active areas were those in the northern part of the country. The Federal District of Mexico City whose institutions were involved in over 70% of all international coauthorships showed a much lower level of international activity.

Table 2

Journals publishing > 20 Mexican studies in international cooperation

Title	Number of studies	Impact factor 1990
Physical Review B-Condensed Matter	64	3.62
Revista Mexicana de Astronomia y Astrofisica	63	0.79
Astrophysical Journal	63	3.30
Astronomy and Astrophysics	53	2.34
Abstracts of Papers of the American Chemical Society	52	0.50
Phytochemistry	39	1.15
Journal of Chemical Physics	35	3.49
Journal of Mathematical Physics	33	0.83
Physical Review C-Nuclear Physics	29	1.99
Crop Sciences	29	1.68
Biophysical Journal	28	4.73
Physical Review Letters	24	7.59
Phytopathology	23	1.67
Physical Review A-General Physics	22	2.09
Physics Letters B	22	3.12
Journal of Organic Chemistry	22	2.60
Clinical Research	22	1.37
Bulletin of the Seismological Society of America	22	1.45
Comptes Rendus de L Academie des Sciences Serie II-Mecanique	21	0.50
Solid State Communications	21	2.06

Fig. 12. Percentage of Mexican studies in international cooperation according to geographic zone

Discussion

Our results confirm increasing levels of international cooperation in Mexican science, not only in absolute numbers but also with respect to increasing percentages. In 1989 and 1990 one in three Mexican SCI documents was internationally coauthored. This figure is similar to that reported for Israeli science[9] and shows an increase over the figure of one in four reported by *Schubert* and *Braun* for Mexican science between 1981 and 1985.[10] *Narvaez-Berthelemot* et al.[11] in a study from 1981 to 1986, however, report a much higher incidence for Mexico of 31%.[12]

While the USA remains unchallenged as the international partner of Mexico in the science and technology endeavour, especially in the Life Sciences fields, nonetheless cooperation with Europe is gaining importance. A rise in European coauthorship from 1987 onwards is probably a result of the implementation in 1986 of the EC's International Science Cooperation (ISC) programme with Mexico, and an increased output of coauthored papers between Mexico and Spain due to the Spanish National Research Council's programme with Latin American institutions.[13] An increase in the number of joint Mexican/EC papers in SCI as a result of the EC initiative has already been described.[14] Cooperation of Mexico with other Latin American countries is increasing but is still insignificant compared to that with industrialised countries.

The fact that Mexico and the United States are neighbouring countries compounds the effect that American science has on world science generally. According to *Schott*, typically about a third of the influence upon research of a country is from American science.[15] Institutions in the northern areas of Mexico show higher percentages of international collaboration than the major centres of Mexican scientific research suggesting that proximity leads to higher levels of cooperation. Subjects of mutual concern, particulary in the biological and medical fields, such as the presence and spread of animal and plant diseases, would be obvious choices for US/Mexico research partnership.

The extent of international collaboration is probably considerably greater than that represented in SCI. Although perhaps not frequently published in Mexican national journals, some internationally coauthored articles will most likely appear in international journals not covered by the SCI. Taking into consideration that the SCI is biased towards US journals, joint articles with European colleagues are probably under-represented by our results. Also, as pointed out by *Czapski* et al.,[9] scientists spending sabbaticals abroad do not necessarily include their home institutional

address in papers published as a result of joint research activity during this period. Ironically this activity, which represents international cooperative activity in its purest form, when counterparts are actually physically working together on a day-to-day basis for a prolonged period, will not be apparent in the international databases, using the methodology proposed by *Frame* and *Carpenter*.[2] In contrast, discussion papers registered in the SCI database will be counted as international partnerships due to the ISI's method of including all discussants addresses in the same record. Hence the apparent high level of international coauthorship in discussion papers found in the present study. The relationship between authors in a discussion paper represents a mutual interest rather than a collaboration. Some authors suggest that only three or four types of SCI articles (articles, notes, reviews and, perhaps, letters) should be taken into consideration as these represent true contributions to the fields in question as indicated by significant citation rates.[12]

In spite of these limitations *Lewison* et al. consider that SCI is not seriously flawed as a statistical source of information on patterns of international collaboration in science among the nations of Latin America.[16] However, the results of an earlier study published by our group indicate that coverage of the database chosen as the source of internationally coauthored articles will affect not only the size of resulting population but also the areas where this collaboration is shown to take place. Using a multidisciplinary database containing predominantly national journals will retrieve more studies in applied areas than a similar search in SCI which is biased towards more universal, basic research.[17]

Latin American scientific research is concentrated in the universities,[18] and particularly in the dominant government funded, large national universities. The mega National University of Mexico (UNAM) accounts for approximately 42% of Mexico's SCI contributions (unpublished results of the author) and 44% of all foreign collaborations. Not surprisingly then university-university partnership is dominant in this activity. In the case of collaboration with France, however, research is equally as important with French research centres as it is with French universities, probably due to the strength of the national network of research centres. A weak link between Mexican universities and the private sector, both at home and abroad, is confirmed by our results.

There is some discussion as to whether high levels of international collaboration in the case of scientific communities from developing countries represent a strength or a weakness. Do foreign scientists from more developed countries actively search out the developing country research for his/her particular expertise or local situation,

or does the developing country scientist need the experience and facilities offered by foreign partner in order to carry out research? If, as *Pao* points out,[19] scientists collaborate to procure funding, the collaboration will be of equal benefit to both parties. The motivations and rewards from cooperative research will depend upon the circumstances prevailing in individual cases, few of which will correspond entirely to either of the two extremes mentioned above. What is important is that international coauthorship for developing countries is one of the indicators, while not the only one, of incorporation into international scientific networks necessary for the advancement of science and technology in these countries.

Most collaborations, it appears, come about in a spontaneous manner, sometimes as the result of an informal contact made during a scientific meeting suggesting that the scenario for the collaboration (a common research interest, the need of a particular piece of equipment or expertise, for instance) is in place before the contact takes place. The availability of funding as part of a formal programme of international collaboration in science will provide the bilateral research project with possible means of support.

Many developing countries, such as Mexico, offer unique conditions for carrying out research which might not be available to the foreign researcher except through contact with a local scientist. The tropical environment is almost exclusive of developing countries, as is the traditional use of medicinal plants, of much interest in the international context to many groups of scientists, among them biologists, environmentalists, and ecologists. It is not surprising, therefore, to find a growing tendency for foreign cooperation with Mexico, especially in the biological fields.

Although the present paper indicates the extent to which Mexican scientists publish jointly with foreign colleagues, it tells us little about the characteristics of this joint activity. In order to establish adequate policies with respect to cooperation in science with foreign institutions, we need to know more about the special circumstances conducive to this activity and necessary for ensuring its success. For a complete picture, we should look beyond purely scientific consideration to the possible effects of social, cultural and other factors, such as compatibility of goals, personality traits and ways of working of the scientists involved.

There is little doubt that international cooperation is here to stay. Further research is, therefore, required to determine the motivations and mechanisms underlying this activity, especially in the case of the developing world where it equates to the integration of national scientists into the global scientific community.

The author wishes to thank *Héctor Delgado* for the design of the database used in this study, and *Angélica Ma. Rosas, Gustavo Blancas, Esther Ramírez, Margarita Rodríguez* and *Miguel Angel Ramírez* for technical assistance.

References

1. T. SCHOTT, Scientific productivity and international integration of small countries: Mathematics in Denmark and Israel, *Minerva*, 25 (1987) 3–20.
2. J. D. FRAME, M. P. CARPENTER, International research collaboration, *Social Studies of Science*, 9 (1979) 481–497.
3. M. LECLERC, Y. OKUBO, L. FRIGOLETTO, J. F. MIQUEL, Scientific co-operation between Canada and the European Community, *Science and Public Policy*, 19 (1992) 15–24.
4. H. F. MOED, R. E. DE BRUIN, A. J. NEDERHOF, R. J. W. TIJSSEN, International scientific co-operation and awareness within the European Community: Problems and perspectives, *Scientometrics*, 21 (1991) 291–311.
5. J. M. RUSSELL, N. NARVAEZ-BERTHELEMOT, Use of the bibliometrical method to determine the scientific activity of Latin America: The case of international co-operation, *International Journal of Information and Library Research*, 4 (1992) 127–137.
6. J. O. ALONSO-GAMBOA, Catálogo de instituciones registradas en la base de datos Bibliografía Latinoamericana (Biblat, Clase y Periódica). 2ª versión. Centro de Información Científica y Humanística, Universidad Nacional Autónoma de México, México, DF, 1990.
7. E. NOMA, Subject Classification and Influence Weights for 3,000 journals, CHI Research/Computer Horizons, Inc., Cherry Hill, New Jersey, 1986.
8. *Journal Citation Reports*, A Bibliometric Analysis of Science Journals in the ISI Database. 1990 Science Citation Index. Institute for Scientific Information, Philadelphia, 1991 [Microfiche Card 2].
9. G. CZAPSKI, A. FRENKEL, D. KOHN, A. SHOHAM, Cooperation between Israeli and foreign researchers, *Scientometrics*, 25 (1992) 381–400.
10. A. SCHUBERT, T. BRAUN, International collaboration in the sciences, 1981–1985, *Scientometrics*, 19 (1990) 3–10.
11. N. NARVAEZ-BERTHELEMOT, L. P. FRIGOLETTO, J. F. MIQUEL, International scientific collaboration in Latin America, *Scientometrics*, 24 (1992) 373–392.
12. See notes and comments.
13. M. T. FERNANDEZ, A. AGIS, A. MARTIN, A. CABRERO, I. GOMEZ, Co-operative research projects between the Spanish National Research Council and Latin American institutions, *Scientometrics*, 23 (1992) 137–148.
14. C. KESSLER, International Scientific Co-operation. Consolidated Report of Activities 1986–1990 EC-Mexico, Commission of the European Communities, Scientific and Technical Communications Unit, Directorate-General Telecommunications, Information Industries and Innovation. Publication no. EUR 13970 EN, Brussels, 1992.
15. T. SCHOTT, International influence in science: Beyond center and periphery, *Social Science Research*, 17 (1988) 219–238.
16. G. LEWISON, A. FAWCETT-JONES, C. KESSLER, Latin American scientific output 1986–1991 and international co-authorship patterns, *Scientometrics*, 27 (1993) 317–336.
17. N. NARVAEZ-BERTHELEMOT, M. ALMADA DE ASCENCIO, J. M. RUSSELL, International scientific collaboration: cooperation between Latin America and Spain, as seen from different databases, *Journal of Information Science*, 19 (1993) 389–394.
18. H. M. C. VESSURI, The universities, scientific research and the national interest in Latin America, *Minerva*, 24 (1986) 1–38.
19. M. L. PAO, Global and local collaborators: a study of scientific collaboration, *Information Processing and Management*, 28 (1992) 99–109.

Notes and comments

To Ref. 12. The discrepancies in the figures for the level of international collaboration of Mexican science produced by different groups could possibly be explained by the use of distinct SCI-derived databases including different document types or based on slightly different journal sets. Braun and the Hungarian group argue for the use of articles, letters, notes and reviews in evaluation counts [T. BRAUN, W. GLÄNZEL, A. SCHUBERT, Some data on the distribution of journal publication types in the Science Citation Index database, *Scientometrics*, 15 (1989) 325–330] while Narváez-Berthelemot and the group at LEPI in their appraisal of international scientific cooperation used the fixed journal set developed by Computer Horizons Inc. (CHI) in 1981 (11). The CHI database includes only three document types, namely articles, notes and reviews. In the present study I took into account all SCI-registered documents, regardless of type, for a comprehensive analysis of internationally coauthored Mexican scientific research.