COLLABORATION AND RESEARCH PERFORMANCE IN SCIENCE: A STUDY OF SCIENTISTS AT THE NATIONAL UNIVERSITY OF MEXICO (UNAM)

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

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ABSTRACT

The present study looks at the relationship between collaboration and performance in science in a sample of 15 Mexican researchers from the National University of Mexico (UNAM) with high visibility in the international scientific literature. Three scientists were chosen from each of the following fields where the UNAM is known to make important contributions to world science: Biomedical Research, Chemistry, Physics, Astronomy and Astrophysics, and Geosciences. The links that the scientists had established with the international scientific community were analysed using a combination of methodologies. Curricular, bibliometric and scientometric data were used to determine aspects such as: a)the research trajectory and environment of the 15 scientists; b)their publications in mainstream and non-mainstream literature and c)the relationship of these parameters with other variables, such as age and disciplines; d)co-authorships with institutional, national and foreign colleagues; e)the effect of sabbaticals and other prolonged visits to institutions abroad on the production of papers and co-authorship patterns; and f)the relationship between co-authorship and citations patterns. Taking into consideration that behind the bibliometric data is a multi-layered social world constructed of and driven along by the communication behaviour of individuals, which can be determined only by consulting the scientists concerned, the 15 scientists were asked to answer a questionnaire and were subsequently interviewed. Questions were designed to test the validity of assumptions derived from the analysis of the data in the first part of the study, as well as to determine the importance of links established with colleagues abroad, especially during sabbaticals. Results indicate the importance of contact and collaboration with foreign colleagues in the development of the research careers of Mexican scientists, as well as for facilitating their integration into the wider scientific community. The repercussions of this individual activity for the development of Mexican research is discussed, particularly in relation to possible gains for other colleagues and in the training of new researchers.

Chapter 1

Introduction

Science, together with technology, has long been recognised as an essential driving force in the development process. Developing countries (DCs) therefore require an indigenous scientific infrastructure in order to decrease their dependence on the more scientifically advanced countries where the production and efficient utilisation of scientific knowledge is concentrated.

Over the centuries scientific ideas and institutional arrangements have diffused from a centre, located where scientists have recognised the greatest accomplishments. The values and fundamental direction of the intellectual life of the centre are taken up by the peripheral communities. The adoption of models emanating from the metropolis is indicative of the true links of the universal system of centre and periphery in the global intellectual community.

Because of their isolation from the centre, scientists from peripheral communities often find themselves left out of the intellectual discourse that is at the very foundation of the knowledge enterprise. Countries on the periphery must therefore seek means to integrate into the international scientific community. One of the ways to compensate for the scientific smallness of the peripheral communities is to collaborate with institutions in countries at the scientific centre. Contact between scientists across national borders has become an increasingly important part of research work such that it is now generally recognised that an endogenous scientific community in a peripheral country can develop only when its members have sustained links with other researchers from the scientifically advanced countries.

Experience would suggest that the most productive scientists from DCs are those who have had the opportunity to establish and maintain communication with experienced scientists from the most advanced Western countries. Contact is thought to be facilitated by study abroad or by visits to foreign institutions. A logical outcome of this exchange of information would be the possibility of working together leading to the co-publication of scientific papers. Collaboration in science is said to enhance productivity, mobility and visibility of the researchers concerned such that it could be expected that the most productive scientists from DCs would frequently be co-authoring with scientists from abroad.

The objective of the present thesis is to examine the relationship between performance in science and the links established by Mexican scientists with the international scientific community The study analyses the case histories of productive scientists to determine how "success" might be related to international visibility and integration into the wider community of science. Theirs roles at the interface between internal and external interactions of their research environment are also determined.

The project contributes to the understanding of the role and mechanisms of international integration and visibility of DC scientists through an analysis of the formal and informal links, publishing patterns and influence patterns of 15 of the most highly productive Mexican scientists. A variety of links are analysed including publication links; co-authorship links; citation links, as well as those established through doctoral, postdoctoral, sabbatical and other prolonged stays spent in foreign institutions.

The researchers, all from the National University of Mexico (Universidad Nacional Autónoma de México, UNAM), the largest institution for higher education and scientific research in the country, were chosen from five research fields where the UNAM is known to make important contributions to world science; namely, Biomedicine, Chemistry, Physics, Astronomy and Astrophysics, and Geosciences. The selection of scientists, three from each of the fields, was based on the production of papers in the mainstream literature.

Their links with and visibility within the international scientific community were analysed using a combination of methodologies. Curricular, bibliometric and scientometric data were used to determine aspects such as; the general characteristics and research trajectory of the 15 scientists; the number and characteristics of their publications in mainstream and non-mainstream literature and the relationship of these parameters with other variables, such as age and disciplines; co-authorships with institutional, national and foreign colleagues; the effect of sabbaticals and other prolonged visits to institutions abroad on the production of papers and co-authorship patterns; and the relationship between co-authorship and citations patterns.

Taking into consideration that behind the bibliometric data is a multilayered social world constructed of and driven along by the communication behaviour of individuals, which can be determined only by consulting the scientists concerned, the 15 scientists were asked to answer a questionnaire and were subsequently interviewed. Questions were designed to test the validity of assumptions derived from the analysis of the data in the first part of the study. Scientists were asked to describe the composition and dynamics of their internal research groups as well as their opinion on relevant aspects of their international scientific activity, such as the importance of links developed with colleagues abroad for the development of their research activity, and the motivations, mechanisms and benefits of sabbatical and other periods spent abroad. While it is generally considered to be the scientists themselves who initiate and perpetuate contact with foreign colleagues, the institutional context is important for providing the necessary conditions under which these collaborations can flourish.

Although the sample of scientists in the present study is small in absolute terms, it represents almost 6% of top level scientists in the country. The strength of the study lies in its in-depth analysis of individual scientists, and the use of different methodological approaches to describe both the formal domain of publication, co-authorship and citation activities, as well as the informal domain of social and communication processes taking place between the actors involved.

As is appropriate for case studies, much of the material is described at the level of individual scientists. However, some kinds of data (particularly numerical data) are aggregated over groups of scientists in the same discipline, or over all those studied. It is in the nature of case studies to cast doubt on the validity of such aggregations as every individual is unique. However, it is felt that the aggregations both shed light on the individual cases, and in some instances, appear to suggest broader patterns.

The thesis is divided into thirteen chapters and includes five appendices containing detailed data from some of the analyses, as well as the questionnaire and interview questions. Chapter 2 reviews the literature on the characteristics of science in developing countries and introduces the reader to the centre/periphery model to define the relationship between the scientifically advanced countries and those having only small scientific communities. Other topics covered in this chapter are evaluation techniques and science policy issues. Chapter 3 discusses the current state of the literature on the constraints to scientific communication in developing countries and the ways that scientists from peripheral countries integrate into the international scientific community through contact and collaboration with colleagues from abroad. A general panorama of scientific research in Mexico is given in Chapter 4.

Chapter 5 presents the framework, goals and objectives, and general hypotheses of the present study. Proposals arising from the general hypothesis are also included. The methodology and procedures are described in Chapter 6.

Results and discussion of findings are presented in Chapters 7 to 12. In some of these qualitative and bibliometric data are combined to achieve a better understanding of certain aspects under study. Bibliometric data illustrating the role of the UNAM in Mexican scientific research as a whole as well as in the five research fields of the 15 scientists analysed in the present study are shown in Chapter 7. Chapter 8 contains the results and discussion of the general characteristics, research trajectory and environment of the 15 UNAM scientists while Chapter 9 gives the bibliometric profiles relating to different aspects of their production, citations and co-authorships. Chapter 10 takes into account both bibliometric and interview results when looking at the effect of sabbaticals on the production and international co-authorship patterns of 13 of the 15 scientists. The links between countries, institutions and authors co-authoring with eight of the 15 scientists and those citing their work are presented and discussed in Chapter 11. The answers given by the 15 scientists to questions on their relationships with both the international and their national scientific communities are analysed in Chapter 12.

Conclusions including policy implications and suggestions for further research are presented in Chapter 13 which is followed by the reference list of literature cited in the present work.

Chapter 2

Science in Developing Countries

2.1 Introduction

Even though science is a global phenomenon, in reality there are limitations to the universality of science which are largely the result of vast differences in the social, intellectual and economic capacities of different countries. As a result of these inequalities, production and efficient utilisation of scientific knowledge are highly concentrated in a few countries, which account for only about one quarter of the world's population (Moravcsik 1985b; Arunachalam 1995). Science is more skewed than the distribution of wealth among nations with less than ten countries accounting for more than 75% of journal articles (Frame, Narin et al. 1977).

In his discussion on why science should be carried out in developing countries (DCs), Moravcsik puts forward a number of reasons in its favour all of which are related directly or indirectly to science as a necessary activity for increasing autonomy and for improving the standard of living of the general population. The sharing of science, he believed, is not an altruistic or a charitable gesture but a necessary process in harmony with the aspirations of countries around the world. Science and technology are indispensable to political and military power, and the concentration of these in the hands of a few countries is generally considered undesirable (Moravcsik 1975).

It is now a widely held view that the problem of national development must be linked to the formation of an indigenous scientific capacity. (Dedijer 1963). Together with technology, science has long been recognised as an essential driving force in the development process (Arunachalam 1995). In 1975, Moravcsik and Ziman wrote that insufficient thought and effort had been given to creating and maintaining indigenous scientific activity in the less developed countries. They considered that the actions of the countries concerned to be uncoordinated and often based on a very poor grasp of the real issues involved. They put much of the blame on the world scientific community for their negligence in responding to the plight of this small fraction of its members. If only 10% of the world's scientists could be effectively involved in cooperation with the scientific communities in the less developed countries, a great stride would have been taken across the gap (Moravcsik and Ziman 1975). Recently, Gaillard examined the mechanisms, ranging from technical assistance to collaborative research programmes, evolved over the last three decades to promote and facilitate scientific cooperation between the industrialised world of the North and the less developed nations of the South. He recognises that one of the constraints for their success is the asymmetry of the collaborations and the dominance of the partners from the North (Gaillard 1994b).

Other arguments in favour of the scientific activity of DCs are focused on humanistic and cultural considerations of research rather than its implications for the physical well-being of society. Science and technology are seen as one form of higher activity to which humanity can and does aspire (Moravcsik 1975). In the same line of thought Lomnitz, a Mexican researcher, believes that scientists as creative members of society, skilled in their chosen profession, and committed to scientific truth, are capable of making more profound changes in society than the research results they produce (Lomnitz 1981).

The psychological components of self-confidence and high morale are also considered necessary to overcome the feelings of inadequacy inherent in peripheral societies (Shils 1976). In order to achieve this, Moravcsik emphasises the need for explicit recognition from and cooperation with the worldwide scientific community (Moravcsik 1978).

Various authors have questioned if science in DCs is different or should be different, from that carried out in the scientifically advanced countries. The existence of a science "special" to DCs was seriously challenged by Moravcsik two decades ago. Activities in basic and applied research, he argued, must by nature adhere to certain universal practices regardless of where, why, how, or by whom they are carried out. Science in DCs is therefore not inherently different from science in the industrialised world, rather, it is at an earlier stage of development (Moravcsik 1978).

The cognitive content of science is, with rare exceptions, context free, rendering scientific findings universally valid, irrespective of who discovers them (Arunachalam 1988; Arunachalam 1995). Roche also questioned the belief that DCs must invent a "new type of science", radically different from Western science. From a historical standpoint science first spread in the USA, Canada, and other countries when these were still in the process of development. Moreover, Western Science has been widely proved to be logically satisfactory, predictive, and practically efficacious (Roche 1987). Dedijer described the peripheral countries that, either in absolute or relative terms, have no science as possessing pre-research cultures where research is no more than an insignificant category in the national division of labour (Dedijer 1963).

Those countries which make only a small contribution to the advancement of knowledge are commonly referred to as being on the periphery while those few countries making the largest contributions are considered to make up the scientific centre. Different interpretations have been given to the centre/periphery dichotomy, nonetheless there is general agreement on the specific conditions and restraints shared by peripheral scientific communities of the developing world regardless of their geographical location or their particular national heritages.

2.2 SCIENCE ON THE PERIPHERY

2.2.1 *Overview of World Science*

In recent history Western science has dominated the world scene, with its centre shifting from the overriding leadership at the end of the XIX century of the Western European countries of France, the United Kingdom and Germany, to a growing influence of the United States of America from the second quarter of the 20th century (Shils 1976). The consolidation of Russian science and the rise of the new technological powers, principally Japan whose R & D activities greatly expanded during the 1980's (Okubo and Miquel 1991), put other important players on the world map of contemporary science.

Scientometric data demonstrate that from 1989-1993, the USA had the highest share of world scientific publication output at 33.78%, followed by the United Kingdom with 8.09%, Japan with 7.89%, Germany with 6.32%, the USSR with 5.86%, France with 4.79% and Canada with 4.16%. All other countries had % figures of <3. India is the most productive developing country, occupying 11th position with a 1.87% world share. The People's Republic of China, and Taiwan ranked 15 and 23, respectively, ahead of the most productive LA country, Brazil, ranked immediately after Taiwan (Braun, Glänzel et al. 1995a). The overall pattern for 1980-84, was similar to that for 1985-89 with Japan increasing its % world share of papers from 6.7% in the earlier period to 7.5% in the second. The notable difference with respect to 1989-93 is that unified Germany overtook the USSR which had held fourth position during the eighties (Braun, Glänzel et al. 1994a; Braun, Glänzel et al. 1994b).

Participation in international scientific literature of the DCs accounts for approximately 5% which Garfield considers remarkable considering the social, economical, and sometimes, political adversities present in many developing nations (Garfield 1987). The Latin American (LA) contribution has increased in recent years with its world share of scientific articles rising from 1.3% to 1.8% in the last decade, making its growth rate surpass that of the world average (Krauskopf, Vera et al. 1995c). Four countries, Brazil, Argentina, Mexico, and Chile account for about 85% of LA papers (Anon 1995).

Brazil is the most productive of the LA countries contributing 0.49% (world ranking=24) of the world total of 1989-1993 mainstream publications, followed by Argentina with 0.30% (ranking=30), Mexico with 0.22% (ranking=35), Chile with 0.16% (ranking=39), and Venezuela with 0.06% (ranking=45). Ranking positions and percentages vary according to scientific field but in general the positions of the LA countries vary little in relation to each other or in relation to the most productive countries (Braun, Glänzel et al. 1995a; Braun, Glänzel et al. 1995b).

Brazil is the leading Latin American country in all fields of Mathematics, Engineering, Chemistry and Physics, except in the case of Inorganic Chemistry and Engineering, and Physical Chemistry where Argentina holds first place (Braun, Glänzel et al. 1995a). With respect to the Life Sciences, Brazil holds one of the first positions in the world publication share in Research Medicine (1.46%) ranking 12, while in General Medicine, Chile is the most productive LA country, ranking 17 with 1.01% of the world share. In Neuroscience both Argentina and Mexico publish more than Brazil. Argentina's contribution to Food Science and Agriculture is slightly above that of Brazil (Braun, Glänzel et al. 1995b).

2.2.2 *Concept of Centre and Periphery*

Although scientific knowledge belongs to no nation, recognition for the advancement of universal knowledge is assigned to those countries responsible for the discoveries (Meadows 1974). Resulting scientific ideas spread from their place of creation, crossing social and national boundaries to influence the course of research elsewhere. The global network of scientific influence, however, is not equally strong between all communities (Schott 1988). The resulting stratification can best be described in terms of Shils model of centre and periphery in society (Shils 1975).

Shils proposed the existence of a central value system that rests, in a fundamental way, on the need of human beings for incorporation into something which transcends and transfigures their concrete individual existence. This is the idea that societies have a centre to which their members gravitate and which influences their conduct in a variety of ways. The centre does not impose itself by means, such as coercion and manipulation, rather it should be seen more as a place where decisions are made and coordinating functions performed.

The concept of centre and periphery in the intellectual community resulted from Shils observations of the anglophilia of Indian scholars. In his essays on intellectuals in DCs he emphasises that the differences that exist between the intellectual communities of the centre and periphery relate not only to individuals but also to institutions such as universities, research institutes, scientific journals and publishing houses. The fact that the centre or metropolis is the seat of creativity, whose standards -moral, cultural, political and intellectual - are taken as the yardsticks by which other societies judge themselves, then whatever emerges from the centre is deemed superior, at the same time conferring inferiority and a sense of inadequacy, on whatever pertains to the periphery. Scientific training carried out at universities of the scientific centre, for instance, inspires greater respect and is more prestigious in general than education received locally (Shils 1976).

The periphery adopts the preferences and values of the centre, evaluating its own performance using criteria developed and applied at the metropolis. As Reddy points out with respect to Indian science, DCs look to the West for their criteria of excellence and their source of recognition (Reddy 1974). The fundamental direction of the intellectual life of the centre is taken up by the peripheral communities. Goals of research in DCs are by and large set on the pattern of goals of research in the advanced countries (Rahman 1975). Place of publication, selection of research topics, concepts and study techniques, and the adoption of models emanating from the metropolis, are indicative of the true links of the universal system of centre and periphery in the intellectual community (Shils 1976). Third World countries, for instance, have copied the Western model of university development with its accompanying Eurocentric knowledge systems (Selvaratnam 1988; Vessuri 1994). Science and technology indicators produced by peripheral countries mirror those traditionally generated in the industrialised countries (Stolte Heiskanen 1986).

2.2.3 *Definition of Centre and Periphery*

The term "science on the periphery" is often used exclusively with respect to DCs where science is seen mainly as a motor for development and modernisation. Nonetheless, it can be argued that the periphery embraces all countries which for historical, economic, socio-cultural or other reasons, produce a smaller share of global R & D activities, regardless of their state of development (Stolte Heiskanen 1987). According to Stolte-Heiskanen, the emphasis on the level of development as the crucial distinction between centre and periphery, obscures the fact that many of the small economically but scientifically advanced countries, for instance in Europe, are also on the periphery due to factors associated with size, language, or history. While the reasons for the countries' peripheral positions may vary, they share similar problems that arise out of their peripherality, including that of their relationship to the centre.

If we recognise the existence of two distinct civilisations, one which is based on the growth of scientific knowledge, the other demonstrating a more or less passive acceptance of results generated by the first (Salomon 1995), then our centre/periphery model would make the distinction between the developed, industrialised countries in the North whatever their size, and the developing world to the South. Shils also refers to a similar division between creators and consumers (Shils 1976). The use of the terms Paradisia and Dominatia by Moravcsik and Ziman also relates directly to this same conception (Moravcsik and Ziman 1975). They sustain that in Dominatia (= the powerful metropolitan countries) scientific knowledge is a natural product as well as the fuel of the advanced industrialised societies; in Paradisia it is a foreign import, an exotic plant that has not yet established and seeded itself in new soil.

Different levels of peripherality are found not only between countries but also within countries with respect to the different scientific fields (Arunachalam 1990b). Scientists in DCs who are working in basic research topics at the forefront of mainstream scientific activity are likely to have more in common and to be in closer contact with the centre than researchers studying problems of local interest only. Isolation from the metropolis may not always be a result of different intellectual preferences or levels; lack of communication technologies and access to information also result in margination.

While economically advanced countries with small scientific communities are likely to hold similar positions with regard to peripherality, large differences in the degrees of marginality exist between DCs. It is no longer possible to consider DCs as a single entity (Gaillard 1994a). The scientific status of the poorer African countries is not comparable with that of the larger Latin American countries, such as Brazil or Mexico. The fact that universities and scientific research centres in DCs are heavily concentrated in the capital cities, generates a local centre/periphery division within these countries which share many of the elements characteristic of that pertaining to the international sphere of scientific activity (Jiménez, Campos et al. 1991).

Although we have seen from certain perspectives that science on the periphery can refer to all those countries which make only small contributions to the global scientific effort, the particular conditions of science in DCs make them a special case in any discussion of the characteristics and conditions of peripheral scientific research. The state of underdevelopment of countries in Latin America, Asia, or Africa signifies different priorities and fewer resources, both material and human, for scientific and technological advancement than in the small industrialised countries such as, say, Denmark, Belgium, or Israel, even though they may share certain conditions inherent in peripherality, such as the isolation of their scientific communities due to national language and publication, and the lack of critical mass with respect to many scientific disciplines.

2.2.4 *Location of Centre and Periphery*

Each individual member of society has a mental picture of where the centre and periphery are located, although consensus is often reached by conglomerates of societies with respect to the typography of the nuclear and peripheral zones. The metropolis of a few countries becomes the metropolis of the world in general (Shils 1976). This idea that the intellectual centre is perceived rather than predetermined, whose location will depend upon a number of factors, such as field, subfield, stage of career, research goals and marginality of the individual scientist, has also been put forward by other authors. Following their analysis of the mobility of scientists between France and the United States, Carlson and Martin-Rovet affirm that a scientific centre is simply where the scientists are attracted to, and that the establishments of the centre maintain high scientific standards, concentrate resources, and are capable of delivering scientific training, access to equipment and useful credentials to scientists and scientific communities on the periphery (Carlson and Martin-Rovet 1995). In other words, an alliance with the scientific centre can confer both material advantages and prestige on institutions and individual scientists from the peripheral countries.

Regardless of their level of development, all countries will look to the most influential and powerful communities in science and technology as their scientific centre. The United States is generally considered to be the mecca of the scientific world. According to Schott, the degree to which the United States is the global centre of science is shown by the fact that, normally, about a third of the influence upon research in a country is from US science (Schott 1988). A community's average influence on others is an operationalisation of its centrality. The United Kingdom is a secondary centre with the (ex-) Federal Republic of Germany as a third but weak centre. This relationship applies when analysing both citations given to each country's work (as measured using the *Science Citation Index* [SCI]) and the distribution of Nobel Prizes in Physics, Chemistry and Medicine.

In recent years studies have been published which question the continuing validity of the classic centre/periphery asymmetry in the face of what is described as a new world order. Leclerc and Gagné write that the old scientific order, which required a stable central hemegony, long represented by the US, has given way to centres of gravity and coherence organised on a continental scale. This collectivisation of the centre has important consequences for those countries that are more or less dependent, in that it implies the rejection of a traditional model for the establishment of relations based on the vertical stratification of relations between centre and periphery. Being on the periphery of science no longer means exclusion from scientific networks (Leclerc and Gagné 1994).

2.2.5 *Intellectual Isolation of the Periphery*

The fact that science is a communal undertaking makes isolation from other scientists a common plight of DCs scientists (Roche 1987; Arunachalam and Manorama 1989). The periphery is not necessarily geographically distant from the scientific centre; but rather its isolation is intellectual. Countries on the periphery of science are left out of the intellectual discourse that is at the very foundation of the knowledge enterprise. Insularity results from an inadequate access to relevant information sources, and poor communication and information exchange within the local scientific community and with the international invisible college (Arunachalam 1995). A study on the publication and citation rates of different areas of Indian research showed that ease of access to information and traditions (of long history, international exchange, emergence of sound leadership, etc.) play a role in strengthening the scientific enterprise of a developing country (Arunachalam and Manorama 1988).

In science, communication is basically open, involving the exchange of information between the producers of discoveries (i.e. the centre) and an audience consisting of other workers in the field (Cole and Cole 1973). So called invisible colleges are merely groups of scientists working in the same speciality who exchange information and occasionally meet at conferences. Observed differences in the effective scopes (in the context of scientific communication, this is perceived as the extent to which a scientist makes use of communication facilities) of scientists is possibly related to their location in the stratification system. Taking into consideration that peripheral scientists in general occupy the lower echelons of the stratification system in science, this implies that both their low social status and the poor information technology infrastructure of DCs will work against their ability to integrate into the global scientific community limiting their possibilities of information access and exchange.

In their discussion on the universalism and its consequences in science Cole and Cole conclude that science departs from the ideal of universalism only where the process of accumulative advantage is at work. Scientists who occupy the most prestigious instrumental and symbolic positions stand out as a group whose contributions to the advancement of knowledge has been considerably above average. The high level of universalism in science only indicates that work will be judged upon its merits (Fuchs 1996). It does not however ensure that all scientists will have an equal chance of producing high-quality work and of receiving recognition (Cole and Cole 1973). These findings have important implications for scientists from the DCs in that their isolation and inferior intellectual environment and material working conditions make them less likely or able to aspire to high positions within the social system of international science.

The work of the Cole brothers also discusses the Matthew Effect in science which consists "in the accruing of greater increments of recognition for particular scientific contributions to scientists of considerable repute and the withholding of such recognition from scientists who have not yet made their mark" (Cole and Cole 1973). Once again DC researchers will be at a disadvantage in the global scientific environment, however it is most likely that the best scientists will be favoured by this effect within their own national communities. Cole and Cole suggest that local prestige probably goes a long way to make up for failure to achieve wider recognition.

An adequate environment for carrying out scientific research involves the existence of a certain "critical mass" of scientists in close geographical proximity with considerable overlapping of interests promoting daily communication (Moravcsik 1975). Storer defines "critical mass" as an audience of sufficient size and competence to provide adequate feedback to its members so that they need not feel totally dependent upon feedback from abroad (Storer 1970). The size of critical mass cannot be determined by hard and fast rules, but this need not be more than three to five researchers working in very closely related fields and in daily contact with each other (Moravcsik 1978). However, DCs have only small groups in some areas of scientific research while in other areas research activity is non-existent. Even where established groups doing advanced work do exist, these have been described as small oases which, in the absence of vigorous contacts with the world community, are in danger of being dried up (Salam 1966).

Ben-David writes of the danger of countries with limited intellectual resources producing mediocre science. However, he believes, that mediocre scientific work can be competent, useful and respectable, but proves detrimental for a scientific system when it becomes a means to its own end or when it suppresses exceptional talent. A further danger of mediocre science is that it might become autarchic as a result of isolation from innovative or high level synthesising work carried out in the large scientific centres (Ben David 1962).

Independent of their place of origin, scientists willing to accept the rules of the scientific game imposed by the centre, are in a position to overcome their state of provinciality (Shils 1976). Small developed countries will share the need of the developing nations to find ways of reducing their separation from the mainstream of scientific activity (Stolte Heiskanen 1987). By and large, isolation with regard to scientists anywhere is associated with low productivity. Isolation means that the scientists will receive less recognition for their work and will lack the necessary information for its completion. Isolation also reduces the motivation to produce, particularly along the right lines (Hagstrom 1965).

Several mechanisms have been proposed for reducing the isolation of scientists on the periphery. In particular, the integration of scientists from DCs into the international scientific community through participation in global communication networks is considered today as a necessary requisite for overcoming some of the restraints of a peripheral position, as well as for strengthening and consolidating the formation of national scientific communities. The most important circles of individual scientists and institutions are those of the intellectual metropolis; the rest of the intellectual world lives in their shadow, receiving inspiration from them and adjusting its behaviour to conform with model set by the centre (Shils 1976).

2.3 Education and Manpower in Developing Countries

In the context of science in the developing world there is a wide range of strategic areas where investment is needed to improve performance. In spite of the diversity of these needs (laboratories, equipment, easy access to information sources, etc) the acute shortage of human resources in every aspect of scientific activity is often considered to require the most urgent attention (Moravcsik 1975). In many cases DCs recognised the urgent need for increasing scientific manpower. The first efforts of many Asian and African countries at science planning emphasised the need to increase the output of scientists and engineers (Eisemon 1982). However, India and Sub-Sahara Africa, for instance, continue to have some of the lowest figures within the Third World for the number of scientists and engineers per 1,000 head of population, 0.1 and 0.2, respectively, compared to 0.5 for LA (Granovsky 1994).

Developing countries, such as Mexico reported a total of 14,000 scientists and engineers involved in research and experimental development for all sectors in 1993, while developed countries like the USA presented a total of 960,000 in 1991, Japan with 511,000 in 1992, and France with 130,000 in 1991. Sweden with a population of less than 9 million (compared to Mexico with a population approaching 90 million) had 26,000 scientists and engineers in 1991 (Consejo Nacional de Ciencia y Tecnología 1996). Chile reported approximately 6,000 scientists and engineers for 1993 out of a total population of just over 13 million (Comisión Nacional de Investigación Científica y Tecnológica 1995).

The wide discrepancies between the developing and the developed countries with respect to scientific manpower is shown by the large difference in the 1990 numbers of scientists and engineers as a percentage of the total population of different countries. Figures for the industrialised countries are equal or greater than 2%, while those for the DCs are generally found between 0.1 and 0.4% (Papon and Barre 1996).

While injection of large sums of money may, for instance, facilitate the building within a few years of research laboratories, or the stocking of libraries, the development of manpower is a long-range proposition (Moravcsik 1975). The training of scientists is a costly undertaking and an investment that will be realised only in the long run (Frame 1979b). One of the most pernicious traits of poor quality is self-perpetuation with bad teachers and research supervisors breeding poor successors. While the discussion of manpower development is often centred on the researchers, other staff members such as technicians and managers are necessary elements in building a solid scientific structure. Moravcsik stresses the importance of having first class formulators of science policy which he believes are an even rarer phenomenon than first class scientists in DCs. The lack of recognition of the important role that these "ancillary" players occupy in the research process is indicated by the absence of formal training for these professionals in the developing world.

The adequate provision of scientific manpower for DCs is dependent on an adequate educational and training system. Figures for the number of students in higher education per 100,000 inhabitants for LA countries in 1990 place Peru at the top of the list with 3.45, followed by Argentina with 3.39, Venezuela with 2.85, Costa Rica with 2.46, and Uruguay with 2.32. Mexico occupies 11th position with 1.55. A considerable increase in the number of students in higher education for the majority of LA countries was apparent between 1980 and 1990 (Cardoza and Villegas 1996).

By the early 80s, a number of DCs boasted a general student population comparable with the OECD countries in relative terms (2% or more of the total population). This can be partially explained by the creation and overpopulation of many new public universities (Gaillard 1994a). Deficiencies can be found at all levels of the educational system in DCs. Eisemon and Davis mention that in the case of Africa few countries include instruction in science and related subjects in primary school (Eisemon and Davis 1991). In Mexico, the UNAM provides secondary education for intending students in an attempt to improve the preparation of entrants to their degree courses (Maddox and Gee 1994).

Due to the deficiencies of the national educational system specialist training often has to be obtained abroad. The development of postgraduate courses in developing nations, such as those of Latin America, is recent compared to the industrialised world with little standardisation or control of quality both between and within countries (Morales 1983; Morales 1989).

The dilemma for science policy makers is whether it is better for students to get their postgraduate training at home or abroad. However, in recent years the voices in favour of domestic postgraduate training have been heard more loudly, partly because of diminishing budgets to support expensive training abroad, but also to the increasing availability and, in some areas, quality of local options.

Foreign training is not the panacea it was at first thought to be. Graduates returning home often find, for instance, their foreign training too specialised to resolve local requirements (Orskov 1993). Local research groups are often lacking in the area or problem the students spent several years studying in, well-equipped foreign laboratories (Galina and Russell 1994). A possible solution and one which has positive repercussions in the ensuing productivity, is PhD training nationally followed by a postdoctoral stay in a foreign university (De Meis and Longo 1990). Mike Moravcsik was also a firm believer that advanced education of scientists in a country should be carried out to a large extent on their home soil (Moravcsik 1964), a view also supported by researchers in Chile (Saavedra, MacKenzie et al. 1993).

In the early 1960s Moravcsik wrote that one of the striking characteristics of scientific life in DCs is that modern research is carried out mostly by quite young people (Moravcsik 1964). At that time higher education in most DCs was very recent. The present day situation of at least some of the DC scientific communities appears to be vastly different. A recent study on the Chilean scientific workforce indicates that this has been dangerously ageing through the years and that the number of young people entering scientific research is decreasing (Saavedra, MacKenzie et al. 1993). Their reluctance to choose scientific research as a career option is ascribed to the sclerosis prevailing in the national university system (Krauskopf 1992).

The migration of highly-qualified scientific personnel to the scientifically advanced countries (Fenton 1986) as well as to more lucrative positions in the scientific administration apparatus (Galina and Russell 1994) is a constant drain on the human resources for scientific research. Previous studies suggest that the great majority of Latin American scientists, at least in the applied area of tropical bovine reproduction, do not stay long in research activities (Russell and Galina 1988). It is well recognised that scientists in DCs are poorly paid and do not enjoy the social prestige and position afforded to scientists from the industrialised world (Gaillard 1987; Gaillard 1991). The migration, both temporary and permanent, of individual researchers across state boundaries is as old as the history of science itself (Dedijer 1961). On a worldwide scale, individual professional migrants are motivated by the magnetic influence of the richest nations, the flow of scientific migration being heavily weighted from periphery and towards centre, principally the USA (Thomas 1967). South-South collaboration in the many areas where DC scientists are at the forefront of scientific research has been proposed as a way of preventing the brain drain from the developing to the developed world (Violini 1994).

2.4 Financial and Material Resources in Developing Countries

Rossi when referring at the beginning of the 70's to the precarious situation of science in DCs, mentions that India with over half a billion inhabitants had a similar budget for R & D activities as a country like Belgium with a population of less than 10 million (Rossi 1973). More recent figures show that the expenditure per capita in R & D by governments of the DCs continues to be well below that of the industrialised countries. The US, for instance, currently spends over $200 US dollars annually on research per inhabitant, whereas in most LA countries the equivalent figure is less than $10 (Sarukhân and De la Fuente 1993). When research expenditure is examined in the terms of production of papers, however, LA scientists are holding out well. The USA and the European Union invest 40 to 50 times as much money as LA but produce only about 20 to 25 times the number of publications (Ayala 1995).

Official S & T indicators for Latin American countries make little reference to defense spending. While in countries like the USA and the UK, several times more money was channeled into defense spending from 1995-1996 than into other areas such as energy and health (National Science Board 1998), Mexican federal S & T expenditure for 1995 by administrative sector lists the Navy in ninth position receiving only 0.16% of the total. Favoured sectors are principally public education, energy and agriculture, livestock and rural development, and health (Consejo Nacional de Ciencia y Tecnología 1996). S & T indicators for Brazil and Chile make no specific mention of spending in the defense sector (Ministry of Science and Technology 1996; Comisión Nacional de Investigación Científica y Tecnológica 1997).

DCs also channel a reduced percentage of their Gross Domestic Product (GDP) into activities related to science and technology. In 1994 the federal science and technology expenditure of Mexico was 0.46% of its GDP (Consejo Nacional de Ciencia y Tecnología 1996) while Chile reports a figure of 0.76 (Comisión Nacional de Investigación Científica y Tecnológica 1995). The corresponding figure for US R & D expenditure is 2.5%. Italy directed less resources into R & D activities in 1993 (1.3% of its GDP), than did Canada (1.5%), while the figures for Japan and Germany were considerably higher (2.7 and 2.5%, respectively) (National Science Board 1996). However, the OECD countries as a group spend on average 0.45% of their GDP on R & D activities. For the eight most productive countries of LA the figure is 0.35% which implies that funding for S & T in LA countries is approaching levels found internationally (Carnero Roque 1995). It has been suggested that DCs should be spending approximately 1% of the GDP on fundamental research (Moravcsik 1975).

All DCs rely to some extent or another on research funding from abroad. The extent of external funding varies between countries. Thailand, for instance, receives slightly under one third of its funding from external sources while Senegal receives close to two thirds. In general, it is estimated that foreign aid accounts for close to 40% of expenditure of R & D in DCs (Gaillard 1991). The mechanisms implemented by the industrialised countries for the promotion and support of research activities in DCs include: technical assistance, overseas training, institution building, institutional twinning arrangements, and collaborative research partnership (Gaillard 1994b). However, the aid provided has not always achieved its objective. The construction of an institutional framework for science with the establishment of science teaching programmes, scientific societies, and publishing institutions, has not guaranteed an advance in scientific work in a more substantial sense in countries such as Nigeria and Kenya (Eisemon 1979) .

A major complaint of scientists in DCs is the lack of up to date equipment, second only to considerations of funding (Gaillard and Ouattar 1988). Currency devaluations in countries such as Venezuela, have eroded the budgets available for buying not only sophisticated equipment from abroad, but also complementary equipment such as refrigerators and trolleys, and even experimental animals (Vessuri 1985). Consequently, international funding agencies have channeled significant economic resources into science equipment for DCs that have sometimes been shelved because of a lack of local expertise. In other instances, the pretext of a lack of suitable equipment is used to cover up for a poor grasp of scientific knowledge and methods by DC scientists (Galina and Russell 1994). Nonetheless, the obsolescence of scientific equipment continues to be a priority consideration in the elaboration of national science policy, as indicated by the case of Mexico (Sarukhán and De la Fuente 1993), confirming the importance of laboratory work and of having access to properly performing scientific equipment for carrying out research activities in DCs, even in areas traditionally associated with field work, such as forestry or animal sciences (Gaillard and Ouattar 1988).

2.5 SCIENTIFIC RESEARCH AND COMMUNICATION IN DEVELOPING COUNTRIES

2.5.1 *Research Orientations*

Although much of the research produced by Third World countries is considered inferior to that published by the developed nations, it is wrong to dismiss all work carried out as being of universally poor quality (Garfield 1987). Over 30 years ago Salam wrote that in a number of fields, advanced scientific research in DCs is beginning to reach the stage of maturity in which first rate work can be done (Salam 1966). A report on LA science published recently in the multidisciplinary journal, *Science*, indicates that the sophistication and extent of research in the region is steadily increasing and that first class work is being done which will have repercussions not only for Latin Americans but also for the rest of the world (Appenzeller 1995; Koshland 1995).

Small developed countries are known to produce sophisticated research in certain areas in spite of sharing with DCs certain disadvantages of peripherality. Arunachalam and Singh studied a case in point - superconductivity research in Israel - where citation counts, in spite of a reduced production of papers, were second only to US groups (Arunachalam and Singh 1985).

A popular topic for debate in the scientific communities of the DCs is the relative importance that should be given to basic and applied research, taking into consideration that basic research is international while applied research is often focussed on more local concerns (Storer 1970). Moravscik asks the question of how badly in need are DCs of fundamental research. Fundamental research of today, he argued, is the applied science of tomorrow and applied work can be carried out successfully only if the research workers have constant access to persons working in fundamental research. He also considers that achievements in the basic sciences serve as a source of great encouragement and high morale in the DCs (Moravcsik 1964).

The idea that two types of science and scientists exist in DCs has been put forward by many authors. Russell and Galina refer to two distinct categories that they have termed elite and non-elite, in accordance with the objectives of the research pursued. While elite scientists carry out research of a basic or applied nature which advances universal knowledge (the so called international science), the contribution of the non-elite scientists can be measured only at local level (national science). The polarity of objectives is reflected in the ways in which these two types of research are disseminated; the elite in international journals and meetings where English is the lingua franca while the results of applied local "new" science will be disseminated in local journals and meetings in the native language of the country concerned. The difference in national prestige of these two kinds of science and scientists is reflected in the major role played by the elite group in science policy decisions and in the allocation of research funding (Russell and Galina 1998).

These appraisals are supported by Arunachalam's description of Indian science. He makes the same distinction with regard to internationally relevant and visible research published in international journals whose scientists form part of the global invisible colleges, and on the other level, science which tackles problems of little current interest or significance to the international scientific community which is published predominantly in Indian journals or less prestigious international journals. He emphasises the fact that little contact exists between these two types of scientists. He also points out that when the elite scientists publish in local journals, they usually limit this channel to the papers that they consider of inferior quality (Arunachalam 1988; Arunachalam and Manorama 1989).

Taking research in soil science as neither totally fundamental nor totally applied research, Chatelin and Arvanitis found evidence for the existence of a scientific community lying between centre and periphery which has been able to resolve the fundamental conflict between international and national achievements in DCs (Chatelin and Arvanitis 1989). They report that both orientations - international and local - can coexist in the same country, within a common discipline, and inside a single research institution. In an earlier paper, they mention the existence of very applied research that shows a high international profile and argue that what is international is not the science itself but the way it is used. According to these authors, Third World countries adopt different strategies than those used by developed countries - that is, different thematic orientations, different ways of treating science and of disseminating results (Arvanitis and Chatelin 1988).

In the same line of thinking, Davis and Eisemon considered the widely held view that Third World scientific communities are stratified according to their ability to participate in the advancement of international knowledge, as a characterisation that is too sweeping (Davis and Eisemon 1989). However, their analysis is focussed on the newly industrialised countries (NICs) of South East Asia which the authors themselves state have large vigourous scientific communities compared to most developing countries. They believe that the majority of publishing scientists seek and obtain local as well as international recognition. Parochialism and cosmopolitanism seemed to be intertwined rather than representing orientations that stratify the local scientific communities.

In their study on Mexican scientists Liberman and Wolf mention that, even in the national context, there are marked differences between those scientists who have published in international journals as opposed to national publications, with respect to their position in the institutional hierarchy and within the informal communication networks (Liberman and Wolf 1990).

With respect to the situation in Latin America, Reig accepts the division between national and international science only with respect to the different level and degree of theoretical advancement inherent in research concerned with universal topics in contrast to that directed towards solving more local problems (Reig 1991). Among Brazilian academics, the chief obligation is to contribute to the stock of knowledge, the best indicator of which is publication in internationally recognised journals. Publication in local journals is typical of applied fields such as agriculture and medicine (Schwartzman 1986).

In certain areas of science, developing countries offer unique situations for study, such as the bio-diversity of the tropical rainforests. With the tropical environment being found almost exclusively in developing countries, the relative contribution of DCs to research in many aspects of tropical science, such as soils and animal production, is therefore not surprising (Galina and Russell 1987; Russell and Galina 1987; Arvanitis and Chatelin 1994). However, DCs in general are taking little advantage of indigenous traditions and knowledge with respect to the potential use of their natural environment, and are letting foreign scientists derive benefit from what can be considered their natural heritage in areas such as ethnobotany (Arunachalam 1995). Other authors report that researchers from North America and Europe are heading south to LA countries, drawn by unique resources and local scientific talents (Appenzeller 1995).

2.5.2 *Publishing and Citation Practices*

Several studies have been published on the extent to which DC scientists do, or should publish in the national and the international literature [1] (Galina and Russell 1987; Russell and Galina 1987; Reig 1989; Rabinovitch 1990; Gaillard 1991; Comité Editorial de la Revista de Investigación Clínica 1994). The mainstream literature is said to account for only about half of the scientific articles from DCs (Gaillard 1989). A study on Mexican science found this figure to be nearer to a third (Rosas Gutiérrez and Escalante Vargas 1995). However, there were large field differences with papers in Chemistry and Physics as the only subjects appearing more frequently in the international than the national literature (Russell, Rosas et al. 1994). This evidence supports the tendency that basic research is more likely than applied research to be published in the international literature and to be picked up by the international databases (Narváez-Berthelemot, Almada de Ascencio et al. 1993).

Studies on Brazilian scientists in different fields show marked differences in publishing patterns. Three quarters of Brazilian papers in Chemistry were published internationally while the corresponding figure for Electrical Engineering was 57% (Spagnolo

[1] International literature is taken to mean those journals, also termed mainstream, which are included in the Institute for Scientific Information (ISI) databases.

1990). Approximately 90% of biochemical research is published in international journals (Meneghini 1992) while the tendency is reversed for agricultural scientists who publish a similar percentage in national titles (Velho and Krige 1984). Research topics in Agriculture, however, are mainly applied and like the related area of Animal Science, show a greater tendency towards publication in national journals (Manten 1980; Galina and Russell 1987).

Even though some applied scientific research from DCs is on topics pertaining to specific geographical, economic, or social circumstances of the countries concerned, few of these are strictly country-specific (Moravcsik 1988). This suggests that findings are of interest to a wider audience than that reached by local publication. Manten found that approximately 20% of animal science papers were classified by experts as internationally relevant while only 5% of these studies reach the international literature (Manten 1980).

Many discussion have centred on the important role that national journals play in the scientific research process of DCs and the possible ways of improving their visibility (Cetto 1993; Cetto and Hillerud 1995; Russell and Macías-Chapula 1995). A recent feature article in *Scientific American* referred to articles published in national journals from DCs as "lost science"(Gibbs 1995). These publications are poorly represented in the international databases, particularly in the Science Citation Index which is commonly used for scientometric studies of world science (Krauskopf and Vera 1995a). It is suggested that the visibility of these publications could well change in the near future as a result of Internet access and CD-ROM technology (Gibbs 1995).

However, the limitations of the great majority of journals from DCs are not only related to their poor visibility. Poor quality, deficient editorial standards, and lack of continuity in publication are other factors that are often mentioned (Benitez Bribiesca, Galindo Miranda et al. 1988; Almada de Ascencio and Pérez de Almada 1991). National journals tend to cover general subject areas, rather than scientific specialities, due to the lack of specialist groups in most disciplines in DCs (del Rio 1982), which may be at a disadvantage when competing with the more highly specialised mainstream literature for global visibility.

Proposals with respect to the situation of journals from Latin America have focussed on the need to develop appropriate evaluation systems and to define a basic core of quality journals for the region. The content of these core journals should then become available through the international information services, thus validating these publications as an alternative to the mainstream literature for the communication of research results from the region (Vessuri 1995).

Studies on the citation practices of scientific communities on the periphery have shown that researchers preferentially cite mainstream papers over those published in national journals, even in areas such as Agriculture, often considered to be of local relevance only (Velho 1986). However, place of publication (i.e in a national or international journal) has been shown to affect the extent to which peripheral scientists cite the international literature. These are more likely to cite papers from national journals when publishing nationally than when publishing internationally (Lancaster, Kim Lee et al. 1990; Bekavac, Petrak et al. 1994). In addition, non-mainstream Third World journals have been shown to cite much older literature than their mainstream counterparts (Arunachalam and Manorama 1988; Davis and Eisemon 1989).

2.6 Science Policy and Development

Science policy is considered the most neglected aspect of national policy even in developed countries (Dedijer 1963). Institutions concerned with science policy in the industrialised countries were first set up only from 1957 - the date of the first sputnik. From the 1950s to the 1970s, science policy went from an age of pragmatism to the general awareness of the role played by scientific and technological research in the "wealth of nations" and in the struggle for international competition (Salomon 1994).

Science is often said to know no international boundaries, yet science policy has still to achieve international status in spite of a tendency towards increasing globalisation. Some of the issues that science policy must wrestle with, such as diminishing budgets in the face of increasing demands, are globally relevant while many others will have financial, material, cultural, and social ramifications specific to one country or a set of countries (Blanpied 1993). One of the primary differences between science activity in the developed and developing world is that while the former concentrates on doing science, in the latter the scientific community must simultaneously create conditions under which science can be successfully carried out (Moravcsik 1975).

The planning, organisation, and management (what Moravscik termed "providing for science") of science in DCs are in a more rudimentary state than science itself (Moravcsik 1975). Nonetheless, many African countries have national science policy units, a legacy of vigorous promotion by UNESCO of "science planning" in the 1960s and 1970s. However, these are not fulfilling the ambitious role originally envisaged for them (Eisemon and Davis 1991). While much energy and manpower in DCs are channeled into planning, much less attention is given to specific decision-making and even less to implementation (Moravcsik 1975).

Krishna mentions the severe limitations of S & T policy in India and points out the difference between his country and others such as South Korea and Taiwan. These latter nations produce less scientific literature than India but, by the 1980s, had productivity rates in the manufacturing sector and high-technology trade that not only surpassed India but also many developed countries. He attributes this success to innovation management (the impact side of R & D), rather than the size of R & D investment (the input side of R & D) (Krishna Fall/Winter 1993-1994).

Vessuri agrees that recent research contributions have emphasised the systemic and comprehensive state intervention in the economies of the newly industrialised countries. The state has constantly proved itself as the most important factor in the developing countries' successful or failed use of S & T for industrial development (Vessuri 1994).

In spite of the considerable interest by national and international organisations in the problem of science for development, there is little systematic information and knowledge on some of its basic aspects (Dedijer 1963). The literature on science in the Third World shows that there is little consensus from both the intellectual and political angles about what scientific development entails. The divergences of opinion go deep enough to question the adequacy of our basic assumptions about science in particular and development in general (Anderson and Buck 1980).

Moravcsik described two different viewpoints with respect to the nature of science in the developing world. One he believed was close to the view prevailing among administrators while the second could be said to be much closer to the realities of science as a human activity and hence to be more functional (Moravcsik 1986b). Related to this idea that there is no unequivocal blueprint for science development, he points out in another paper that there is no simple, quick, objective and infallible method for making science policy decisions in DCs. However, projecting the situation at hand into a structured and multidimensional framework of well-defined arguments and justifications is likely to he helpful. This framework should be constructed in three simultaneous directions: broad objectives of science; contextual and structural criteria; and manpower (Moravcsik 1986a).

Many policy decisions in DCs have focussed on the importance of reducing the physical and intellectual isolation of science in these countries by strategies, such as increased regional collaboration (in the case of Latin America) as one of the most effective ways of rapidly building up a more solid R & D base (Vessuri 1994). In spite of these, marginality in S & T is increasing in many DCs with their communities alienated from a world where academic networking is rapidly expanding (Vessuri 1994).

2.7 Evaluation of Science in Developing Countries

Assessment of science and technology is very much neglected in DCs. It is paradoxical that the countries less able to afford investment in the development of science and technology are those who pay least attention to its evaluation in terms of return for investment (Morita Lau 1985). A major problem in DCs is the lack of valid and reliable facts, data, and similar hard evidence in connection with scientific and technical information in general (Saracevic 1980). However, in order to formulate a practical system of evaluation it is necessary to define the goals and objectives of S & T which are numerous taking into consideration that these activities have impacts on all aspects of human life (Moravcsik 1985a).

Apart from the need to define what each individual or government understands by development and how they see the role of S & T activities in this context, the tools and mechanisms for evaluating these activities are generally lacking in DCs. Bibliometric databases, peer review teams, reliable statistical and other data on S & T activities with respect to all sectors (industrial, educational, private, etc.), are just some of the areas where information is essential for correct decision making. Moravcsik described the tools available ten years ago as "woefully rudimentary". He emphasised the limitations of both data based (e.g. bibliometric measures, patent counts, production and manpower statistics) and perceptual indicators (peer review, for instance) with respect to R & D assessment in DCs (Moravcsik 1985a).

In general, input indicators (financial resources, trained manpower, equipment, etc.) are more readily available than output indicators, especially those related to the impact of science on national or individual aspirations (Moravcsik 1985a). Frame when assessing the relative merits of different indicators of S & T activity in DCs, found publication indicators to be the most reliable. Publication counts have the advantage over other indicators that they can be assigned to different sub-fields whereas other indicators are heavily aggregated (Frame 1980).

In recent years, there has been growing interest in the area of accountability of S & T related activities in DCs. Suggestions have been made that developing nations need to devise a "new" set of indicators appropriate to the particular conditions prevailing in peripheral scientific communities (Arvanitis and Gaillard 1990). In particular, the appropriateness of using the *Science Citation Index* (SCI) for the production of publication indicators for DCs has been discussed at considerable length in the specialist literature (Arvanitis, Russell et al. 1996; Russell and Galina 1998). The discussion is usually centred around the under-representation of national journals from DCs in the SCI on the one hand (Krauskopf and Vera 1995a) and the special attributes of this multidisciplinary file for making scientometric comparisons between countries, on the other (Carpenter and Narin 1981).

Vessuri also emphasises the importance of developing indicators tailormade for the special circumstances and interests of the DCs and the creation of the necessary bodies to facilitate their local use. She insists on the special importance of indicators which measure scientific capacity in terms of social goals (Vessuri 1986a).

Several authors point out that universalistic assumptions about the social organisation of science and the contemporary characteristics of R & D activities come from studies on and by the centre (Moravcsik 1985b; Stolte Heiskanen 1987). For instance, the image of a scientist held by Mexican secondary students conforms to the universal image of scientists emanating from the scientific centre (Rodríguez Sala de Gómezgil 1977). Moravcsik proposes that the DCs offer a domain for research into the science of science which is at an earlier phase of development than that of the industrialised countries. It presents the opportunity to study science development at stages which in Western civilisation lie in the past and are only accessible by historical methods.

In spite of these needs, the institutional development of the social study of science in developing regions of the world such as Latin America, is seen as fragile. Its chances for survival and success lie with its ability to bridge the research gap between academia, public-decision making and industry (Vessuri 1987). To help find ways of developing a scientific community with a scientific tradition in DCs will require the input of the social sciences for basic information, special studies and for empirical understanding of how to go about this difficult task (Dedijer 1963). Moravscik also emphasises the need for a much deeper understanding of what science is and how it works as a universally necessary ingredient for any kind of science building anywhere. He considers that at least some members of the local scientific community should have the ability, interest, and background to explore the history, philosophy and general context of science in DCs (Moravcsik 1978). Arunachalam also laments the tardy realisation of the scientific establishment in India of the importance of following the example of the West by studying the processes of knowledge production and utilization (Arunachalam 1990a).

Some progress had been made with respect to the lack of systematic and reliable information on science activities in DCs. The recent formation of an Iberoamerican network of specialists focussed on the development of adequate methodologies for the construction of national indicators is a promising sign. The objective of this regional group is to generate data which can be used to make comparisons between countries and which will lead to better policy decisions. This initiative involves collaboration between researchers from the academic sector and officials from the government bodies responsible for science planning (Albornoz 1996; Anon 1996).

However, more in-depth studies are required of science as a human activity in DCs, particularly with respect to the role of social and other factors affecting scientific performance, which are not apparent from considerations of scientometric indicators alone. Science needs to be studied at the level of individual researchers, situating their professional activity within the social, cultural, political and economical environment in which these actors live and work.

Chapter 3

Integration of Scientists from Developing Countries into the Global Scientific Community

3.1 Introduction

As we have seen from the previous chapter, the condition of peripherality imposes many constraints on the research scientist from DCs, many of which can be overcome, or at least partially compensated for, by integration into the international community of science. This implies interaction through the exchange of ideas and information, and, in many instances, direct collaboration with colleagues from other countries, particularly those at the scientific centre. Publication in mainstream journals exposes the DC scientists' work to possible censure or sanction by their international peers, as well as offering their findings for citation and use by other authors, thus increasing their visibility, recognition and influence within the global scientific community.

In order to integrate into the global scientific community scientists must first earn a place in the national scientific community. Later on, through foreign colleagues to whom the scientists respond and who respond to them, the scientists become integrated into the world scientific community. The national scientific community of a country is informally organised by the web of ties created both between its members and with foreign colleagues. The individual, national, and global webs are nested: a scientist's collegial circle is nested in the web of the scientist's national community, which in turn is nested in the global scientific community (Schott 1991; Schott 1993; Schott 1995). Increasing integration into the wider scientific community is seen as a progression from the scientist's immediate institutional environment, passing through the national context into the global sphere.

Consequently increasing internationalisation, visibility, and impact of scientists and scientific achievements from DCs are achieved through their progressive incorporation into and recognition by the three nested environments: internal (institutional), external (national) and international (outside the country). Informal contact with fellow scientists leads first to information exchange, followed in some cases by formal collaboration and the publication of co-authored papers. From a bibliometric viewpoint, increasing visibility is associated with an increasing presence in the national and the international scientific literature while increasing influence and impact are registered by the number of citations given by national and international colleagues.

Whether or not researchers collaborate they do belong to scientific networks. Contact and communication with peers in itself can provide a vast intellectual exchange which is sufficient for the development of new ideas (Melin and Persson 1996). Influence is channeled through a variety of media, notably publications, preprints, lectures, discussions, telephone, facsimile messages, postal mail, and perhaps, also through rumour (Schott 1995).

A significant part of a scientist's working life is taken up with communication in its different forms (Meadows 1974). In her research on Mexican scientists, Sofia Liberman found that an average of 30% of their time is spent in communication related activities indicating that the exchange of information is incisive in scientific research (Liberman 1992).

In creating new information a scientist draws upon the tradition of knowledge which he has received either through his own scientific experience or by communication from other scientists past or present. Interaction between colleagues from different societies confirms and reinforces the participants' belief in the universality of science (Schott 1991).

Although science per se is international, and contact between scientists across national borders has become an increasingly important part of research work, membership in the world community of science does not entail the equality of all its members (Schott 1991; Kyvik and Larsen 1994). However, independent of the position a country holds in the hierarchy of world science, the importance of active participation in the international scientific discourse is self-evident. While formal and informal links established with both scientific institutions and with other scientists, either as individuals or as groups, are important for scientists anywhere in the world, for those working in peripheral societies, and more importantly for those from DCs, these constitute essential lifelines linking them to the mainstream of scientific discourse (Liberman and Wolf 1990).

Understandably, "internationality" is typically the concern of the scientific communities on the periphery, and the so-called international science is to a great extent the national science of the centre (Stolte Heiskanen 1987). Notwithstanding that communication in science should be a two way process, information transfer, as we have seen, is weighted heavily from centre to periphery. In the special case of science on the periphery, international participation is usually concerned with scientific communication to and from the international centres (Stolte Heiskanen 1987). While the works of the centre diffuse easily and are highly valued (Schott 1991), scientists and scientific achievements from peripheral societies must overcome numerous obstacles to gain recognition on the international front.

Communication plays a major role in the impact and utilization of research results. The relative inaccessibility to scientists on the periphery of formal channels for the publication of results, renders their scientific achievements invisible to the centre thus limiting any possible effect or influence that these might have on the further direction of research (Stolte Heiskanen 1987). To make up for this, DCs have evolved indigenous information products and activities to promote the transfer of their own information and knowledge to the wider scientific community (Menou 1983).

Integration into the international scientific community for researchers from DCs often means overcoming the linguistic aspects of cultural barriers. Developing societies having a major communication language as their mother tongue, particularly English, will have an important advantage over those groups whose languages reach smaller audiences.

Notwithstanding, objective and subjective cultural traits, other than language, have been shown to affect the generation, presentation, transfer and use of information in different societies. What Menou believes is required is research into the understanding of the factors involved in the various steps of the communication cycle in order to facilitate information transfer between members of different societies (Menou 1983).

3.2 Formal and Informal Communication in Science

The activities of a scientist then imply participation in formal and informal scientific organisations which are systems to validate, legitimise and communicate the results of scientific research. Both formal and informal communication activities play vital roles in scientific activity and in the process of knowledge production, such that the external cycle of knowledge reproduction through the publication of results, has several stages including discussion of preliminary results with colleagues (Liberman, Seligman et al. 1991).

According to Meadows, formal and informal communications have important differences. The contribution of the less distinguished scientists is more important at the informal level than the formal level. Junior members of staff and research students who figure little in formal communication or in research, can play important roles in informal communication. For instance, they may sift the literature for information relevant to the senior scientists' interest and communicate the findings orally to their superiors (Meadows 1987). Data derived from studies by Garvey *et al.* on the information exchange activities of scientists and engineers in the US, found that younger scientists relied heavily on national meetings to obtain new information from informal networks whereas the more prominent scientists found this new information readily accessible to them (Garvey, Lin et al. 1972a; Garvey, Lin et al. 1972b).

Ideas are spawned while researchers are thinking on their own. Discussion of the idea with colleagues gives the researcher access to the specialised knowledge and skills of other scientists and can lead to formal collaboration (Westland 1990). In the early stages of research, communication is primarily with collaborators, colleagues, and trusted peers, individually or in small groups. Later the researchers "go public" through the presentation of research results in larger open forums, or as journal articles (McCain 1991).

Active researchers rely heavily upon informal media for information crucial to their continuing research (Garvey, Lin et al. 1970). Informal communication comprises all those ways in which scientists find information needed for their research outside the generally accepted institutional arrangements for communication, publication in scientific journals and presentation at open meetings of scientific societies. However, there is not always a sharp decision between the informal and formal spheres in information exchange settings such as the meeting of a learned society (Woolf 1975).

In the informal context, communication implies membership of informal groups of researchers working in similar fields or concerned with similar problems (Liberman and Wolf

1990). These so called "invisible colleges", (a concept first formally defined by Price and Beaver (Price and Beaver 1966) and later developed by Diana Crane (Crane 1969; Crane 1972; Crane 1989)) have been described by Lievrouw as "sets of informal communication relations among individuals who share a specific common interest or goal " (Lievrouw 1988). Cronin sees them as simple, yet complex bush telegraph systems serving the needs of the scientific community. Although the shortcomings of the invisible colleges arise from their informal character, it is their very informality which seems to be the key to their survival (Cronin 1982).

The majority of these "invisible" mutual interest groups do not manifest their existence outside the limits of the group itself. Networks of linkages between researchers, both within and across fields, are not immediately apparent and need exposure by different techniques such as sociometric analysis or citation analysis in order to become perceptible (Cronin 1982). Nor are these social networks created by official policy initiatives but arise spontaneously as the result of the communication and information needs of groups of specialists. Membership transcends national boundaries and, in theory, is open to all qualified parties (Russell 1993). The invisible college "system" is in a state of constant flux due to the development of new interests, thrusts, and paradigms within different research fields, making the average life expectancy of an invisible college probably quite short (Paisley 1972).

Activities of the invisible college, as originally described by Price and Beaver, include interaction at select meetings; travel from one centre to another; exchange of preprints and reprints, and formal collaboration in research (Price and Beaver 1966). In a more modern context, we might envisage members of invisible colleges as those taking part in electronic discussion groups and other types of computerised networking. Nonetheless, the gradual transition from print-on-paper, remote voice-only and face-to-face communication to fully wired up systems, will not necessarily require that the idea of an invisible college be conceptually redefined (Cronin 1982).

Weller believes that although the model of invisible colleges continues to exist today within the context of an electronic environment, information is less likely to stay within a small group of researchers thus removing the element of "closed access." While In the traditional model of scientific communication membership in the invisible colleges was limited to a small group of researchers, in today's electronic environment it is common to forward email or listserve messages to other colleagues thus widening the circle of potential receptors (Weller 1996). In communication networks, scientists are envisaged as nodes from which lines of communication run, linking them to their peers. The number and intensity of such lines will vary from scientist to scientist (Meadows 1974). Scientists often regard their segment of the larger network as their own invisible college (Griffith and Miller 1970).

Melin sees the Internet as a new potential indicator of an invisible college that did not exist in the early 1970s. The very belonging to an electronic mailing list is a sign of membership of a network. However, as he points out, the shaping and confirmation of an electronic college through electronic mailing lists has not yet been well researched and we can only wait for clarifying studies (Melin 1997b).

Both the work by Crane in agricultural innovation (Crane 1969) and the later work of Susan Crawford in sleep research (Crawford 1971), support the idea of a core group of highly productive, influential figures who hold the informal network together. In their work on psychologists, Garvey and Griffith also identified a small group of "significant" creators of scientific information, who produced most of the material that required or warranted scientific information-exchange activities in the field, and it was their work that kept psychology going as a scientific discipline (Garvey and Griffith 1971). According to Meadows, the greater the flow of information through a network, the more obvious becomes the dominant part played by a relatively few scientists (Meadows 1974). Griffith and Mullins proposed that invisible colleges might be consistent throughout science (Griffith and Mullins 1972) and later work by Judith Weedman in communication spanning professional boundaries, suggested that the individuals central to the informal part of the structure were also more likely to take advantage of formal channels (Weedman 1992).

Formal communication in the sciences on the other hand is primarily carried on through articles appearing in scientific journals (Hagstrom 1965; Cole and Cole 1973). Normally the immediate research community should at least know of the work prior to journal publication, which marks the entry of information into the formal domain. Once published, the article is cited, reviewed and evaluated thus establishing the integrative process in science by which information is built upon, evaluated in the light of, and linked to new information which has been produced since its publication (Garvey, Lin et al. 1972c; Griffith 1989). The most crucial point, therefore, in the process of dissemination of scientific information is the transfer from the informal to the formal domain, which occurs with journal publication, after that begins the procedure by which the work is assimilated into the established scientific literature of the field (Garvey and Griffith 1971). Results do not become genuinely public until journal publication, by which time the information might be out of date on the research front by an estimated six months to one year (Garvey, Lin et al. 1972c).

The main difference between the formal and informal domains of scientific communication is that the flow of information through the informal channels is relatively free of filtering or monitoring; the individual researcher is free to choose both the communication media and the audience. In contrast, before information can be formally presented, it must be evaluated thoroughly by the scientist's peers. Throughout the informal process, researchers are seeking prevenient evaluation of their work in order to send a finished product for publication (Garvey and Griffith 1971). The invisible college not only reacts quickly, authoritatively, and on target to new ideas, but also identifies conceptual and methodological weaknesses in an idea before it is becomes public via journal publication (Paisley 1972). The boundary that exists between the formal and informal domains is one that science has deliberately erected to curtail, temporarily, the flow of information until it has been examined against the current state of knowledge in a discipline (Garvey and Griffith 1971).

The exchange of information, Schott suggests, is not a mechanical process determined only by the participant's self-interest, it is also affected by the institutional context. A framework of institutionalised norms, role expectations and formal arrangements in a social group regulates interaction and, specifically, processes of exchange which lead to the circulation of information and influence. He also suggested that since scientific work is not insulated from other spheres of life where some associations like friendship are shaped in part by age similarity that age peerage might be hypothesised to affect scientific exchange and influence. However, according to this author, the norm of universalism can be expected to reduce spillover from other walks of like, which suggests the hypothesis of no-effect from age peerage (Schott 1987a).

While informal communication in the sciences is largely unplanned, and sometimes appears accidental, it does exhibit a certain amount of regularity. Certain individuals, for example, tend to be the most frequent transmitters and recipients of information, the most frequent hosts to visiting scientists as well as carrying out the most visits to other institutions. They tend to be the people who serve as editors of journals and members of different evaluation committees. Menzel described these eminent scientists as "scientific troubadours" (Menzel 1966).

A somewhat similar picture has been drawn for information flow in the technologies. "Technological gatekeepers" are a small number of key individuals orientated towards the use of scientific literature and other information sources. They also differ from their colleagues by being acquainted with a larger range of technologists outside their own organisations and outside their own specialities (Allen 1970). They are the only information source whose use has consistently shown a positive correlation with technical performance. In order to act as gatekeepers in an international sense, an individual must be well integrated into both domestic and foreign networks (Allen, Piepmeier et al. 1971).

3.2.1 *Constraints to Scientific Communication in Developing Countries*

The difficulty of access for scientists from DCs to both formal and informal communication channels both as producers and as users of information can be almost invariably related to the condition described in the previous chapter, as science on the periphery.

A study on ecologists in DCs, identified the main restraint to efficient communication as difficulty of access to specialised literature. Libraries were inadequately stocked due to limited budgets. Reprints were not always sent when solicited and many scientists expressed concern about the time lag inherent in postal requests (Cooley and Golley 1989). Other authors too have laid stress on the problems of formal information access in DCs, especially with respect to locating national journals (Menou 1990; Alonso-Gamboa and

Reyna-Espinosa 1995; Russell and Macías-Chapula 1995). The ecologists also mentioned the problems associated with pursuing a scientific career in a DC, such as lack of money; too few meetings; restricted number of national colleagues with which to share ideas and critically review work; inadequate facilities; poorly trained staff; lack of time for carrying out research; geographical isolation; and political problems (Cooley and Golley 1989).

In a survey of Nigerian natural and physical scientists, more than 80% of the scientists referred to lack of information as an impediment to research. Strategies used to contend with this problem included asking scientists outside the country to do literature searches and to supply photocopies; taking advantage of trips abroad to obtain information, or consulting scientific societies' bulletins, journals and lists of publications to learn about new findings (Ehikhamenor 1990).

The importance for DC scientists of help received from colleagues abroad is widely recognised, such that certain DC countries have set up networks which promote this kind of cooperation and information exchange. The Colombian government, for instance, with the help of the French institute, ORSTOM (Institut Français de Recherche Scientifique pour Développement en Coopération) has developed a network known as RedCaldas, which links scientists working in Colombia with their co-nationals affiliated to foreign institutions. An added advantage of this type of linkage is that Colombian scientists working abroad can continue to contribute to the scientific and technological development of their home country (Meyer and Charum 1994).

The conclusion of Arvanitis and Chatelin´s study on tropical soil sciences, is that a country can be autonomous in terms of national publications, when a strategy is adopted of international communication in order to avoid insularisation. In terms of policy, this means encouraging participation in international meetings more than publication in mainstream journals. Their data showed that countries from the South were not well represented at international meetings. They also mention that the two external factors which limit publication by DC scientists, namely, language access and publication opportunities, are less important in informal than formal communication (Arvanitis and Chatelin 1988). In their study on Mexican physicists, Liberman and collaborators found that scientists gave a much higher value to meetings abroad as far as establishing informal contact with colleagues is concerned than national events. They reported attending three or four meetings a year. Contact at meetings was believed to reinforce communication networks (Liberman, Seligman et al. 1991).

Garvey in his classic work on communication in science, highlighted the importance of international meetings not only for alerting participants to recently completed work and new investigations, but also for providing an information exchange environment which facilitates the development, extension and continuation of scientific correspondence and collaboration after the meeting. For scientists from the less scientifically affluent nations to keep alive on the research front, attendance at international meetings is absolutely necessary to tap the information exchange which takes place there (Garvey 1979).

In Chu's work on communication patterns in the discovery of high-Tc superconductors, informal channels were found to play a greater role than the formal. However, the fact that Chinese scientists did better overall in the formal domain than the informal one, suggests that scientists from DCs, regardless of the high level of research they might carry out, are not able to escape the confines of a communication system which suffers from great disparities between developed and developing countries. Until DC scientists are able to enjoy a communication environment akin to that of scientists in the industrialised world, will they be able to take their rightful place in the highly stratified system of world scientific hierarchy (Chu 1992b).

Obstacles to getting papers accepted for publication in mainstream journals is often mentioned as a frustrating constraint for DC scientists. Apart from the difficulty inherent in publishing in a foreign language, it is often felt that there is a bias in the referee system against manuscripts received from DCs due to their generally inferior position in the international scientific hierarchy. An analysis of the acceptance and rejection rates of scientists submitting manuscripts for publication in *Physical Review*, showed that the higher the rank of the scientist submitting the paper, the greater chance of its being accepted for publication. Although rank and authority in science are acquired through past performance, once acquired they tend to be ascribed for an indeterminate duration suggesting that peer review decisions might be skewed by deference to rank. In addition papers submitted by physicists in the foremost departments were accepted more frequently for publication that those from other universities (Zuckerman and Merton 1971).

Scientists in DCs often encounter problems when looking for a suitable vehicle to disseminate their findings. A serious constraint for DC researchers working of problems of local interest, is that the majority of established journals from the industrialised world publish papers on basic aspects of science or on applied research of universal importance. The majority of journals from the developing world seldom have enough continuity or prestige to compete with mainstream journals and are rarely cited (Galina and Russell 1994). The peer review system of national journals leaves much to be desired in comparison with international journals, making publication in these parochial titles much less prestigious than in their international counterparts (Reig 1989)

3.2.2 *Role of New Communication Technologies*

The development and spread of information technology over the last couple of decades has revolutionised the ways scientists communicate. Thanks to the Web, work in progress, broadsides, early drafts and refereed articles are now almost immediately and globally sharable, with authors able to choose the individuals or groups to whom they wish to disseminate their information (Cronin and McKim 1996). In today's world scientists can communicate and interact through cheaper flights, telecommunications and the establishment of Internet (Melin 1997a).

The Internet is already reshaping the way science is done not only with respect to the exchange of electronic mail and manuscript files, but also in relation to the collaboration process. Although it is thought that collaboration is not usually initiated by electronic communication, rather it requires face-to-face contact, once the link is established electronic interchange makes it possible to handle several collaborative projects at the same time, especially in the case of international co-authorships (Hoke 1994). Carley also states that email does not stimulate new relationships; rather it enhances the impact of a strong invisible college and proximity ties (Carley and Wendt 1991).

In the opinion of Hoke, Internet ties the scientific world together and scientists who might have found themselves at the periphery of the scientific enterprise in the past are finding new access to the process of science as the network's influence expands (Hoke 1994). A case in point is that electronic preprints are becoming rapidly available to anyone, located anywhere in the world and at anytime provided they have access to the necessary computer and telecommunications environment. In scientific communities such as that of high-energy physics, the pre-existing hardcopy preprint habit had largely supplanted journals as the primary communication medium before the arrival of the electronic preprint archives (Ginsparg 1996). The consequence for developing countries of this change in communication habits is the prospect of ready access to preprint material which in its printed format took several weeks to arrive by conventional mail and which could often be supplied only through personal contacts. Electronic preprint boards, like that developed by Ginsburg in high-enery physics, can be accessed from almost anywhere through email and scanned to identify preprints of interest which can then be downloaded and stored. Physicists can also submit preprints to the system providing an opportunity for DC scientists to contribute to these banks of current knowledge (Report 1993).

Stichweh too believes that the differentiation of science into centres and peripheries is being weakened by the developments in the availability of computer-mediated communications (email, file transfer, online publications, etc.) (Stichweh 1996). This viewpoint is also held by other authors who believe that the World Wide Web makes possible new kinds of technology transfer for educational purposes and that by connecting and interacting with remote data sets hosted by First World institutions, scientists in DCs will be able to compensate, at least in part, for their isolation from the scientific centre (Cronin 1982; Cronin and McKim 1996). Other authors also believe that peripheral scientists become more central as electronic communities develop which could change our definition of what constitutes peripherality (Lederberg and Uncapher (1989) cited in (Glasner 1996).

A recent article on whether the Internet will help solve the problems of the developing world reports the view of Arunachalam who believes that it might eventually. However, in the short-term it will widen the gulf between the haves and the have-nots. In developing countries like India, many researchers cannot access the new technology for reasons such as cost, outdated equipment and political factors. Even for those scientists who do have access to the Internet the poor telecommunications infrastructure of the country often means that downloading material can take several hours, a task which in the developed world would be only a matter of minutes. Arunachalam also states that it is not just a matter of resources but also of time. India has the means to provide access in the major cities where higher education institutions and major research laboratories are located. The major difference he believes between the First and the Third World is the time it takes to transfer something from the realm of possibility to reality (Report 1998).

Arunachalam also believes that history has repeatedly shown that technology inevitably enhances existing inequalities. He mentions the profound concern also expressed by the UN's Administrative Committee on Coordination in their 1997 statement on Universal Access to Basic Communication and Information Services on the deepening mal distribution of access, resources and opportunities with respect to these services world-wide. It is the concern of this Committee that most developing countries are not sharing in the communication revolution (Arunachalam 1998).

In Latin American countries too the concentration of the major higher education and research establishments in the principal cities means that communication and telematic facilities are also centralised. This is creating an information gap within the developing countries between those scientists working in the large urban areas and those working in the more rural areas who find themselves virtually isolated from the electronic environment. As Voutssas and Cetto, two Mexican specialists, point out First World and Third World users exist side-by-side in Third World countries (Voutssas and Cetto 1996).

It has been suggested that a DC scientist with the good fortune to have email access and a network of good personal contacts with the scientific centre will suffer little from the lack of appropriate information (Galina and Russell 1994). Holderness nonetheless, believes that to make the most of the information age, you need to be male, speak English and live in an industrialised country (Holderness 1993). Most software is developed in English, and in many parts of the world, there is a fundamental lack of access to communication networks. It is ironical that the best network access is in those countries which are already provided with well-stocked and well-run libraries (Holderness 1993).

The recently coined term "collaboratory" refers to the combination of technology, tools and infrastructure that allow scientists to work with remote facilities and each other as if they were located in the same place and effectively interfaced (Glasner 1996). According to Susan Crawford, collaboratories function much like electronic visible colleges (Crawford 1996). The new electronic technologies, such as email, remote accessing, and teleconferencing, facilitate scientific communication and co-operation, particularly in research areas which are information intensive and have a great need to share information. The process of sharing information of all kinds in a seamless fashion, regardless of geographic location, may be a "cyberplatonic" dream. In order to understand this process better, we need to have deeper knowledge of the process of collaboration itself. The question as to whether craft knowledge (protocols, software) can ever be fully shared in electronic form, leads to the conclusion that interpersonal communication will always be a part of the development of any scientific community and that the collaboratory concept may do no more than re-configure the customary view of science (Glasner 1996).

With respect to DCs, more than a decade ago Moravcsik stressed that the crucial ingredient in the communication system between scientists is the person-to-person contact for propagating ideas, overviews, critiques, conceptual advances, speculations, and other forms which go far beyond simple pieces of facts. For this reason, he believed that computerised information systems had a relatively unimportant role to play, even without taking into account their unreliability in DCs (Moravcsik 1986b). Possibly for the same reason, Meadows believes that the research community is more likely to accept the computer screen for the handling of informal rather than formal information and that a greater use of information technology should lead to enhanced productivity (Meadows 1991). However, other authors emphasise the important implications of CD-ROM technology for access to formal scientific information in DCs where telecommunications infrastructure is poor or nonexistent (Russell 1993).

3.3 Collaboration in Science

Research collaboration is a phenomenon of growing interest from a research policy perspective as well as for a deeper understanding of the social and cognitive mechanisms that shape scientific practice today (Melin 1997a). Collaboration in science has been increasing within and especially across national borders, a phenomenon which Katz and Hicks argue is intrinsic to modern scientific culture rather than the direct result of science policy directives. (Katz and Hicks 1995).

Nonetheless, science policy initiatives have encouraged researchers to communicate and collaborate in order to share facilities and reduce costs (Melin 1997a). Most science policy directives are aimed at fostering collaboration between institutions, sectors, as well as between regions and countries. However, direct co-operation occurs between two or more researchers who are the fundamental unit of collaboration (Katz and Martin 1997).

At the microlevel there are more personal reasons for collaborating. Scientists might argue that the collaborator had certain data of interest or that they just met somewhere, realised they had a common interest and decided to collaborate (Melin 1997a). Kreiner and Schultz also emphasise the occurrence of accidental connections when describing informal collaboration in R & D, requiring the temporary reshuffling of communication and collaboration links (Kreiner and Schultz 1993).

Over 30 years ago, Price and Beaver attributed the acceleration in the amount of multiple authorship in several regions of science partly to the building of new communication mechanisms derived from the increased mobility of scientists, and partly to an effort to utilise larger and larger quantities of lower level research manpower. If this is the case, they explain, then the conventional explication of collaboration as the utilisation of many different skills and pairs of hands to do a single job otherwise impossible to perform, is woefully inadequate and misleading (Price and Beaver 1966).

Although a wide range of factors apparently contributing to collaborative activity have been identified, few specific reasons have been clearly established to explain how and why it occurs. Collaboration is intrinsically a social process, indicating that many contributing factors can and will be involved (Katz and Martin 1997). Melin agrees that few studies are available at the microlevel of individual researchers (Melin 1997a).

Collaboration can be of many types with respect to the status and expectations of the people or institutions involved. Beckmann (cited by (Westland 1990)) divides collaboration into two main types: peer and mentor. Peer collaboration is a vehicle for amalgamating the diverse talents of several researchers and is common in technically complex and equipment intensive fields. This type of collaboration may also be required when budgets are tight and equipment could be shared. Mentor collaboration is the norm on PhD related research and is often an extension of the mentor's own research (Westland 1990).

Subramanyam mentioned six kinds of research collaboration including the teacher-pupil collaboration (referred to by Pao as the master-apprentice model (Pao 1992)); collaboration among colleagues, a common practice in corporate research centres, often involving the pooling of expertise from different specialities; researcher-consultant collaboration where in large scale projects, assistance of a consultant can be sought; supervisor-assistant collaboration concerned with the support given by laboratory and technical staff; collaboration between organisations; and international collaboration (Subramanyam 1983).

Collaboration varies from one discipline to another with the more experimental disciplines having higher degrees of local collaboration (Schott 1994; Schott 1995). Simultaneous increases in both local and foreign collaboration suggest disciplines that may be both local and cosmopolitan in their collaborative orientations (Schott 1995). Mobility is typically less frequent in applied than basic research with life scientists in the peripheral country of Ireland reporting a lower rate of foreign contact than did their colleagues in the physical and formal sciences (Herzog 1983).

Collaboration can be divided into that involving a clear division of labour or that where there is mutual discussion and intellectual exchange over all research issues (Melin 1997a). Teamwork is far more common in the laboratory sciences than in the formal sciences, although collaboration between peers involving no division of labour may be as common in the latter as the former. Because of these patterns of teamwork, most of the papers in the laboratory sciences have two or more authors. For disciplines in which most publications have more than one author, the average number of publications per professional is higher (Hagstrom 1965). Meadows suggests that collaboration occurs most frequently in those fields where research grants are most readily available (Meadows 1974).

In her study on collaboration in agricultural research publications, Balog found that scientists from universities were much more likely to write papers in collaboration with other academics rather than to co-author with researchers from government institutions, in spite of a considerable amount of co-operation between the two sectors over the use of equipment and facilities. She attributed this situation to the fact that university research is generally less results orientated than government research (Balog 1979/1980).

3.3.1 *Collaboration and Productivity*

Collaboration is said to enhance productivity, mobility and visibility of the scientists concerned and is the result of the professionalisation of the research activity. Collaboration reflects relationships of dependency within a hierarchically stratified professional community, and serves as a means of professional mobility (Beaver and Rosen 1978; Beaver and Rosen 1979a; Beaver and Rosen 1979b). From the standpoint of the scientist, collaboration is a mechanism to advance research, as well as a means to increase productivity and visibility (Pao 1992).

Visibility can be specifically defined as the extent to which members of the scientific community are acquainted with a particular scientist's work and in this sense, is strongly correlated with productivity. While both the number and scientific worth of a researcher's papers are important for determining visibility, the more significant of the two appears to be quality of the work published which can be linked to the frequency with which this is cited by other members of the scientific community (Meadows 1974). In their work on the output of physicists, the Cole brothers found that quality had a strong independent effect on visibility after controlling for the quantity of output (Cole and Cole 1973).

Price and Beaver studied an elite group of scientists and found that the most productive members were by far the most collaborative, constituting a small but highly prolific core of authors linked by co-authorship to a transient group of much less productive authors. They suggested that part of the social function of collaboration is to squeeze papers out of a rather large population of people who have less than a whole paper in them (Price and Beaver 1966).

Other authors also agree that the most collaborative authors are the most productive. Pao arrived at this conclusion in her study of researchers in computational musicology. In spite of the tendency for humanists to work alone, the few who did show important levels of collaboration were amply rewarded by increased productivity (Pao 1980; Pao 1982). Results from a study on the scientific output and co-authorships of Croatian chemists confirmed productivity to be a correlate of research collaboration (Pravdic and Oluic-Vukovic 1986).

Productivity is affected by the type of collaboration. Collaboration with highly productive scientists increase productivity. High group productivity might be the consequence of the preferences given to some specific type of collaborative links (e.g.

among themselves) (Pravdic and Oluic-Vukovic 1986). Pao mentions two types of scientists identified from her work on schistosomiasis research, which she terms "local" and "global" collaborators. "Locals" are those who restricted their co-authorship to within their local group while "globals" who in addition, also co-author with members of other groups. Striking differences in productivity were found between the two groups with the "global" collaborators showing a much higher production of articles and a higher tendency to receive research funding (Pao 1992)

Research carried out on Nigerian scientists showed no correlation between productivity and the following research and communication variables: frequency of collaborative work or joint authorship; number of communication links; number of memberships of scientific societies; number of scientific meetings attended annually; seniority or years of experience as a professional scientist. These findings were attributed to the inconsistent performance of these scientists in research and communication activities due to a host of constraints typical of DCs (Ehikhamenor 1990).

With regard to Norwegian scientists, Kyvik and Larsen found a clear correlation between number of contacts abroad and number of articles, especially with respect to articles published in non-Scandinavian languages. They also found a correlation between productivity and type of conference attendance abroad. The most productive scientists were those most likely to be invited to give papers, followed by those who had papers accepted for presentation while those merely attending were the least productive (Kyvik and Larsen 1994).

The productivity of researchers who have access only to the formal communication channels, is likely to suffer due to the fact that the feedback of ideas would be intolerably long (Liberman, Seligman et al. 1991). Gordon from a study on a leading astronomy journal, suggests that multiple authorship increases the probability of a paper being accepted for publication, a relationship which the author believes will hold in other areas of research which use large scale, highly complex experimental or observational equipment. These areas have, relatively speaking, a clearly identifiable division between theorists and various kinds of experimentalists (Gordon 1980).

Other studies have shown that the number of co-authors also appears to be strongly related with the impact of a paper, especially when the authors are from different countries. Meneghini found that Brazilian papers published in international co-authorship were cited on average four times more than non-collaborative papers. This author also found that papers involving collaboration between national institutions attained higher impact (1.6 times) than non collaborative publications (Meneghini 1996). In his work on cancer research literature, Stephen Lawani showed that as the number of authors per paper increases so does the proportion of highly cited papers, suggesting that those who produce the most, also produce the best (Lawani 1986). Co-authoring with a foreign colleague increases the probability of a paper being cited both at world level and with respect to papers written by countries within the European Community (Lewison 1991; Narin, Stevens et al. 1991).

With respect to scientists from DCs, experience suggests that the most productive scientists are those who have had the opportunity to do most of their studies abroad and have established and maintained contact with experienced scientists from the most advanced Western countries (Gaillard 1991). By and large, isolation is associated with low productivity (Hagstrom 1965). In his study on former IFS (International Foundation for Science) grantees from all developing regions of the world, Gaillard found that the fields in which the scientists work together most are the fields in which most is published linking collaborative research with productivity (Gaillard 1991).

Despite the acquisition of abundant data and sophisticated research designs, there is really little consensus concerning the determinants of scholarly productivity (Wanner, Lewis et al. 1981). Given the complex relationship between collaboration and productivity, Harsanyi recommends the concomitant use of non-bibliometric methods for studying collaboration, as well as the application of meta analysis (Harsanyi 1993). As we have seen from earlier in this chapter, communication is associated with high performance. However, as Allen points out, it is not easy to determine whether communication causes high performance or whether high performers merely communicate more (Allen 1970). Pelz and Andrews, however, found a positive relationship between colleague contacts and performance, confirming their hypothesis that by interacting with each other, scientists can contribute to each other's effectiveness (Pelz and Andrews 1966).

3.3.2 *International Collaboration*

Scientific cooperation between countries is seen as a means of promotion of international amity as well as enabling the creation of multinational scientific teams better able to tackle the multidisciplinary problems of today (Lewison, Fawcett-Jones et al. 1993). The internationalisation of academic and scientific contacts is also believed to introduce new knowledge and values to local systems (Efana 1993).

Scientific cooperation among countries has always been considered as positive for the scientific enterprise and can lead to increased impact of the work produced. Lewison, for instance, found that multinational European Community papers were more highly cited on average than those published by individual countries (Lewison 1991). In addition, cooperative papers in physics for the peripheral countries of Sweden and Spain were found to be published in journals with higher impact factors than papers involving only national institutions (Gómez and Méndez 1990)

It is well-documented that there has been a steady increase in the number of internationally co-authored papers in science and technology, both for the scientifically advanced countries such as the US (National Science Board 1996), as well as for developing countries such as Mexico (Russell 1995). The integration of activities among scientists from different countries is an increasingly important topic for science policy makers as well as for the scientists themselves (Moed, De Bruin et al. 1991).

Participation involves nearly every country but is not evenly distributed around the world. In physics research within the OECD countries, countries at the core are strongly connected (Gómez and Méndez 1990). With respect to the invention of technology, the network of collaborations forms a hierarchy of a few highly inventive centres, especially the US, dominating collaboration with the peripheries (Schott 1994).

It is not therefore surprising that collaboration is said to be embedded in geopolitical links. From his work on collaboration in the invention of tehcnology, Schott found that a position is occupied in the world network by nations that have similar patterns of collaboration with others. Mexico, for instance, is considered a quasi-periphery along with other countries such as Denmark, Spain, India, Brazil and Venezuela, while the "true" periphery is occupied by Taiwan, Argentina, New Zealand, Chile, Peru, Costa Rica, among others (Schott 1994).

The dependence on the international scene is higher for smaller countries where a small number of scientists have a greater chance to collaborate with the larger number of scientists from other countries (Melin and Persson 1996). Luukonen agrees that small countries (peripheral countries) will have higher relative levels of papers written in international collaboration due to science becoming increasingly specialised and the need to look for partners outside the country, or, alternatively, it could be for reasons of cost sharing (Luukkonen, Tijssen et al. 1993).

On the other hand, a large isolated centre such as the US, collaborates little internationally; copublication with foreigners representing 7.7% of total copublication by Americans, as opposed for example, the 26% of French collaboration that is international (Carlson and Martin-Rovet 1995). Latin American countries, such as Mexico and Venezuela show higher percentages of papers written in international collaboration representing approximately one third of all their mainstream papers, the main partners being the USA and, to a lesser extent, Canada and the European countries of France, Great Britain and Germany (Narváez-Berthelemot, Frigoletto et al. 1992; Russell 1995).

Not only does the size of the scientific community within a country affect the opportunities for collaboration but also the way in which science is organised and the type of science that predominates. There are more chances for collaboration when scientific research is concentrated in a few big institutions rather than spread out over many smaller ones (Meadows 1974). It can be assumed that this would apply equally to collaboration in both the national and international domains.

Beside the size of the countries, different types of interactions within the networks depend upon geographical dispersion, as well as cultural, linguistic, and political barriers (Melin and Persson 1996). Subramanyam also mentions the role played by extra scientific factors, such as geography, politics, and language in determining who collaborates with whom in the international scientific community (Subramanyam 1983). Geographical considerations have been identified as affecting the collaborative activity of sectors and countries. An investigation into the intra-national university-university collaboration in

Canada, Australia, and the UK showed that research cooperation decreases exponentially with the distance separating the research partners (Katz 1994). In his study on communication networks in an aerospace firm, Allen found that members of R & D teams are more likely to communicate with those who are located nearest to them (Allen 1970).

Frame and Carpenter also attributed a number of non science considerations including geographic locale, and linguistic, cultural, and political factors, as influencing how much international collaboration occurs and who collaborates with whom (Frame 1979a). In the later work of Narin *et al.*, scientific cooperation in Europe was found to be heavily dependent on linguistic and historical factors. These authors, however, found that the magnitude of international co-authorship is only weakly dependent on the scientific size of a country (Narin, Stevens et al. 1991).

Leclerc and Gagné maintain that, despite political conflicts, distance, language barriers, cultural differences and development disparities, economic logic continues to gain ground in scientific relations (Leclerc and Gagné 1994). According to Okubo *et al.* influences brought about by the social, intellectual and economic structures of the different civilisations create different balances of the supply and demand of scientific knowledge and that within this network, scientific knowledge is not shared in a like manner between countries (Okubo, Miquel et al. 1992).

The levels of international collaboration show a great deal of variation by discipline with applied fields showing more national collaboration between institutions and less international collaboration than basic fields. The three fields that showed most international collaborations in the 70s and 80s are Earth and Space Sciences, Mathematics, and Physics whereas Clinical Medicine showed the least (Frame 1979a; Luukkonen, Persson et al. 1992).

International collaboration too is often one sided in the sense that it does not benefit in equal measure all countries taking part, especially when it involves nations occupying diverse positions in the scientific hierarchy. Meneghini mentions the likelihood of Brazilian partners playing secondary roles in international collaborations, especially those concerned with topics at the frontiers of science, and that lack of leadership when performing these collaborations, may be detrimental in terms of national scientific development (Meneghini 1996). In her study on the Amazonia National Research Institute in Brazil, Lea Velho found that the possible political and financial benefits obtained from international cooperation programmes involving scientific work at this institute, often overruled scientific considerations. The Brazilian scientists were in most cases, the poor partners of the collaborations which failed to produce the expected co-authored output of initiatives traditionally deserving this name. She attributes this result to the circumstances under which the international partnerships were developed and implemented (Velho 1995).

Gaillard agrees that North-South partnership is conditioned by clear differences in the functioning of scientific activities in the North and the South and is necessarily a collaboration between unequal partners. All collaboration, however, should be based on a strong mutual interest and only occurs when both parties have something to gain from it. Personal friendship between collaborators is important for overcoming the many frustrations implicit in any partnership (Gaillard 1994b).

Few South/South partnerships occur although initiatives of certain NGOs have encouraged this type of linkage (Sagasti 1976). Latin American nations continue to send tens of thousands of students to Europe and the US for advanced scientific training, compared to only a few hundred to each other. The more developed countries such as Brazil or Argentina, have more frequent cooperation with the rest of Latin America, but by and large, joint research projects and publications are overwhelmingly with the US and Europe (Boucher 1990). Sagasti proposes Third World cooperation as a way of achieving technological self reliance and outlines a framework which would lead to a process of identifying common interests, organising specific cooperation activities, and applying the results in accordance with the interests and objectives of a given country (Sagasti 1976).

3.3.3 *Motivations and Benefits of Collaboration*

The motivations for collaboration have been related not only to factors associated with science activity, such as the desire to increase knowledge, exchange skills and data, and enhance professional advancement (Beaver and Rosen 1979a) but also to better and less expensive ways of communication (travel, fax, email etc.) as well as to government initiatives to increase contacts in science through travel money and intergovernmental science programmes (Luukkonen, Tijssen et al. 1993). Luukkonen and co-workers believe that the establishment of such programmes indicates that international scientific collaboration is seen as a good thing *per se* and has become a political objective (Luukkonen, Persson et al. 1992).

Katz and Martin suggest that escalating costs of scientific instrumentation encourage scientists to pool their resources either at regional, national or (in the most expensive cases) at international level (Katz and Martin 1997). They, like Terttu Luukonen, believe that cheaper travel and communication in real time have facilitated collaborative projects. Other reasons that they put forward for the increase in research collaboration are the fact that science is a social institution which, for some fields, may entail the creation of formal collaborations; the increasing need for specialisation, especially in those fields which require complex instrumentation; the growing importance of interdisciplinary fields, and finally, political factors encouraging greater levels of collaboration between researchers, particularly with respect to questions of regional integration.

However, Moed *et al.* mention that more insight is required into the motives of scientists to cooperate internationally, such as access to complementary expertise and equipment, cost sharing, the existence of stimulating structures and a favourable scientific climate, a high degree of mobility, and so on (Moed, De Bruin et al. 1991).

Katz and Martin describe several benefits from collaborating, namely, pooling of skills; transfer of knowledge and skills, especially tacit knowledge; cross fertilisation of ideas leading to new insights or perspectives; intellectual companionship, and the enhanced visibility of the work. They also mention a snowball effect when the benefits of working with others are not confined to the links with the immediate collaborators, but plug the researcher into a wider network of contacts within the scientific community (Katz and Martin 1997). This last benefit is one that is especially pertinent for scientists working in DCs who are seeking their integration into the global scientific community.

In an evaluation of cooperative research projects between the Spanish National Research Council and Latin American institutions, non quantifiable outputs were described as: cultural impact; networking effects with scientists establishing permanent collaboration and co-authorships; transfer of knowledge between groups and towards industry; mobility of researchers; and training of human resources. The shortcomings of the programme, as pointed out by the Spanish scientists involved, were: limited financial resources; too short visits; bureaucratic problems; and technical difficulties in communication with Latin American partners due to the large distances involved (Fernández, Agis et al. 1992). According to Franklin's work on the community of science in Europe, collaboration in general, and international collaboration in particular, serves as the greatest liberator of research potential from the limitations imposed by national and institutional shortcomings (Franklin 1988).

3.3.4 *Collaboration as a Way of Overcoming Peripherality*

Scientists who do not participate in activities of formal and informal communication with colleagues find themselves isolated from their peers, running the risk that their work will become obsolete and that due recognition for their achievements will not be forthcoming. The reward system is at the core of what we recognise today as the social structure of science and intrinsic to its survival as a legitimate and honourable human activity. Competition between scientists is associated with the motivation to be rewarded with recognition by colleagues both within and exterior to their own scientific communities to attain credibility and leadership which holds them in good stead for obtaining resources (Liberman and Wolf 1990).

It is now generally recognised that an endogenous scientific community in a peripheral country can only develop when its members have sustained links with other researchers from the scientifically advanced countries. It has been suggested that one of the ways for countries on the periphery to compensate for scientific smallness is to collaborate with institutions in countries at the scientific centre (Kyvik and Larsen 1994). As long ago as 1968 Aran and Ben-David (Aran and Ben-David 1968) reported that the volume and pattern of research output of medical researchers in Israel is a function of the institutionalisation of research and of their resocialisation into the research environment, the main aspect of which is the induction of the practitioner into the international community of scientists.

However, contact with researchers in scientifically advanced countries is a two-way relationship. Scientists in peripheral countries must be seen as attractive partners for collaborative activities and in order for this to happen, a scientist must first become visible to the wider scientific community (Kyvik and Larsen 1996). Melin suggests that the peripheral country scientists must first have access to the international scientific network, then must become visible through publication in international journals which will lead to their attractiveness as possible partners for international collaboration (Melin 1996).

In their study on the development of a Mexican biomedical research institute Lomnitz *et. al.* showed the changes that took place in terms of the emergence of a "critical mass" of researchers in the field, of increasing international visibility, and participation in international colleges which resulted in greater productivity and more horizontal collaboration with colleagues from other institutions (Lomnitz, Rees et al. 1987). Well stocked libraries and frequent trips abroad plus sabbatical leaves are important elements in strategies to help overcome the problem of isolation (Roche 1987).

Several authors have studied scientifically small countries to test the hypothesis that problems associated with marginality can be compensated for through international integration. Schott in his study on mathematics in Denmark and Israel showed that productivity can be increased by the integration of research activities into the international scientific environment, both at individual and at institutional level (Schott 1987b). Individual integration is the participation of scientists in international networks of informal communications about the problems, procedures and results of research. Such integration, Schott believes, is not either completely present or totally absent but is rather a matter of degree; the higher the degree of integration, the better the performance.

The Norwegian case was studied by Skoie who showed that the effectiveness of the scientists in any field of research is affected by the degree of close contact with colleagues abroad. He attributes the strong tendency for Norwegian scientists to make visits abroad to an effort to participate actively in a larger scientific community (Skoie 1969).

Persson and Melin in their study on the OECD countries, found that growth, equalization and integration go hand in hand. The distribution of science among these countries is becoming more equal in terms of inputs, outputs and collaboration (Persson and Melin 1996).

Shiva and Bandyopadhyay attribute the deficiencies of scientists in contemporary India ultimately to the fact that these start their research careers far removed from the vital centres of Western science. A distinctive feature of the small group of Indian scientists who succeed in achieving a higher degree of recognition than their colleagues, in spite of common handicaps, is a greater amount of personal contact with the leading centres of research in Western countries. These links can be achieved through journals or exchange of preprints but unless the scientists meet face to face at regular intervals, the communication is significantly reduced and of shorter duration. Only those scientists who had actually participated in this type of dialogue were aware of its importance. Sustained and successful research by Indian scientists working in India in a rapidly growing area of scientific knowledge depends very often on long and repeated association with foreign laboratories. However, irregular visits abroad do not provide Indian scientists with the full richness of social relations which contribute to productive work. What is also lacking is informal contact with other local scientists. The isolation of individual scientists even in their local situation accentuates the tendency to seek contact with Western scientists (Shiva and Bandyopadhyay 1980).

Dedijer in the early 1960s expounded the differences between scientific communities at the centre and those on the periphery. The scientific community of a large industrialised countries is big enough to permit differentiation with sufficient members in different fields to permit complex interactions. It has its own evaluation system and communication channels which are linked up with other scientific communities across political boundaries by personal contact, by mutual appreciation and by public communication and formal association as well as by fundamental affinity. In contrast in DCs scientists are few in number, scattered geographically and across a narrow range of scientific fields, in isolation from each other. They feel peripheral and out of touch with the important developments in science unless they can visit and be visited by important scientists from the more developed countries. A scientific policy, to be effective, must build a scientific community with its own traditions, closely linked to the international scientific community, and the universal standards of science (Dedijer 1963).

There is evidence to suppose that the most important ties between scientists at the centre and on the periphery are interpersonal ones, the direct person to person relationship based on common interests and mutual respect (Herzog 1983). The mechanisms most frequently advocated to foster this type of interpersonal relationship are: study in major foreign universities; research sabbaticals; visits by distinguished foreign visitors over extended periods of time; and joint projects with foreign colleagues either at personal or institutional level. Salam also emphasises the fact that the personal element counts more than the institutional one in advanced scientific research and that personal face-to-face stimulation with colleagues in the international community is necessary for the first rate individuals working in DCs (Salam 1966).

Gaillard in his study on scientists from a wide range of DCs found that co-authoring with foreign specialists is most prevalent among scientists who studied or went on postdoctoral study tours abroad. In most cases these publications are produced in the years immediately following the stay abroad; sustained collaboration is rare. Other associations develop when a foreign professor visits the DC scientist's institution or when expertise is brought in from abroad (Gaillard 1991).

Herzog in his study on scientists from the Republic of Ireland, found shared work experience to be the single most productive source of foreign colleagues, provided that it takes place in a foreign organisation. He found a difference between fields with high and low paradigm development, those classified as high, such as the physical sciences, had freer international exchange while low paradigm fields, such as agriculture, give rise to distinctive national research traditions with little international collaboration (Herzog 1983). Another study in Ireland showed that the fostering of interpersonal and interinstitutional contacts favours a scientist's ability to keep abreast of foreign technological development and to be an effective way for a country to import technological information (Allen 1973).

3.3.5 *Measurement of Collaboration, Integration, and Influence*

Participation of a scientist or a scientific community in world science can be measured in terms of several concepts, including knowledge production, intellectual influence, and collaboration. Indicators for these three variables can be constructed from the scientific literature: publications indicate knowledge production, citations indicate intellectual influence, and co-authorships indicate collaboration (Schott 1993).

However, Luukonen and collaborators believe that not all collaborative efforts end up in co-authorship, nor does co-authoring of papers imply a close collaboration between authors. Nonetheless, in most cases, co-authorship implies fairly active cooperation between the scientists, much more so than that involved in intellectual exchange which might show up in the acknowledgments section of a paper (Luukkonen, Persson et al. 1992).

Other authors argue that we could expect significant scientific collaboration to lead to co-authored papers due to the claims of priority of the authors involved. A small scale study at a Swedish university indicated that only five percent of authors had experienced situations in which collaboration did not lead to co-authored papers (Melin and Persson 1996). In general, co-authorships are considered a legitimate way of measuring collaborations, particularly with respect to international partnerships (Meadows 1974; Frame 1979a; Melin 1997a).

In certain disagreement with this, Katz and Martin point out that collaboration and co-authorship are not necessarily synonymous (Katz and Martin 1997). They cite hypothetical cases where researchers who have not collaborated during the experimental phase, decide to pool their findings and write them up in a joint paper and, at the other extreme, where two researchers collaborate intensively in all aspects of the research but decide to write individual papers for their distinct disciplinary audiences (Katz and Martin 1997). Moed *et al.* cite a similar situation where two research groups each focuses on a different part of the research, each publishing its own part of the joint project (Moed, De Bruin et al. 1991). Edge´s experience is that co-authorship measures tend to underestimate the level of mutual influence and collaboration (Edge 1979).

Co-authorship then, according to Katz and Martin, can never be more than a rather imperfect or partial indicator of research collaboration between individuals (Katz and Martin 1997). Authors might be included, for instance, for social reasons, as recognised sometime ago by Hagstrom (Hagstrom 1965) and recent investigation of several instances of scientific fraud, have shown just how frequent is the practice of making colleagues “honourary co-authors" (Katz and Martin 1997). Peters and van Raan argue that co-author analysis can identify linkages on the intellectual and/on social level and can quite reliably identify who are the most influential figures within research groups. However, not all influential figures can be detected in this way for which reason an expert's opinion is also needed (Peters and Van Raan 1991).

According to Subramanyam, the precise nature and magnitude of collaboration cannot be easily determined by the usual methods of observation, interviews or questionnaires because of the complex nature of human interaction that take place between or among collaborators over a period of time (Subramanyam 1983). Bibliometric techniques, however, can be used to determine the number of authors of a research paper which can be taken as an adequate measure of collaboration (Subramanyam 1983; Melin and Persson 1996). The principal advantages of this method is that it is invariant, easily and inexpensively ascertainable, quantifiable, and non reactive (Subramanyam 1983).

Zuckerman refers to the fact that one of the main limitations in studies of scientific collaboration and of joint authorship, is that coworkers cannot always agree on what led them to particular ideas, or even on who did what (Zuckerman 1987), a view previously voiced by other authors (Edge 1979). Informal information exchange resists measurement as it is equally capricious; a symptom of the lack of organisation of inarticulated knowledge into visible, discrete, and measurable units (Collins 1974). For much the same reasons, information specialists have initially rejected the idea of attempting to formalise informal communication activities.

The published paper, on the contrary, is taken as the final product of the scientific research process. However, this new knowledge must be used to be incorporated into the process of knowledge accumulation (citations, influence). In the opinion of several authors, output measures in spite of the constraints, appear to be valid criteria for scientific performance, particularly when these are used in conjunction with other indicators of scholarship, such as peer judgment and citation analysis, lead to a single interpretation (Jones 1980; De Meis, De Cássia et al. 1992).

The adequacy of using citation analysis as one means of tracking intellectual influence has been the subject of much discussion. On the positive side, Cronin mentions citation analysis as a possible method for uncovering invisible colleges. For this procedure to be sound, however, it has to be assumed that the network of informal communication ties will be formally enshrined in the citation profiles of publishing authors (Cronin 1982). In the opinion of Griffith, the discovery of a bibliographic, information structure disclosed by co-citation analysis, that parallels social and intellectual structure was of major importance in our understanding of the social and cognitive processes in science (Griffith 1989).

Schott mentions citations and co-authorships as indicators of influence and collaboration occurring in collegial ties (Schott 1995). In his comparative study between scientists in Brazil, other parts of Latin American (Chile and Uruguay), and Israel, he found that collaborations and received influences reported by the scientists in a questionnaire were similar to the collaborations and influences indicated by co-authorships and the citations in their articles (Schott 1995).

Ferreiro Alaez *et al.* in their work on the international integration of Spanish physicists also perceive publication and citation counts as a measure of integration (Ferreiro Alaez, López Aguado et al. 1986). Melin and Persson, in their examination of a Swedish university, came to the conclusion that citation analysis, in addition to co-authorship studies, can be used to determine the interaction between individual scientists, their research organisations and countries. They suggest that a combination of these two techniques could be an interesting approach. Scientific networks are most likely based on several different types of interactions that reinforce one another - scientists who read and cite the same literature tend to meet which could foster collaboration in co-authored studies and lead to citing each others papers (Melin and Persson 1996).

On the downside, the findings of MacRoberts and MacRoberts call into question the practice of culling references from bibliographies and using them as data. The mere presence of a reference is not a marker of influence, nor is the absence of a reference evidence that it is uninfluential. The problem, they maintain, seems to derive from an unwillingness to descend to the events in order to see whether data accord with them (MacRoberts and MacRoberts 1986). According to Hagstrom work rarely gets challenged; it is often superseded or passed over but not challenged (Hagstrom 1965).

Crane sums up this controversy by stating that the use of citation linkages between scientific papers is an approximate rather than an exact measure of intellectual debts. Social factors, as well as intellectual considerations within a research area affect the dissemination of information within it and the extent to which information is likely to be used in later publications (Crane 1972). In the opinion of Lievrouw, the real strength of citation analysis in communication research is that clusters or maps of research articles can be interpreted as networks of interpersonal contacts (Lievrouw 1989).

As with other areas of science studies, formal communication activities, commonly explored by analysing publication and citation patterns of scientists, have been studied to a much greater extent with respect to the developed countries than DCs. Studies carried out on scientists from DCs which have emerged since the early 1980s, point to the fact that formal scientific communication between the developed and the developing world is unidirectional, scientists from DCs cite preferentially their First World colleagues with little or no reciprocal citations forthcoming from researchers at the scientific centre to papers from the Third World. This happens not only in areas of research considered to be of particular interest to the DCs concerned and therefore published almost exclusively in national journals, but also with respect to areas, such as superconductivity, at the cutting edge of scientific research worldwide (Chu 1992a).

Empirical research can only discover the existence of operationalisations of a relation, not the relation itself. In spite of the operational attractiveness of techniques such as sociometrics, the sociologist has to be concerned, at least at first, with the actor's interpretation of these items, before they can be treated as sociologically relevant. Bibliometrics and questionnaires are quite appropriate techniques for Information Science where information is treated as though it can be contained in discrete visible packages of roughly equal value (Collins 1974).

Edge in his review of quantitative measures of communication, maintains that the tendency to characterise science in terms of formal processes obscures key features of scientific research. The proposal that the informal can be grasped in terms of the formal diverts attention away from what he termed the "soft underbelly" understanding of communication activities. In his opinion, quantitative methods are of limited use to the historians of science, "soft" data taking preference over "hard" data (Edge 1979).

Lievrouw defines bibliometrics as "the quantification of bibliographic information for use in analysis". While information scientists approach science as a generator of documents; sociologists, historians, and communication researchers, on the other hand, approach science as a social system. However, she believes that the aims of the two fields are converging. Communication scientists find themselves increasingly concerned with information as a commodity or social good while information scientists are becoming more concerned with the human element in information systems and flows (Lievrouw 1988).

Chapter 4

Scientific Research in Mexico

4.1 Latin American Context

Latin America, a region of nearly 20 countries and 450 million people, is a vast potential source of scientific brainpower and resources (Koshland 1995). Nonetheless, its contribution to world science is not in relation to its scientific potential and is much less than many industrialised countries with much smaller populations.

Scientific performance varies considerably between the different countries that make up Latin America. In absolute numbers of publications (articles, notes, reviews and conference proceedings) in mainstream journals produced from 1981 to 1993, Brazil is the most productive country followed by Argentina, Mexico, Chile and Venezuela. However the ranking changes dramatically with respect to the number of papers produced per capita, with Chile heading the list followed by Argentina, Costa Rica, Jamaica, Venezuela, Brazil, Mexico, Cuba, Colombia and Peru. Citation data for the countries with more than 1,000 papers in the 13 year period studied, showed that LA and the Caribbean have overall citation impact which is 40-60% lower than the world average. In certain fields, however, the region´s researchers are on a par or show better citation rates than the world average; for example, Colombia and Chile in agricultural sciences; Chile in astrophysics; Costa Rica and Peru in clinical medicine; Venezuela in engineering, and ecology and environmental science; and both Venezuela and Mexico in mathematics. In some of these cases the number of papers was small suggesting that these results may have been skewed by a few highly cited papers (Krauskopf, Vera et al. 1995c).

In Latin American countries scientific research is carried out mainly within the higher education sector and, more particularly within the mega national universities developed as a result of government policy to make higher education available to a larger percentage of an ever increasing population (Vessuri 1986b; Krauskopf 1992). Universities in the region are based on the Napoleonic model (José Yacamán 1994a) with a sharp division between research and teaching activities, such that researchers in the UNAM, for instance, hardly ever teach classes of undergraduates, while teachers of undergraduates are not expected to be competent at research (Maddox and Gee 1994). Nonetheless, the university offers a fine environment for research, precisely because it is a centre for the free discussion of ideas and positions on the world's different problems (Di Prisco 1983). In contrast to what is generally believed, the universities in Latin America continue to have the highest qualified academic personnel and the most productive scientifically speaking (Vessuri 1986a).

Latin American scientists, like their colleagues elsewhere, have to struggle with lower budgets than they would like, but show resourcefulness in the use of scarce funds and symbiotic collaboration with scientists in areas where better funding or equipment are available (Koshland 1995). Funding for scientific research comes almost exclusively from federal funds. Unlike countries such as the USA where a number of government agencies handle official funding for research, in many Latin American countries, a single agency is responsible for allocating the limited budgets assigned to science and technology.

Faced with the threat of an intensified brain drain due to the inherent difficulties of academic science in DCs, several Latin American countries, such as Argentina, Brazil, Mexico, and Venezuela have implemented programmes to supplement the salaries of their most productive researchers. These initiatives are aimed at preserving the core of the national stock of researchers while encouraging increased productivity, participation and self-evaluation of the national research community (Vessuri 1994).

4.2 Research Funding in Mexico

The federal government is the principal funding body for scientific research, as well as the principal executor of S & T activities in the country (Parra Moreno 1992). According to data published in 1986, the federal government provides more than 90% of the nation's research funding (Mayagoitia Domínguez 1986), although more recent sources put this figure at 83% (Parra Moreno 1992) Industry contributes with another 8%, and the rest is covered by state governments or by external and non lucrative institutions (Parra Moreno 1992). Other authors confirm that Mexican science is not strongly related to the productive sector and receives little support from it (Jiménez, Hunya et al. 1988; Martuscelli and Soberón 1994; Castaños-Lomnitz 1995). Federal financing is administered by the government scientific agency, National Science and Technology Council (Consejo Nacional de Ciencia y Tecnología, CONACYT), founded in 1970 to formulate plans and programmes to promote the scientific and technological development of the country (Saldaña and Medina-Peña 1988).

Approximately 70% of government S & T expenditure is earmarked for R & D activities and 18% to support postgraduate education (Parra Moreno 1992). In 1995 the public education sector was expected to receive 62.3% of the federal S & T budget, of which CONACYT obtained 32%, the UNAM, 23.5%, and the research institutes belonging to the SEP-CONACYT[1] system, 17.7%. The energy sector was allocated 22.2% of the federal S & T budget of which the Mexican Petroleum Institute (Instituto Mexicano de Petroleo, IMP) and the Institute of Electrical Research (Instituto de Investigaciones Eléctricas, IEE) were the principal recipients. Another 6.4% of the budget was assigned to the agricultural, livestock and rural development sector, of which 66.3% went to the National Institute of Forestry, Farming and Livestock Research (Instituto Nacional de

[1] SEP-CONACYT refers to the research centres administered by CONACYT and the Ministry of Public Education (Secretaría de Educación Pública) of which CONACYT forms a part.

Investigaciones Forestales y Agropecuarias, INIFAP) (Consejo Nacional de Ciencia y Tecnología 1996).

In 1994 Mexico spent 0.46% of its GDP on science and technology (Consejo Nacional de Ciencia y Tecnología 1996), a figure considerably lower than the 1% considered as the minimum for developing countries (Velasco 1981). The economic crisis of the 80s, had seen this figure gradually reduced from 0.43% in 1980 to 0.27% in both 1988 and 1989, after which it has showed a gradual upward trend (Consejo Nacional de Ciencia y Tecnología 1996).

4.3 RESEARCH INFRASTRUCTURE

4.3.1 *Research Institutions*

Mexican scientific research is concentrated in the government funded public universities and in the national research institutes. More than 90% of the higher education institutes which carry out R & D activities are public institutions (Parra Moreno 1992).

Scientific research is highly centralised within the federal district of Mexico City which houses the world's largest urban population (Malo, Garza et al. 1988; Jiménez, Campos et al. 1991). It is also the main location of the country's principal research institutions, namely the UNAM, the National Polytechnic Institute (Instituto Politécnico Nacional, IPN), and the Metropolitan Autonomous University (Universidad Autónoma Metropolitan, UAM). Scientific research thus follows the country's generalised model of geographic and political centralism (Pacheco Méndez 1994).

Mexican research institutes are of two types; those which form part of the universities and those independent of the higher education system, which are integrated into the federally funded SEP-CONACYT system. In 1990, the SEP-CONACYT system of research institutes was integrated to provide a balance between basic research and technological development, as well as to foster closer ties between scientific research centres and the private sector. The system comprises 27 separate institutions of which 9 are in the exact and the natural sciences, 9 in the social sciences and humanities, 7 focused on technological development and 2 are service centres. Since regionalisation is one of the system's major goals, more than two thirds of the institutions are located in 15 centres outside Mexico City. In the present climate of globalisation, these institutions play an important role in linking national scientific activity to world trends through multiple collaborations with research institutions in different parts of the world (Martínez García 1994) [2].

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[2] Information obtained on April 7, 1997 from the CONACYT website: http://info.main.conacyt.mx

Important national research institutes, apart from the IMP, IEE and INIFAP already mentioned, are those in the health sector, particularly the National Institute of Nutrition (Instituto Nacional de la Nutrición "Dr. Salvador Zubirán", INNSZ), National Institute of Cardiology (Instituto Nacional de Cardiología "Dr. Ignacio Chávez", INC) and the Mexican Institute for Social Security (Instituto Mexicano del Seguro Social, IMSS). In other areas, prominent research institutes are the National Institute of Fisheries (Instituto Nacional de Pesca) and the National Institute of Nuclear Research (Instituto Nacional de Investigaciones Nucleares, ININ) (Parra Moreno 1992).

4.3.2 *National University of Mexico (UNAM)*

The UNAM is the largest Mexican institution for higher education and one of the oldest and most prestigious in Latin America; its origins date back to the middle of the 16th century. With a total student population of around 150,000, the UNAM employs approximately 27,000 teachers, researchers and other academic staff. It has the largest output of graduates at both master's and doctoral level of all the institutions in the country and is the custodian of the country's most important bibliographic archives (Coordinación de la Investigación Científica 1988).

Scientific research in the UNAM dates back to the last quarter of the last century. However, it was not until 1929 when the institution was granted independent status that the first research institutes were formally established within the UNAM. Since then the number of research centres and institutes has gradually increased and by 1996, the number totalled 37, of which 22 are in the area of S & T. Almost a quarter of the total institutional budget is assigned to research activities (De la Fuente 1991). Research is also carried out within the teaching faculties and through special interdisciplinary programmes (Coordinación de la Investigación Científica 1988). In 1983, 63% of UNAM research projects in all areas were carried out in the research institutes and centres, and the remaining 37% within the teaching institutes, a split which is more marked when considering only the exact and natural sciences, 72% and 28%, respectively (Rodríguez Sala 1988).

Although the research activity in the UNAM is concentrated in the main campus situated on the southern edge of Mexico City, important nuclei have been created in other parts of the City and in other regions of the country in an effort to decentralise Mexican scientific research. Experimental stations are scattered around the country in strategic areas where the local environment provides important conditions for research. Approximately 25 observatories, laboratories and other types of experimental stations belonging to the UNAM are situated outside Mexico City (Coordinación de la Investigación Científica 1988).

In a survey of science in Mexico carried out by the journal *Nature*, the UNAM is referred to as the "cradle of Mexican science" (Maddox and Gee 1994). In 1995, 1,997 scientists held research positions in the UNAM, 1077 of which were working in the natural and applied sciences (Secretaría General. Dirección General de Asuntos de Personal Académico 1995). In spite of the prominent nature of scientific activity in the UNAM, it is wrong to suppose that its research environment is akin to that which exists in British or North American universities. At the UNAM, as in other Latin American universities, scientists are subjected to extracurricular pressures that are often in conflict with each other. This situation can be attributed to the burden imposed on the Latin American universities as a result of varying social and political agendas. They are required, for instance, to endorse qualifications for the social assent of the middle classes; and to train national political leaders while constituting a political battleground and a refuge for dissidents (Lomnitz 1979).

Both basic and applied research is carried out in the UNAM which contributes both to universal knowledge and to a greater understanding of local problems. As well as the 3,000 or so projects in basic research fields, such as biology, physics, chemistry, or astronomy, research is also carried out in multidisciplinary subjects, such as health, energy, and food. Research directed at generating knowledge on the physical and biological nature of the national territory is given special importance (Coordinación de la Investigación Científica 1988; Secretaría Administrativa 1994). The type of research that is carried out in the UNAM differs slightly from that carried out in the rest of the country. While 62% of UNAM research projects focus on the basic sciences, the figure for the rest of the country is 32% (Chavero González 1989).

At the beginning of 1997 the UNAM had research institutes or centres (year of creation in brackets) in the following scientific fields: Astronomy (1929); Biology (1929); Geology (1929); Geography (1938); Physics (1938); Chemistry (1941); Mathematics (1942); Biomedical Research (1945); Geophysics (1945): Engineering (1956); Applied Mathematics and Systems (1958); Materials Research (1967); Nuclear Sciences (1967); Instrumentation (1971); Marine Sciences and Limnology (1973); Atmospheric Sciences (1977); Cellular Physiology (1979); Nitrogen Fixation (1980); Genetic Engineering and Biotechnology (1982); Ecology (1988); Neurobiology (1993); Energy (1995) (Coordinación de la Investigación Científica 1988; Oficina del Abogado General 1996).

The UNAM produces approximately 42% of all Mexican papers published in the mainstream scientific literature and 44% of those co-authored with institutions abroad (Russell 1995), thus making this the most important research institution in the country. From 1980 to 1989, researchers at the UNAM published a total of 1,616 studies with foreign institutions representing 29.5% of its total output in the international scientific literature. This international activity was concentrated in clinical medicine (19.8%), physics (17.3%) and in biology (15.7%). However, the percentage of Mexican studies in clinical medicine which resulted from co-operation with foreign institutions was low compared to other fields, only 17.0% compared to earth and space sciences (44.7% of all contributions), engineering and technology (38.9%), and biology (35.9%).

4.3.3 *Research Journals*

Up to September 1995 a total of 4456 Mexican journals had been assigned ISSN (International Standard Serial Number) codes, of which 3,387 were still being published. The world total for 1996 was 511,231, indicating a 0.66% Mexican contribution (Rovalo de Robles 1996). Of the total of current titles, 37% are in the social sciences and the humanities, 11.4% in the health sciences, 9.7% in the agricultural sciences, 9% in the exact and natural sciences, and 7.4% in engineering. One quarter of titles are classified as "other titles" (Consejo Nacional de Ciencia y Tecnología 1996).

An article published in 1973, indicated a total of 2,537 titles of which 1,786 were considered scientific or technical. Agricultural journals were the most numerous with 40% of the total S & T titles, followed by medical titles with 38% and engineering journals with 12% (Velásquez 1972).

Of 500 titles of selected Mexican journals, approximately 50% corresponded to S & T areas. A total of 44% were edited by higher education establishments, 22.4% were government publications and only 6.4% were produced by commercial publishing houses (Orozco Tenorio 1986). A list of Mexican high quality journals with international presence, published by CONACYT after strict evaluation of titles submitted by their editors, comprised 68 publications of which 28 were in science, technology or medicine (11 in the natural sciences, 5 in applied sciences, 5 in earth sciences, 4 in the exact sciences, 3 in the health sciences) and 40 in the social sciences and humanities (21 in human sciences and 19 in the social sciences). Twenty one of these titles are edited by the UNAM [3].

The 1989 serials collection of the British Library contained 126 Mexican journals representing 19.6% of their Latin American collection. Sixty eight titles corresponded to science, technology and medicine and 58 to the social sciences and humanities. The greatest number of journals were in clinical medicine (n=25), in biology (n=17) and in earth and space sciences (n=16) (Narváez-Berthelemot 1995b).

In 1995 only two Mexican journals were included in the *Science Citation Index*, namely, *Revista Mexicana de Astronomía y Astrofísica*, edited by the Institute of Astronomy of the UNAM; and *Revista Mexicana de Física*, published by the Mexican Society of Physics (Institute for Scientific Information 1996a). The *Social Science Citation Index* for that year covered four Mexican titles, three in the area of health: *Revista Mexicana de Psicología*, published by the Mexican Society of Psychology; *Salud Mental* edited by the National Institute of Psychiatry (Instituto Nacional de Psiquiatría); *Salud Pública de México*, edited by the Health Ministry (Secretaría de Salud), and the fourth in economics, namely *Trimestre Económico*, published by Fondo de Cultura Económica, a Mexican government publishing house (Institute for Scientific Information 1996b). Three Mexican medical journals had been previously included in the SCI in recent years: *Patología,* published by the Mexican Society for Pathology up until 1981; *Revista de*

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[3] Information obtained on April 7, 1997 from the CONACYT website: http://info.main.conacyt.mx

Investigación Clínica, edited by the INNSZ which ceased to be indexed in 1986 (Delgado and Russell 1991); and *Archivos de Investigación Médica* (now *Archives of Medical Research*) produced by the IMSS, was covered until the mid 90s.

4.4 Research Areas and Production

In 1994 1,584 articles and reports were published by institutions within the Mexican Republic in the mainstream scientific and technological literature, in comparison with 164 in the social sciences and 36 in the arts and humanities, giving a total of 1,784. The number of articles published in 1980 for these three areas were 632, 96 and 20, respectively, making a total of 748. A 138.5% increase in the visibility of Mexican articles in the mainstream literature was therefore apparent from 1980 to 1994, which was more marked in S & T area amounting to a 150.6% increase (Consejo Nacional de Ciencia y Tecnología 1996).

Medical science is the most traditional research area of Latin America. The most numerous Mexican articles published in the mainstream literature and the most cited continue to be those from the health sciences (Martínez Palomo 1994). A search carried out on the 1980-1989 *Science Citation Index* CD-ROMs revealed a total of 5296 Mexican articles in medical journals of which over 10% were in neuroscience titles, 9.3% in the pharmaceutical field and 8% in biochemistry and molecular biology. Over one quarter of the articles appeared in journals published in Mexico (Delgado and Russell 1991). It is important to bear in mind that Mexican biomedical research suffered a severe setback during the mid 80s following the 1985 earthquake, due to the destruction of the National Medical Centre, the foremost medical research institute at that time in Mexico (Pérez-Tamayo 1986).

A previous study in the health sciences field identified 3198 Mexican articles published in national journals compared to 1,862 in foreign titles from 1982-1986 using four international bio-science databases (Licea de Arenas 1988). All fields of scientific research in Mexico with the exception of physics and chemistry, showed higher production in national journals than in international journals (Russell, Rosas et al. 1994).

Data based on the performance of the members of the National System of Researchers (see following section) showed physics to the most productive field of the exact sciences in both 1988 and in 1989 with medicine, biology and chemistry leading the area of the natural sciences and health. Psychology, economy and sociology were the fields in the social sciences and humanities with most production, while in the applied sciences and technologies area, agronomy far outled the other fields (José Yacamán 1994b).

In the opinion of Aréchiga, a well-known Mexican medical researcher, bibliometric studies have shown the important impact of the work of Mexican scientists, particularly in areas such as cardiology, physics and biology. Although small in number, Mexican researchers in the biomedical area have been cited above that of the world average, sometimes reaching citations levels several-fold higher. This same author mentions the important contribution to universal knowledge that Mexican science has made to areas such as the origin of galaxies, the complexities of algebraic topology, or in the analysis of physical, chemical and biological phenomena, as well as in the genesis of human conduct and of social dynamics. The names of Mexican scientists are part of the world scientific vocabulary in lunar topography, in the nomenclature of stars, in mathematical operations, in the phenomenology of physics, chemistry, physiology, cellular and molecular biology, neurobiology and medicine, in the denomination of biological genera and species, of new molecules, and of clinical signs and syndromes. Certain varieties of nutritional plants developed in Mexico have been used successfully to fight world starvation. Moreover, Mexico continues to be a source of food and therapeutic products of recognised international worth (Arèchiga 1994).

4.5 Science Policy

4.5.1 *Organisms responsible for National Science Policy*

CONACYT, as a decentralised government organisation, serves as the consulting and auxiliary body for the federal government with respect to the establishment, instrumentation, implementation and evaluation of national S & T policy. It manages various programmes to support different areas of S & T activity including: scientific research; scientific and technological infrastructure; postgraduate study and sabbaticals both in Mexico and abroad; retention and repatriation of Mexican scientists; the National System of Researchers (SNI); technological modernisation; technological incubators; and visiting lectureships (Parra Moreno 1992; Consejo Nacional de Ciencia y Tecnología 1994).

In 1984 the law to co-ordinate and promote scientific and technological development was passed and included the creation of the Planning Commission for Scientific and Technological Development. Among the members of this Commission are high ranking officials of government ministries with S & T responsibilities, of CONACYT, as well as the vice chancellors of the UNAM and IPN (Parra Moreno 1992).

The incorporation of Mexico into the OECD in 1994 has led to its participation in the committee for S & T policy whose principal objectives include the fostering of cooperation between the member states with respect to S & T policy; the integration of S & T policy with other sectors of goverment policy; a better understanding of the process by which S & T contribute to economic growth, social development and the creation of jobs; and identify initiatives which will guarantee the strengthening and continuity of basic research, education and the high level preparation of future generations. An evaluation published by the OECD on Mexican S & T policy included several recommendations including one on international scientific co-operation. The report recommended that Mexico should concentrate its efforts in a few, far reaching interdisciplinary programmes to achieve greater utility and to give Mexican scientists more international experience (Rosenzweig Pichardo 1995).

4.5.2 *The National System of Researchers (SNI)*

As a response to declining salaries of researchers due to the economic crisis, the Mexican government created in 1984 the National System of Researchers (Sistema Nacional de Investigadores, SNI) in order to advance scientific research and to prevent the possible disintegration of the Mexican scientific community (Malo 1992). Membership of the SNI is open to researchers from all knowledge fields working full-time in recognised Mexican institutes of scientific research, following an evaluation of their productivity and contribution to the formation of new researchers. Membership entitles the scientists to a monthly payment over and above that received as institutional salary.

In 1995, there were 5,868 members of the SNI, of which 17.5% worked in the Physical and Mathematical Sciences, 31.9% in the Biological, Biomedical and Chemical Sciences, 28.3% in the Social Sciences and the Humanities, and 22.3% in Engineering and Technology. Of these only 6.7% had been assigned the highest category (Level III) of membership, with 14.3% at the intermediate level (Level II) and 52.4% at the lowest level (Level I). The remaining 26.6% are designated "Candidates" and are young researchers <40 years of age who are completing a doctoral degree (Consejo Nacional de Ciencia y Tecnología 1996).

In 1991, more than half of the total membership of the SNI worked in the higher education sector. Approximately 26% were affiliated to the UNAM, 7% to the IPN (and its Centre for Research and Advanced Studies; Centro de Investigación y de Estudios Avanzados, CINVESTAV) and 5% to the UAM (Parra Moreno 1992). By 1995, 1,955 (33.3% of the total) members of the SNI were affiliated to the UNAM (Consejo Nacional de Ciencia y Tecnología 1996) either in the category of lecturer, or in the category of researcher.

Approximately 9% of the members of the SNI between 1984 and 1987 had obtained their first degree abroad, of which one quarter had graduated in the USA, and another quarter in either Argentina or Uruguay. In general, these scientists were foreign immigrants who made up approximately 10% of the total members of the SNI (Garza and Malo 1988). A more recent study on the 1993 composition of the SNI (Members levels I, II, and III) revealed a foreign born population of 15%, 46% of which were working in the Social Sciences and the Humanities, and 24% in the Life Sciences (Narvaéz-Berthelemot and Rosas 1996). Like other scientific communities in Latin America, Mexico has been enriched by the input provided by foreign scientists. In 1939 Mexico received an important number of exiles from the Spanish civil war (De la Fuente 1991) and in later years, from the military dictatorships of Latin American countries, such as Chile, Argentina and Uruguay.

The role of foreign institutions in the postgraduate education of Mexican scientists is demonstrated by the figures for the 1984 to 1987 SNI population. Approximately one third of Master's degree and two thirds of doctoral degrees were awarded by institutions abroad. Half of the Master's degrees were granted by institutions within the USA while Great Britain and France were responsible for another third. At doctoral level the participation of US institutions diminished to around 40% while that of France increased to 21%. These three countries, USA, Great Britain and France, between them awarded more than 75% of foreign postgraduate degrees (Garza and Malo 1988). According to Carvajal and Lomnitz, scientific research in DCs, and particularly in Mexico, was, in the past, stimulated by sending researchers to foreign institutions for postgraduate study (Carvajal and Lomnitz 1984). However, in recent years the percentage of foreign degrees is likely to have decreased due to budgetary restrictions and the growing number and importance of national postgraduate courses. A certain endogamy was found with respect to the relationship between the Mexican institutions where the scientists had studied and their institutions of employment (Garza and Malo 1988).

It should be borne in mind that the SNI represents an elitist groups of Mexican scientists. Results from a 1993 R & D survey estimate the total number of people engaged in research and experimental development to be in the region of 14,000 (Consejo Nacional de Ciencia y Tecnología 1996). Evaluation of researchers in Mexico is based on the publication of results in recognised journals of high prestige which generally implies mainstream titles, as well as in the number of times these publications are cited (Aréchiga 1994; José Yacamán 1994b). The application of these international criteria derived from the centre benefit those scientists studying topics of a fundamental nature while working against those engaged in applied research areas with a strong social commitment, such as engineering, and the social sciences (Saldaña and Medina-Peña 1988).

4.5.3 *International Science Policy*

The fostering of international co-operation is a central element of S & T policy of Mexico. With a view to improving the well-being of the developing nations and to narrow the gap between the rich and the poor, DCs must foster the transfer of knowledge and innovations from their places of origin, while also investing in the development of their own S & T capability. Within this context international co-operation is an efficient way to rationalise the efforts made by different countries in S & T, to optimise results and to reduce costs (Consejo Nacional de Ciencia y Tecnología 1993).

CONACYT is responsible for negotiating and co-ordinating bilateral and multilateral agreements with academic and research bodies in other countries and regions. These agreements cover different S & T related activities including research collaboration, interchange of experts, technicians and researchers for both research and teaching, and exchange of information, material and equipment (Consejo Nacional de Ciencia y Tecnología 1994).

International S & T links are particularly important with the the US and Canada, Mexico's North American trade partners and with the countries of the EU because of their high standards of research and education. With respect to Latin America, Mexico should take on a leading role due to its geographic position and its level of scientific development (Rosenzweig Pichardo 1995).

The estimated number of international S & T agreements for 1993 was 78, 45 of which were bilateral, one with the OAS and 32 with other organisations. The total number for 1980 was 60, including 7 with the United Nations, a figure which was reduced to 33 in 1989 after which it showed a gradual increase (Consejo Nacional de Ciencia y Tecnología 1993). Different types of agreement are presently in force between Mexico and the following countries: in Europe; Belgium, Bulgaria, Czech Republic, France, Germany, Great Britain, Hungary, Italy, Poland, Russia, Slovenia and Spain; in Asia, Korea and Japan, and in the American continent; Argentina, Brazil, Canada, Chile, Colombia, Costa Rica, Cuba, Peru, US and Venezuela. Multilateral cooperation in S & T occurs with: Centro Latinoamericano de Física (Latin American Centre of Physics, CLAF); Programa Iberoamericano de Ciencia y Tecnología para el Desarrollo (Iberoamerican Programme of Science and Technology for Development, CYTED); Organisation of American States, OAS; International Foundation for Science, IFS; and the International Development Research Centre, IDRC (Consejo Nacional de Ciencia y Tecnología 1994).

Chapter 5

The Present Study

5.1 Framework of the Present Study

There is a strong tendency in many Latin American countries, Mexico among them, for research performance in science to be evaluated using parameters developed in countries at the scientific centre. The number of papers published in mainstream journals is frequently taken as the principal indicator.

The majority of Mexican scientists, nonetheless, do not publish regularly in international journals sometimes because their work is mainly of local interest or their research is not of the required calibre to compete in the international sphere. Other reasons relate to an insufficient grasp of English or a general lack of understanding of how to go about preparing a paper for mainstream publication. Because of this, these scientists find themselves isolated from the wider scientific fraternity and generally occupy the lower echelons of their own research communities. As we have seen in Section 2.5.1, the elite members of the national scientific communities are those who publish internationally and who have found ways of promoting themselves and their research beyond the boundaries of national science.

The present study looks at the relationship between collaboration and performance in a small sample of Mexican scientists with high visibility in the international scientific literature using different methodological approaches. The links that these scientists have established with both the international and their own scientific communities are analysed using indicators of national and international prestige, co-authorship and citation patterns, and the profile of visits made to other institutions. Their reasons for establishing these links, the importance of these links for their scientific work and the mechanisms involved are established by questionnaire and interview techniques.

The different variables studied in the present thesis can be placed in the wider context of the relationships present during the different stages of the research process. Figure 5.-1 is a simplified model developed to link the elements associated with the different stages of input, experimentation and/or observation, output, impact and results. The variables by which these elements can be measured are also indicated in the model as are the contributing factors not directly related to the research process but which possibly affect its outcome.

The present analysis is focussed on the characteristics of the experimental, output and impact stages of the research process that could give some insight into the relationship between collaboration and performance. Bibliometric and scientometric techniques are applied to determine such variables as the number of papers taken to represent output, co-authorships of papers as an indicator of collaboration in the research process and citations as indicators of impact and influence.

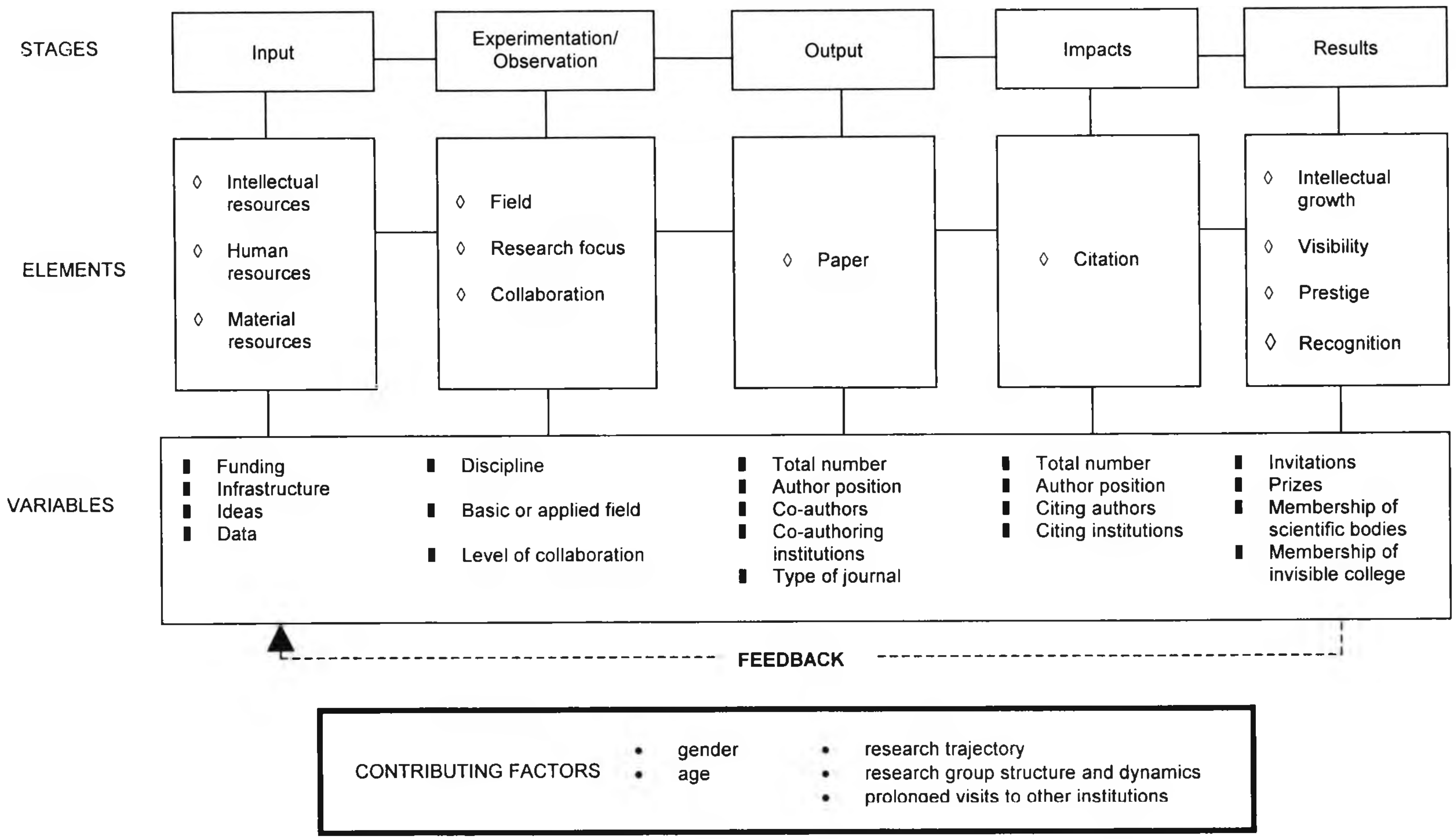

Figure 5-1. A simplified model relating the principal elements and variables present at the different stages of the research process

In order to throw light on the role of the links established between the UNAM scientists and their national and international colleagues, other types of variables are studied which indicate the association of these scientists with the wider scientific community. These are such activities as membership of scientific bodies and of invisible colleges or networks, invitations to give courses or talks, and prizes received.

Many of the variables associated with input and results stages of the research process can be determined only by using other techniques. Intangible elements such as ideas or intellectual growth for instance, were ascertained by applying questionnaires and interviews. The roles of the 15 scientists within their internal research groups were described by the respondents or by another group member CVs were consulted to determine contributing factors, such as age or visits made to other institutions.

I consider that the combination of methodologies proposed will allow me to analysis and evaluate the different elements that intervene in the research activity of these UNAM scientists as well as situating them within both their own and the wider scientific communities. Within this framework I intend to examine the relationship between their collaborations, particularly with colleagues abroad, and their productivity.

5.2 Goals and Objectives

The main objective of the present study is to determine how the links that my sample of UNAM scientists have established with the international scientific community relate to their high productivity and to determine their role at the interface between internal and external interactions of their research environments.

The particular conditions conducive to high productivity and visibility in the international (mainstream) literature in scientists from developing countries are examined by analysing their research trajectories, the structure and composition of their internal research groups, their scientific production, co-authorship patterns and impact of their work. I look especially to see how this success is related to collaboration with peers at international level in terms of time spent in other institutions, particularly during sabbatical leaves of absence. Other factors taken into consideration are the particular research areas involved and the focus of the research as theoretical, basic or applied.

A second objective is to determine the mechanisms by which these scientists have made contact and established working relationships with their national and international peers as well as the restraints and benefits associated with these collaborations. I also hope to establish the relative importance given by these scientists to collaborations at national and international levels, and the role of national and mainstream journals in this context.

A third objective is to evaluate the usefulness of the approach applied in the present study that combines bibliometric and curricular data analysis with results obtained via questionnaires and interviews. Also to be assessed is the adequacy of using co-authorship and citation patterns as indicators of international collaborations and links in Mexican science.

The general aim of the study is to contribute to the understanding of the mechanisms by which Mexican scientists integrate into the international scientific community, taking high visibility in the international scientific literature as an indicator of this integration. Results on how joint research endeavours and visits to foreign institutions influence this process will have possible repercussions for Mexican science policy. Of particular significance will be the benefits that can be expected from government and institutional initiatives that promote collaboration and exchange between Mexican scientists and their colleagues abroad, specifically in relation to mechanisms which facilitate the establishment and smooth functioning of these joint ventures.

5.3 General Hypotheses

Collaboration in the research effort is believed to enhance the productivity and visibility of the scientists concerned. It is considered especially important for scientists from developing countries to interact with their counterparts in other countries in an attempt to compensate for the smallness and isolation of their national scientific communities. Therefore it can be expected that researchers from developing countries like Mexico, with sustained high production of articles in the mainstream literature will have established close links with researchers from other countries. Some of these links will have led to joint research work and the publication of co-authored papers.

One of the mechanisms believed to promote and strengthen international collaboration in science is the realisation of prolonged visits made by scientists to each other´s institutions as postgraduate or postdoctoral students, during sabbatical leaves of absence and at other points during their research careers. In the case of Mexican scientists it is proposed that prolonged visits made to foreign institutions will increase their international collaboration profile and enhance performance.

5.3.1 *Proposals arising from the General Hypotheses*

Certain conjectures can be made on the implications of the general hypotheses as a consequence of the fact that these highly productive scientists are members of the small scientific community of a developing country. The following proposals follow on from the general hypotheses and may be observable using bibliometric techniques:

- These highly productive scientists will show higher levels of international co-authorship than their national counterparts working in the same fields.

- Mexican scientists with high publication profiles in the mainstream literature will publish preferentially in international journals contributing little to national or regional journals.

- Internationally co-authored papers will be published preferentially in international journals while papers published in national or regional journals will involve only institutional or national colleagues

- Mexican scientists are more likely to be co-authors in internationally co-authored papers than they are to be first authors.

- The most highly cited papers of Mexican scientists would tend to be those published in co-authorship with institutions from the scientifically advanced countries.

- The extent and depth of the relationships established between Mexican scientists and their foreign counterparts will be related to research objectives. There will be less international collaboration and more co-authorship at institutional and national level with respect to Mexican scientists working on problems considered primarily of local interest. In the case of theoretical and basic problems of universal significance the reverse is likely to be the case.

- Links will be established primarily with scientists and institutions from countries at the scientific centre of world science.

- Joint authorship of research papers will take place with a larger number of foreign scientists than of national peers.

- Joint papers published with foreign scientists following prolonged visits abroad will be published in the years immediately following the stay at the foreign institution.

- A general increase in the production of articles is likely to follow prolonged visits to foreign institutions.

- Increased levels of international co-authorship will result from Mexican scientists spending extended periods of time at foreign institutions.

- There will be a direct link between the countries with which the Mexican scientists publish and those citing their papers.

- There will be a direct link between the institutions with which the Mexican scientists publish and those citing their papers.

- There will be a direct link between the authors with whom the Mexican scientists publish and those citing their papers.

5.3.2 *Open Questions*

Although not directly derived from the hypotheses there are certain open questions related to the broader effects of the international activity of the scientists in the present study. In particular the possible repercussions that their activity could have for the development of science both locally and nationally deserve special attention. An example of this might be the spreading influence of international links away from the individual towards other Mexican scientists who have not established links of their own. Additional questions concern possible ramifications of the scientists' international activity towards other aspects such as the training of students and the implications of this for the consolidation and development of research groups. Of particular importance would be the development of new research areas and the local availability of advanced research techniques.

These open questions are unlikely to be satisfactorily answered by the scientometric techniques applied in the present study. However, it is expected that such considerations will come up as a natural consequence of the questions put to the 15 scientists on the outcome of their interactions with foreign colleagues.

Chapter 6

Methods

6.1 Selection of Methods

Bibliometric techniques have been widely used for research evaluation and have proved useful for determining S & T output indicators at country and regional levels. However, many authors warn of the limitations of literature based data when used to evaluate smaller aggregates of scientists or when used in fields where written knowledge is the not main product (Cozzens 1990).

As we have seen from the discussion on the evaluation of science in DCs in Chapter 3, the danger of using commercial bibliographic databases for S & T indicator development is also frequently put forward, particularly with respect to studies on scientific research in developing countries. Limitations most commonly mentioned relate to poor journal coverage; lack of continuity in journal coverage; inclusion of first author addresses only, and lack of any kind of standardisation in author names and addresses.

In her review on literature based data in research evaluation for managers, Cozzens states that for some evaluation purposes, indicators derived from this type of data, provide by far the best information available, and that other types of input, such as that provided on social interactions from interview techniques, can be used primarily for interpretation (Cozzens 1990).

As we have also seen from Chapter 3, citations and co-authorships are indicators, although imperfect ones, of some of these social interactions such as influence and collaboration occurring among scientists (Schott 1995). Although Price too considered co-authorships to be indicators of social links (Price 1970), the main problem in using scientometric techniques to study these kinds of associations in scientific work is that they fail to uncover the social processes and motivations behind such activities. Melin in his study of Swedish researchers found that there are good reasons to believe that the combination of interviews and questionnaires give a fair and general picture of what scientists think about collaboration. He found that the results from the interviews were in line with those from the questionnaire (Melin 1998).

In the present study I have used a combination of techniques, (analysis of bibliometric and curricular data together with information from questionnaires and interviews) which I believe will provide me with a fairly complete and cohesive picture of the patterns of links established between my sample of 15 highly productive Mexican scientists and the wider scientific communities. In practical terms anyone of these techniques used in isolation would have left specific aspects of these links uncoverea or incomplete.

I consider that the use of different sources of literature based data, namely *Science Citation Index* derived data and curricular data, which were then related to other aspects of these scientists' career and work, would do much to reveal the nature of the relationship between these links and scientific performance. The application of so called bio-bibliometric data in the study of the productivity of scientists has previously been described by Sen and Gan in India (Sen and Gan 1990). Information provided by the 15 scientists on the questionnaire and during the interviews would, as Cozzens suggested, allow me to interpret the bio-bibliometric data and shed light on the social processes and motivations behind their collaborative activities.

Scientists analysed in the present study were all working principally in fields of basic science where publication in refereed journals is the norm making the number of papers published an appropriate indicator for research performance. As national research endeavours are not evenly distributed across fields of science, but are more or less concentrated in selected fields, and even more so in institutions (Schott 1995), the 15 scientists were selected, firstly, from the UNAM, the most important Mexican research institution, and, secondly, from five of the principal research fields covered by this institution.

6.2 Bibliometric Analysis of UNAM Scientific Production 1980-1990

The starting point for the analysis of the publications authored by scientists at the UNAM was the information contained in the database denominated "Frontera". This file was developed by myself with technical assistance, at the Science and Humanities Information Centre (Centro de Información Científica y Humanística, CICH) at the UNAM and has been previously exploited for carrying out scientometric studies on different aspects of the research activity of the Mexican scientists (Russell 1994; Russell 1995)

"Frontera" contains 13,023 records of articles, reviews and other documents published from 1980 to 1990 by authors indicating an institutional address within the Mexican Republic as reported in the 1980-1991 *Science Citation Index* (SCI) CD-ROMs. The coverage of *Science Citation Index*, produced by the Institute for Scientific Information (ISI) in Philadelphia, USA, is exclusive to approximately 3,300 journals considered to form the mainstream core of scientific and technical periodicals worldwide. Selection of journals for coverage is based on a high level of citation of articles appearing in these titles. Addresses of all authors are reported in the SCI which allows for a comprehensive analysis of the publications produced by individual authors, institutions, countries, etc.

The strategy for downloading records from the SCI CD-ROMs to form the "Frontera" database was the presence of the word "Mexico" in the corporate source field, eliminating those corresponding to "New Mexico". The following fields were downloaded from the CD-

ROMs: authors, document title, journal title, volume, year, first and last pages, names and addresses of all author affiliations, type of document (article, review, letter, note, meeting abstract, etc,) language of the document. Records were incorporated into the MICROISIS format, version 2.32.[1] Volumes and page numbers were subsequently eliminated from the records to allow easier manipulation of the file.

Records were individually examined for errors and anomalies in the assignation of Mexican institutions,[2] and the following fields added in each case:

-Discipline of the journal: classified according to the nine discipline categories for journals developed by Computer Horizons Inc. (CHI), namely, Clinical Medicine (CLI); Biomedical Research (BIM); Biology (BIO); Chemistry (CHM); Physics (PHY); Earth and Space Sciences (EAS); Engineering and Technology (ENT); Mathematics (MAT); and Psychology (PSY) (Noma 1986). A multidisciplinary field (MUL) was added to accommodate articles published in multidisciplinary journals, such as *Nature* and *Science*.

-Subdiscipline of the journal: classified according to CHI's 106 subdisciplines for each discipline category. Where a particular title was assigned more than one subdiscipline, I selected a main subdiscipline based on the general subject focus of the group of Mexican articles published in that journal.

-Type of study: divided into those involving only national institutions and those involving institutions abroad.

-Number of institutions: number of national and foreign institutions registered in each record.

-Number of authors: total number of authors accredited in each record.

-Institution: all national institutions reported in each record were coded according to a classification of institutions developed at the CICH (Alonso-Gamboa 1990). Those institutions not previously assigned a code were given one with the prefix "a" followed by sequential numbers.

-Country: Three letter codes were assigned to each record for all countries reporting an institutional address in those countries. Codes were based on the classification previously developed at the CICH (Alonso-Gamboa 1990).

-Type of institution: the main activity of all institutions both national and foreign was coded in accordance with the following categories: education, research, government, private, international, unknown. Coding was based on the classification of institutions previously developed at the CICH (Alonso-Gamboa 1990).

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[1] The MICRO-ISIS computerised documentation system software was developed by the UNESCO in 1985 for generating directories, bibliographies, catalogues, and bibliographical databases in PCs. Its use is widespread in libraries and information centres within Latin America. The MINI-ISIS version is available for mainframe computers.

[2] Records were eliminated which contained the word Mexico in the street name or in any part of the address other than that referring to name of the country. Records was also checked with respect to the correct designation of institutions to the Mexican Republic; in a minimum of cases, Spanisn institutions were wrongly assigned to Mexico.

-Geographical location of the institution: national institutions were assigned a code corresponding to the Mexican state where they were located.

All fields were inverted, including author and co-author fields, allowing for queries to be formulated with respect to different characteristics, and combination of characteristics, of the records contained in the database.

A subfile was formed corresponding to the production of the UNAM by downloading all records from the "Frontera" database containing the code for the UNAM. This UNAM database contains 5,482 records (representing 42.1% of the total number in "Frontera") corresponding to the total number of documents published by the UNAM from 1980 to 1990 in the mainstream set of journals and proceedings covered by the *Science Citation Index*. This file was used to determine the follow aspects of UNAM production:

a) 1980-1990 annual production of all Mexican papers[3] and those of the UNAM.
b) The contribution of the UNAM to Mexican scientific research in different fields from 1980-1990 in different disciplines.
c) 1980-1990 production of UNAM papers in different disciplines
d) Studies in different disciplines involving only one national institution, and those carried out in national or international interinstitutional collaboration with respect to both the UNAM and other Mexican institutions.
e) Annual production of all Mexican papers and UNAM papers in international collaboration 1980-1990.
f) 1980-1990 international collaboration of the UNAM and other Mexican institutions with different regions of the world.

6.3 Selection of the 15 UNAM Scientists

Two lists were generated from the UNAM database to determine the frequency of UNAM authors publishing as first authors, and as co-authors, respectively, from 1985-1989. These lists were used for the selection of the 15 UNAM scientists as described below.

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[3] For the purpose of the present study only four document types were taken into consideration, namely articles, notes, reviews and letters, described here as papers, in accordance with recommendations of other authors (Schubert , Glänzel et al.1989). These four documents types receive a significant number of citations in subsequent publications, and are therefore considered relevant in impact orientated analyses.

Three UNAM scientists from each of the five following research areas were selected for an indepth study of their activities:

Biomedical Research
Chemistry
Physics
Astronomy and Astrophysics
Geosciences

The selection of areas was based on two criteria: the need for representation of a wide range of scientific disciplines, and the need to give special importance to those subject areas where UNAM scientific research makes an important contribution at international level.

The criteria for selection of the individual scientists were based on the 1985-1989 records in the UNAM database [4] and were as follows:

a) Publication between 1985 and 1989 of at least five papers as first author, and a total of between 10 and 35 papers (articles, notes, reviews and letters) as first and co-authors. This strategy was chosen after a preliminary analysis of the publication levels of UNAM scientists in the database, and the need to have a sample of 15 scientists with comparable levels of publication. Four scientists were discarded because of an exceptionally high total production of papers: a chemist with 72 papers; two astronomers with 55 and 41 papers, respectively, and a biomedic with 51.

b) Uniform annotation of author's name appearing in the SCI database. Common surnames were avoided due to ISI's lack of normalisation of authors' names in their citation databases, and to avoid confusion caused by authors having similar surnames.

c) When two authors commonly published together, only one was chosen in order to avoid analysis of basically the same publication set.

d) Scientists had to be affiliated to the UNAM from 1980 to 1993 and be willing to cooperate with the research project.

The application of these criteria resulted in few candidates being available for selection in each of the five main subject fields. In Biomedical Research, and Geosciences[5], for instance, the three scientists chosen in each case were the only ones to fulfill all the requirements.

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[4] Papers reporting a non-UNAM address, such as those written while on sabbatical in foreign and other institutions will not be registered.

[5] One of the geoscientists originally selected for the study died at the end of 1993 before analysis of his curricular and publication data was completed and it was decided to replace him.

Physicist 2 had been a personal friend for many years and I got to know Physicist 3 well soon after the project started when we served for three years on the same academic committee. The other scientists were not known to me personally before the start of the study although several of them I knew by reputation.

6.4 Analysis of the *Curriculum vitae* of the 15 UNAM Scientists

The 15 UNAM scientists selected were contacted by telephone or email to ascertain their willingness to cooperate with the research project. All agreed to provide me with a copy of their *Curriculum vitae* (CV) and to be interviewed at a later date. No special indications were given except that their CV should be as complete and up-to-date as possible. CVs were collected during 1992 and 1993. The geoscientist was replaced during 1994.

All scientists were asked for an update of their CVs in the summer of 1995 in order to analyse 15 years of production (1980-1994).

A format was designed for the systematic annotation of data contained in each scientist's CV. Information lacking in the CVs was obtained directly from the scientists. The major sections of the format were:

- *Personal Information*: name; department; unit; gender; age in 1994; place of birth; telephone number; email address.

- *Administrative Posts:* type of post held; duration.

- *Type of Research*: research field; theoretical, basic or applied.

- *Formal Education and Prolonged Visits to other Institutions:* Undergraduate; Master's; Doctorate; postdocs; fellowships; sabbaticals; other formal visits of more than three months [6]. Note was made of the names of specific scientists and institutions mentioned in relation to these activities.

- *Experience in Research* (as of 1994). years since doctoral degree; years since publication of first scientific paper; years in the UNAM.

- *Indicators of Institutional, National and International Prestige*: position held at the UNAM on the researchers' scale (Associate, Senior, or Emeritus Researcher); position within the National System of Researchers (SNI) (I, II. or III); prizes and other distinctions ("Premio Universidad Nacional",UNAM prize); "Premio Investigación Científica" (prize of the Mexican Academy of Scientific Research, AIC); "Premio Nacional de Ciencia y Tecnología" (national science prize awarded by the Mexican government)]; prize for young scientists of the Organisation of American States; (OEA); Elected membership of the Mexican National College ("Colegio Nacional") and foreign membership of the US National Academy of Sciences.

[6] A research stay of more than 3 months was the parameter used by Martin-Rovet and Carlson in their study on American scientists in France (Martin-Rovet and Carlson 1995).

- *Relationships with the National, Regional and International Scientific Communities*: founder member, office holder, or member of professional and scientific societies; editor, member of editorial board or committee, or invited reviewer of scientific journals; member of evaluation bodies; member of expert committees.

- *Teaching Activities at National, Regional and International Levels*: lecturer in courses, thesis supervision, or external examiner, at undergraduate, master's and doctoral levels; invited lecturer in undergraduate, graduate and refresher courses.

- *Activities in National, Regional and International Scientific Meetings:* papers read in congresses, symposia, and other events; organiser of scientific meetings; conferences given.

Care was taken to differentiate between activities with only local projection and those having relevance in a wider context.

6.5 Analysis of the Production and Co-authorships of the 15 UNAM Scientists

The yearly production of papers (articles, notes, reviews and letters) was determined for the 15 scientists from 1980 to 1994 as indicated in their CVs. These four types of documents, as stated earlier (see footnote 3), are those which receive a significant number of citations and are considered relevant in impact orientated analysis in all scientific fields (Schubert, Glânzel et al.1989). Other authors have also selected these four document types as being representative of research output, such as Borbons and co-authors in their study on the identification of research teams in biomedicine and clinical medicine using bibliometric tools (Bordons, Zulueta et al. 1995).

According to the Hungarian group there is little doubt about the status of articles in evaluative bibliometrics as these are the basic means of communicating new scientific knowledge. Notes are shorter publications in many important journals (such as *Physical Review Letters*) and thus form a key part of the scientific literature. Review articles, although not an original piece of research but rather a synthesis of work by others, do constitute scholarship which in itself is considered a form of research. With regard to the publication type categorised by the SCI database as letters, relative citation rates of the different types of publications show convincingly that these cannot be excluded from evaluative counts without seriously affecting the reliability of the evaluation (Schubert, Glânzel et al.1989).

Although in the present study books, book chapters, meeting and other abstracts, contributions to proceedings of events such as workshops, and unpublished reports appeared in the list of publications in the CVs of some of the scientists, these were not included in the analysis. Books and book chapters do not usually report original research in science and medicine and that reported in abstract form and even as full papers appearing in proceedings may subsequently appear in article form. Unpublished reports and other grey literature are not necessarily subject to rigorous peer review.

The only exception to the above was with respect to full papers published in the IAU (International Astronomical Union) Symposia which are classified as articles in the SCI database and which were frequently listed in the CVs of all three astronomers. I decided to include these after consultation with an astronomer (principal co-author of Astronomer 1) who told me that these constituted an important vehicle for the publication of original research results in her field.

Each paper published was counted as a single unit regardless of the number of authors on the paper. Production from 1980 to 1990 was corroborated with that contained in the UNAM database. Details of types of documents, institutional affiliations of co-authors, number of authors, author position were checked with the UNAM database and with the original papers where necessary.

6.5.1 *Publishing Patterns*

The levels of dissemination of the UNAM articles were determined in accordance with the journals in which they were published, as follows:

1. SCI (mainstream) or non-SCI (non-mainstream)
2. Published in the following countries or regions: USA/Canada; Europe; Latin America; Other

Coverage by SCI was estimated for the year in which each paper was published as indicated in the appropriate section of the annual or five year accumulations of the SCI. Country of publication of the journals was determined using standard reference sources, such as Ulrich's Periodicals Directory, the Serial's Directory or the SCI list of journals by country.

6.5.2 *Comparison with Production Levels of other Mexican Scientists*

Scientists working in the same fields as the 15 scientists, at the UNAM or in other Mexican institutions were identified using a database on CD-ROM produced in 1993 by the National System of Researchers (SNI). The SNI CD-ROM contains data on the 3,937 members (levels I, II and III) of the SNI in 1993 relating to personal information (name, country of birth, date of birth etc.); institutional affiliation and posts; research fields according to the SNI classification; degrees obtained; years in research; years in teaching; research activities; teaching activities; production of papers and other documents. Firstly, the research fields of the 15 scientists were identified as reported in the SNI database. Secondly, other scientists working in the same fields were identified and those reporting a similar number of years in research as the 15 UNAM scientists, were selected.

The number of 1980-1990 papers of the 15 scientists contained in the "Frontera" database were then compared to those produced by the selected members of the SNI working in the same fields. Distinction was made between those papers reporting foreign co-authorship and those involving only national institutions.

I decided to use the production data from the "Frontera" database rather than that provided by the SNI database for several reasons. Firstly, incomplete (and often inaccurate) information is given in the SNI database; secondly, the difficulty of distinguishing between different document types in the SNI database; and thirdly, the fact that members of the SNI renew their membership every third or fourth year (depending of the level of membership assigned) which implies that the data given for most members would not be updated to 1993.

The major limitation of using the "Frontera" database for these comparisons is the fact that only those papers where the Mexican scientist reports a Mexican address are included. Papers written while on sabbatical in other institutions are therefore unlikely to be included.

6.5.3 *Interinstitutional Co-authorship*

Distinctions were made with regard to the different levels of institutional co-authorships in accordance with the following classification:

Level 0 = sole author

Level 1 = co-authored with member(s) of own UNAM faculty, centre or institute

Level 2 = co-authored with member(s) of other UNAM faculty, centre or institute

Level 3 = co-authored with other national institute(s)

Level 4 = co-authored with other institute(s) in Latin America

Level 5= co-authored with foreign institute(s) outside Latin America (USA/Canada; Europe; Other)

Levels 1 and 2 represent UNAM or institutional collaboration; level 3, national collaboration; and levels 4 and 5, international or foreign collaboration.

The number of institutional collaborations at levels 2 to 5 was assigned to each paper according to the number of individual institutional affiliations reported, independent of the number of authors reporting the same institutional affiliations. The number of institutional collaborations at level 1 always corresponded to 1 as this indicator was independent of the number of co-authors from the scientist's own UNAM faculty, centre or institute.

6.6 Determination of the Effect of Sabbaticals on the Production Rates of Papers and International Co-authorships

Sabbaticals selected for analysis corresponded, where possible, to those taken by the 15 scientists during the 15 years comprising the present study. A method was developed (described in sections 10.3 and 10.4) which included the application of the chi square test, to study the effect of these sabbaticals on the following parameters: total production of papers; production of internationally co-authored papers; and the levels of international institutional co-authorships. The effect of sabbaticals and other prolonged visits to foreign institutions on the total number of internationally co-authored papers was also measured.

6.7 Determination of the Citation Patterns of the Papers of the 15 UNAM Scientists

Citation analysis in the present study was carried out primarily to indicate relationships between the UNAM scientists and their colleagues in other institutions both nationally and internationally, as a means of tracing influence of UNAM research in different scientific and geographic spheres, and not as a measure of quality of the research carried out. However, it was also important to be aware of the volumes of the individual citation counts as large differences could be expected between the scientists, which had to be taken into consideration when assessing influence patterns.

Citation analysis was carried out on the 1985-1989 papers of the 15 UNAM scientists using the 1985-1994 SCI CD-ROMs. In each case the 1985-1993 citations were downloaded onto diskettes. Self-citations (a citation in a paper in which the UNAM scientist appeared as a co-author to a paper by that same author) were eliminated as the objective of the analysis was to look for a pervasive influence of the 15 scientist's work. The remaining citing and cited papers were converted into MICRO-ISIS version 2.32 database format. Additional fields were coded corresponding to the countries of the citing institutions. The same three-digit country codes were assigned as previously described for the "Frontera" database. Individual databases were constructed for each of the 15 scientists. Records were manipulated using FOXPRO version 2.0 software to relate data on citing articles with that of the cited articles (authors, institutions, countries, years).

Relationships between citations and author position; institutional collaborations; publication in SCI and non-SCI journals; and place of publication were carried out for all 15 scientists. The relationships between collaborating and citing countries, institutions and authors were done on a representative from each of the five disciplinary groups, except in the case of the physicists where these relationships were analysed for all three members of the group. The individual scientists chosen from the groups of biomedics, chemists, astronomers, and geoscientists (Biomedic 3, Chemist 1, Astronomer 1, and Geoscientist 1), were those whose one-year sabbaticals were chosen for analysis in the present study. I consider that this strategy would allow me, in the case of the physicists, to analyse the links of three members of the same disciplinary group. In the case of the scientists from the other groups, I would be able to relate their collaborating and citation patterns to the links established during their sabbaticals.

The co-authorship patterns (individual authors, institutions and countries) of papers published during the ten year period from 1980-1989 were compared with those of the papers found to cite the 1985 to 1989 production of the 15 UNAM scientists. In the case of the analysis at author level, citations of the co-authors to their papers published with the UNAM scientists were eliminated in order to see the possible influence of papers other than those co-authored with the citing author, on the work of the co-authors. This was not considered relevant at country or institutional level as here the objective was to look at influence links established at higher levels of aggregation. For instance, even when a foreign co-author of one of the UNAM scientists cites the work published together, there is a visible link established between the two institutions and the two countries over and above that occurring between the two authors.

6.8 Questionnaire and Interviews with the 15 scientists

Following analysis of the bibliometric, curricular and citation data, a letter was sent in September 1997 to each of the 15 scientists containing a questionnaire in English on their experiences and opinions on collaboration with foreign scientists (see Appendix 1). The questions were divided into four main topics: the importance of international links; collaboration with researchers abroad; links with different regions; and science policy considerations. The letter requested the scientists to return the completed questionnaire to me prior to the interview, where possible.

All interviews were based on a semi-structured set of questions. The first set of interviews were designed to establish (or corroborate in the case of parameters already analysed) the dynamics and relevance of their relationships with peers both nationally and internationally (see Appendix 2, questions 1-40). Questions related to specific aspects of the collaborations they considered most important for the development of their research work; the motivations and benefits obtained from certain sabbaticals spent abroad; and, in the case of the seven scientists analysed, their relationship with the authors and institutions that most frequently cited their work. The second set of interviews were carried out to determine the configuration and dynamics of the internal research groups of the 15 scientists, particularly with respect to the interactions involving or leading to communication and collaboration with other scientists both nationally and internationally (see Appendix 2, questions 41-46).

The first interviews were carried out between late September and October 1997 with all scientists except Astronomer 3 who is based in Baja California. He replied to the interview questions (in English) by email. Interviews lasted between 45 and 75 minutes and were conducted in Spanish except for Astronomer 2 and Geoscientist 2 who suggested that the interviews could be carried out in English. All interviews, except that with Astronomer 2, were recorded and transcripts made of the recordings. Notes were made during all interviews.

A second set of interviews were carried out between the middle of August and the middle of September 1998 with all scientists except for Chemist 3 (who had died earlier in the year), Astronomer 2 and Astronomer 3. In the case of Chemist 3 the interview was carried out with a member of her research group. In the case of Astronomer 2, one of her doctoral students working at an institution outside Mexico City answered my questions by email. Astronomer 3 again sent his answers by email but this time in Spanish as the questions were put to him in Spanish. The interviews were conducted in Spanish except those with Geoscientist 2 and Geoscientist 3 who suggested that we spoke in English. All interviews were recorded and notes were made during all interviews. Interviews lasted between 30 and 60 minutes

An additional question was put to the scientists during the second interview on the ease with which they were able to communicate in English and write papers in this language.

Chapter 7

Role of the UNAM in Mexican Scientific Research

7.1 Contribution of the UNAM to Mexican Scientific Research

According to data derived from the *Frontera* database, the contribution of the UNAM to the Mexican papers (articles, notes, reviews and letters) published in mainstream scientific journals from 1980 to 1990 increased from 41.7% (total papers = 297 and 712, respectively) in 1980 to 45.6% in 1990 (total papers = 571 and 1253, respectively) (Figure 7-1). The overall percentage of UNAM papers was 44.2% for these 11 years (total UNAM papers = 4,776, total Mexican papers = 10,802). The percentage increase in the number of UNAM papers published from 1980 to 1990 was 92.3%, and for non-UNAM papers 64.4%.

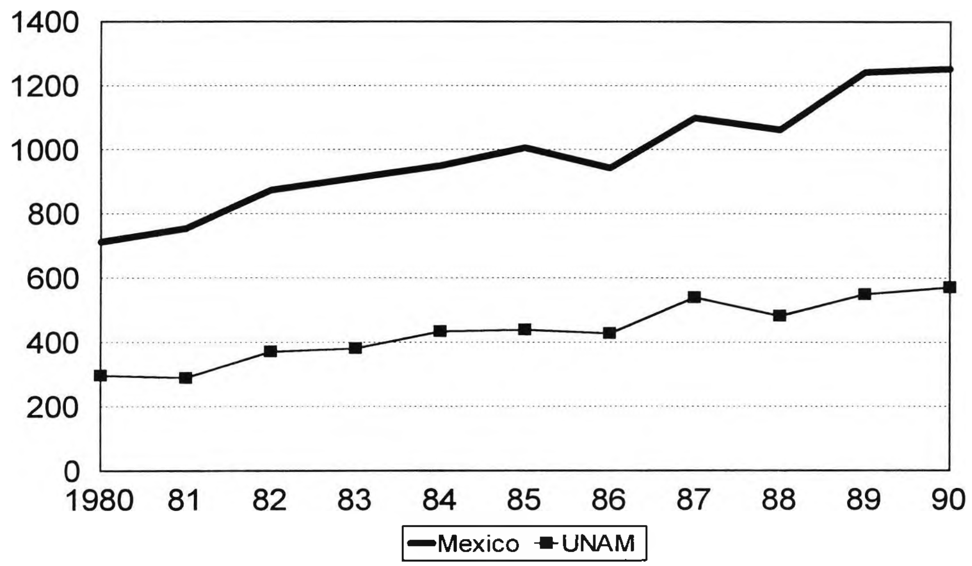


Figure 7-1. Annual production of 1980-1990 Mexican and UNAM papers in mainstream scientific journals

The UNAM contribution varied considerably between disciplines and was lowest in clinical medicine (33%) and greatest in earth and space sciences (74.1%) which included both astronomy and astrophysics, and geosciences (Figure 7-2). In all areas except clinical medicine and biology, the UNAM contribution was greater than its overall contribution to all knowledge fields. Only in the biomedical field can the UNAM be considered the dominant player in the Mexican biological sciences research scene.

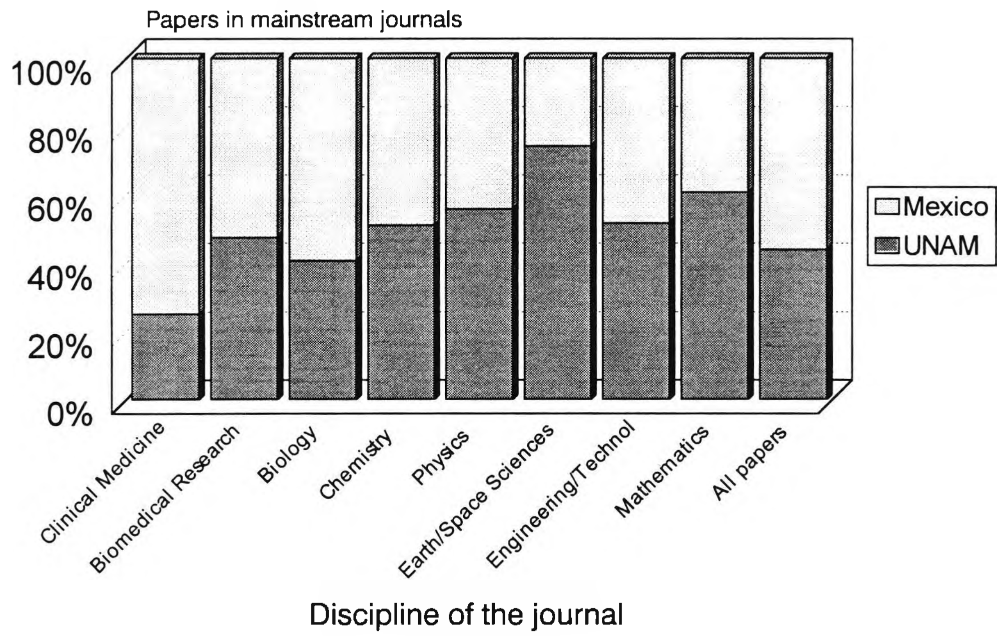


Figure 7-2. Contribution of the UNAM to Mexican scientific research 1980-1990

However, when looking at the number of research papers published in each of these fields, those in clinical medicine were outnumbered by only those in physics (830 and 1009, respectively) (Figure 7-3). Biomedical research, and earth and space sciences are other productive areas for the UNAM.

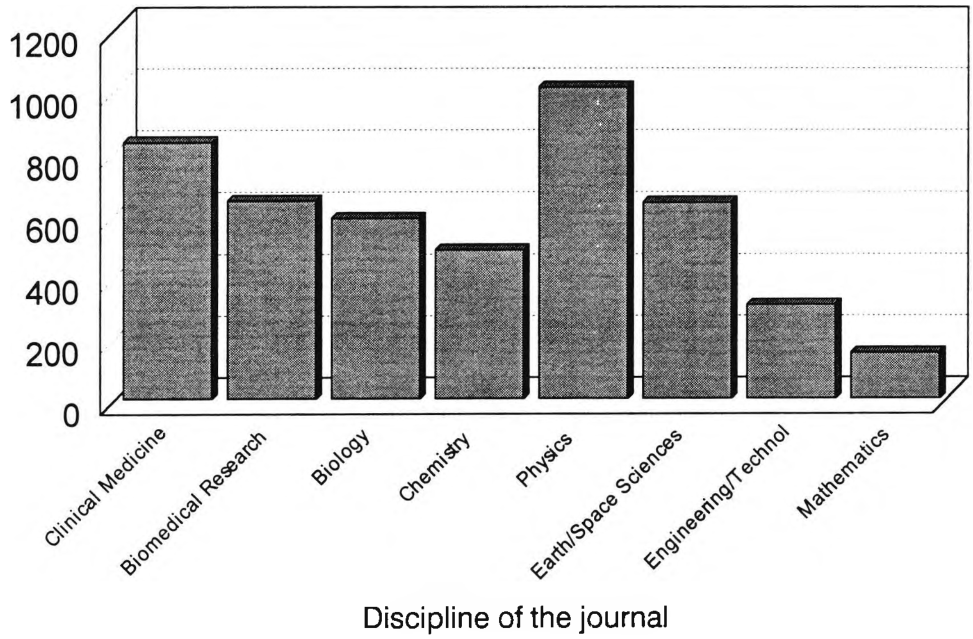


Figure 7-3. 1980-1990 production of UNAM papers in mainstream scientific journals in different disciplines

7.2 Collaborative Patterns of UNAM Scientific Research

Certain differences can be seen between mainstream papers published by the UNAM and by other Mexican research institutions with respect to their patterns of collaboration within the life sciences and chemistry (Figure 7-4). In clinical medicine, for example, the UNAM showed greater levels of co-authorship both with respect to other national institutions and to institutions abroad. This can be explained by the need of UNAM scientists to associate themselves with hospitals and institutes of health, both nationally and internationally. Little difference was found with respect to these patterns in the fields of physics, and earth and space sciences (Figure 7-5), due to the fact that most of the research in these two fields is produced by the UNAM itself.

In all fields except clinical medicine, physics, and earth and space sciences, UNAM papers showed lower levels of international co-authorship than those published by the rest of the Mexican research institutes. The UNAM papers, on the other hand, exhibited higher levels of national co-authorship, demonstrating the senior role that UNAM research plays nationally.

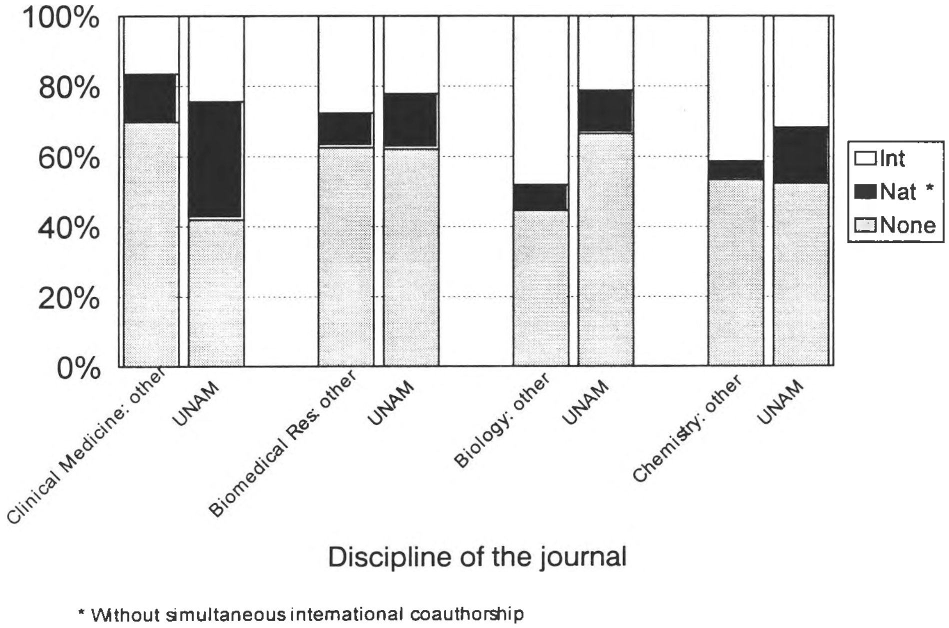


Figure 7-4. 1980-1990 UNAM and non-UNAM Mexican papers in mainstream scientific journals at different levels of institutional co-authorship. Life sciences and chemistry

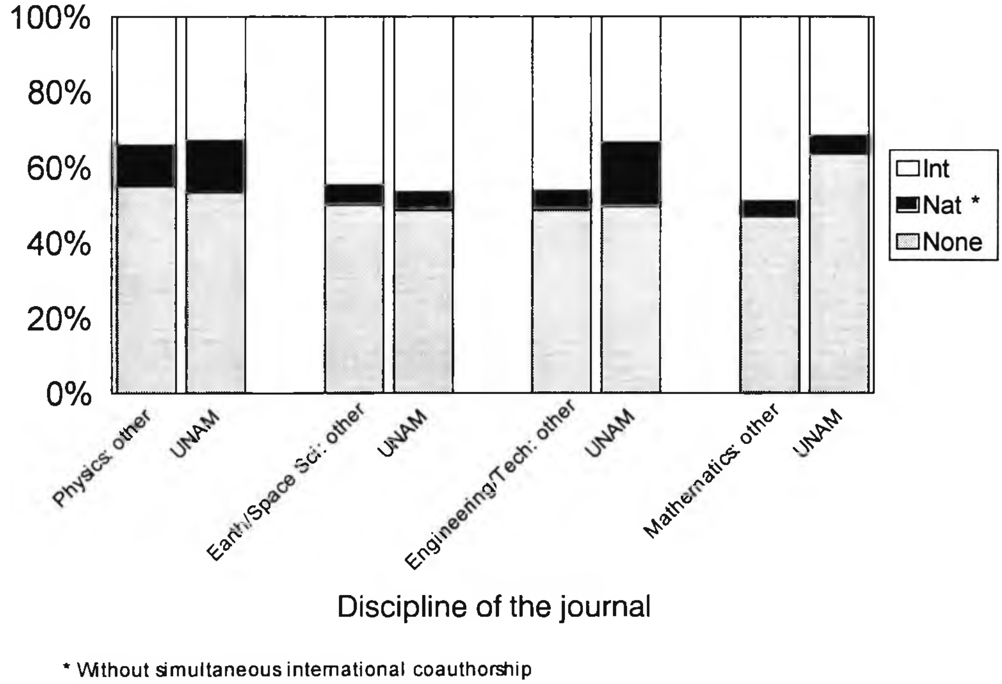


Figure 7-5. 1980-1990 UNAM and non-UNAM Mexican papers in mainstream scientific journals at different levels of institutional co-authorship. Exact sciences, earth and space sciences, and engineering.

7.3 International Collaborative Patterns of UNAM Scientific Research

The number of internationally co-authored papers showed a marked increase from 1980 to 1990 both for UNAM papers and those published by other Mexican research institutes (Figure 7-6). The UNAM increased its annual production of papers co-authored with foreign institutions from 77 to 184 (an increase of 139%) and other Mexican institutions, from 169 to 432 (an increase of 156%). There was little change in the contribution of the UNAM to the total of internationally co-authored Mexican papers, from 31.3% in 1980 to 29.9% in 1990. A steep rise in international papers is apparent from 1986 following a fairly stable period from 1982 to 1986.

Although the USA and Canada were the main international partners of both the UNAM and other Mexican institutes, UNAM scientists showed higher levels of co-authorship with European institutions than other national institutes (Figure 7-7). Co-authorships with other parts of the world were much lower.

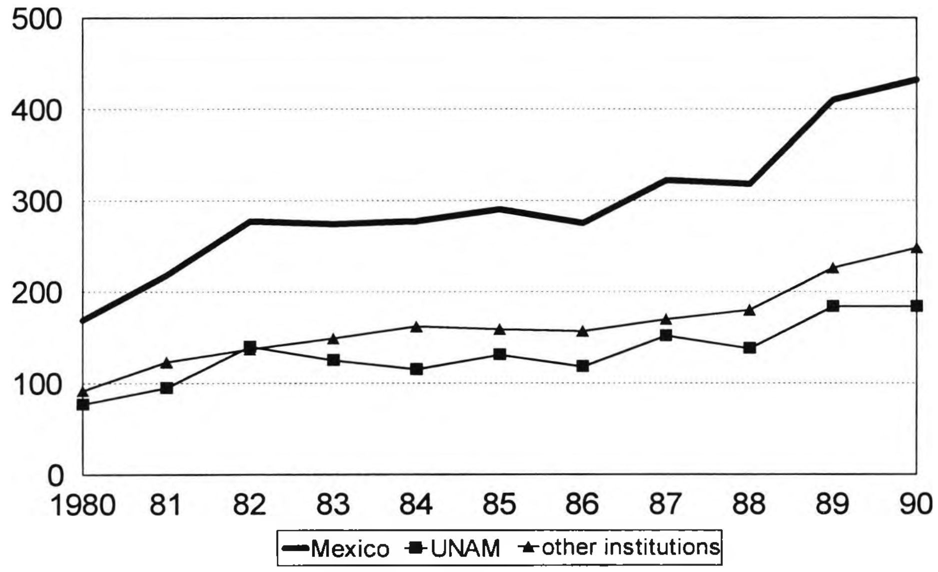


Figure 7-6. Annual production of 1980-1990 Mexican and UNAM papers in international collaboration

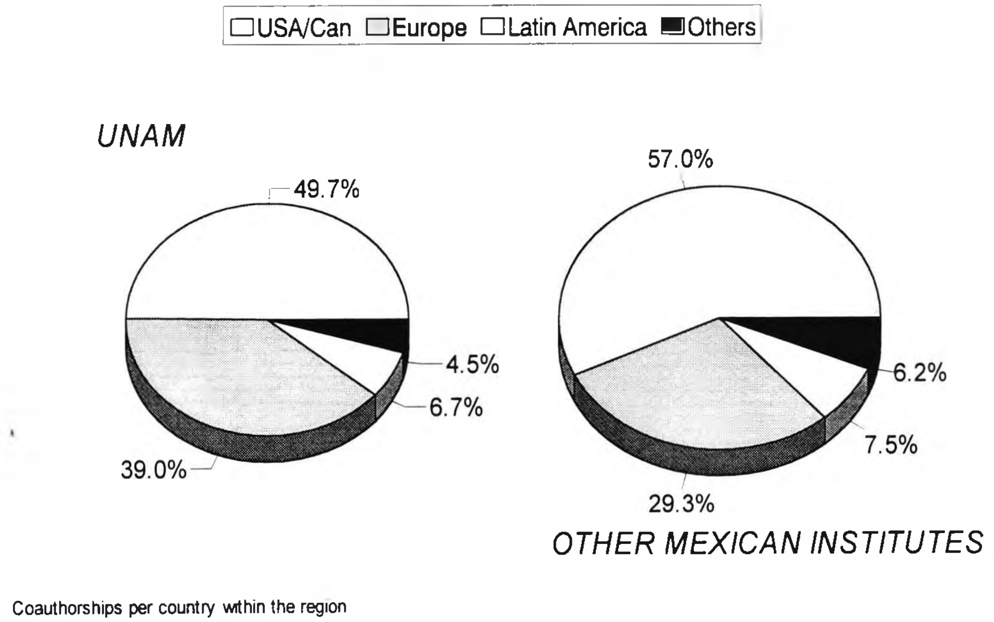


Figure 7-7. 1980-1990 UNAM and non-UNAM Mexican papers in international collaboration with different parts of the world

7.4 Discussion

The fact that the UNAM contribution was greater in all fields than its overall contribution to all knowledge fields, except in clinical medicine and biology, can be explained by the existence of other Mexican institutes, such as the Centre for Research and Advanced Studies (Centro de Investigaci6n y Estudios Avanzados) of the IPN carrying out important work in the biological sciences, and the role played by the state hospitals and health research institutes in clinical medicine research. The dominance of research carried out at the different institutes and centres of the UNAM in the fields of the 15 scientists analysed in the present study is clear, especially with regard to earth and space sciences which includes both astronomy and geosciences and, to a lesser but still significant degree, in the fields of physics, chemistry and biomedicine.

Notwithstanding the central role that the UNAM plays in Mexican science is obvious from any analysis of national research activity. The contribution that the country's largest institution for higher education make to all areas of scientific knowledge coupled with its dominance in others, make it a powerful influence worthy of consideration in any discussion of Mexican research and teaching activities. Its increased presence in the mainstream literature from 1980 onwards as well as notable increases in the number of papers written with colleagues from abroad, particularly those from the more scientifically advanced countries, are indicative of mounting international visibility and an increasingly significant role in international science.

Chapter 8

General Characteristics, Research Trajectory and Environment of the UNAM Scientists

8.1 AGE

The physical and scientific ages (expressed as years since PhD degree) of the 15 UNAM scientists in 1994 are shown in Figure 8-1. Physical age ranged between 43 and 86, and scientific age from 15 to 57 years. The sample is representative of researchers at different stages in their scientific trajectory. In the case of two of the youngest in the group, Physicist 1 and Geoscientist 1, only 15 years had elapsed since they had received their doctorate which meant that the present study covered the first 15 years of their scientific career. At the other end of the scale Astronomer 1 had a scientific age of more than half a century and physical age of 86. This scientist is still an active member of the UNAM research community.

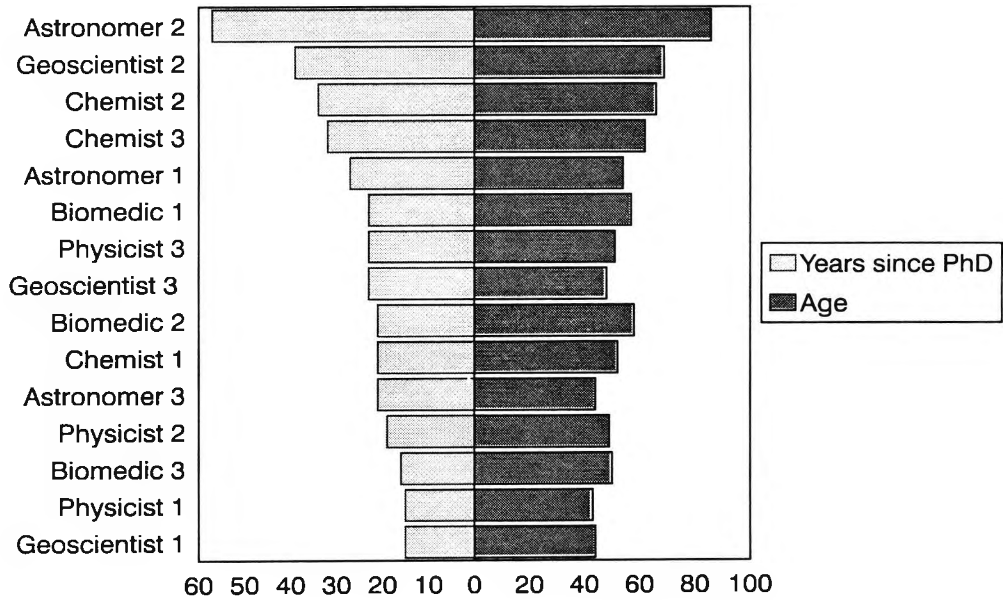


Figure 8-1. Age and years since PhD in 1994 of the 15 scientists

8.2 GENDER

Of the 15 scientists 11 are male and 4 female (Table 8-1). The only all male groups are the Physicists and the Geoscientists.

Table 8-1

Gender of the 15 UNAM Scientists

MALE	FEMALE
Biomedic 1	Biomedic 2 Biomedic 3
Chemist 1 Chemist 2	Chemist 3
Physicist 1 Physicist 2 Physicist 3	
Astronomer 1 Astronomer 3	Astronomer 2
Geoscientist 1 Goscientist 2 Geoscientist 3	

8.3 Administrative Posts

Eight of the 15 scientists report in their CVs that they had occupied administrative posts at some point in their academic career. Seven reported administrative responsibilities during the 15 years of the present study. None of the chemists or the astronomers reported ever having held administrative posts. With the exception of Geoscientist 2 who had been director of a research institute in his native Chile before immigrating to Mexico, these posts had been mainly at the level of head of department, or project manager. Only one of the female scientists, Biomedic 2 reported this type of activity as academic director for undergraduate and postgraduate studies.

8.4 Research Areas

Table 8-2 indicates the characteristics of the research areas of the 15 scientists and the different institutes of the UNAM to which they are affiliated. Not apparent from this table are the links of these scientists with the different faculties in the scientific areas, such as the Faculty of Medicine, the Faculty of Chemistry, the Faculty of Sciences, and the Faculty of Engineering. In all cases the scientists were giving, or at sometime had given, classes at either undergraduate or postgraduate level and all had acted as supervisors in theses at both these levels. They were actively involved in teaching and research supervision in the master's and doctor's programmes offered by their institutes and which do not come under the auspices of the teaching faculties but rather are administered and validated by the UACIPYP (Unidad de Apoyo a los Ciclos Profesionales y de Posgrado).

Table 8-2

Affiliation in the UNAM and research fields of the 15 Scientists

SCIENTIST	RESEARCH INSTITUTE OR FACULTY	RESEARCH FIELD	THEOR BASIC APPLIED
BIOMEDIC 1	*Inst Cellular Physiology*	*Brain transplantation in neurodegenerative disorders, Sleep and Wakefulness*	*Basic/ Appl*
BIOMEDIC 2	*Inst Cellular Physiology*	*Regulation of cellular volume in the brain*	*Basic*[1]
BIOMEDIC 3	*Inst Biomed Research*	*Control of Cysticercosis*	*Basic/ Appl*
CHEMIST 1	*Inst Chemistry*	*Natural Products Chemistry*	*Basic* [2]
CHEMIST 2	*Inst Chemistry*	*Organic Chemistry of Natural Products*	*Basic* [2]
CHEMIST 3	*Inst Chemistry*	*Chemistry of Natural Products, Photochemistry*	*Basic* [2]
PHYSICIST 1	*Inst Nuclear Sciences*	*Nuclear Physics, & Group Theory Methods, Molecular Physics*	*Theor*
PHYSICIST 2	*Inst Physics* [3]	*Chemical, Statistical & Condensed Matter Physics*	*Theor/ Basic*
PHYSICIST 3	*Inst Physics*	*Condensed Matter Theory*	*Theor/ Appl*
ASTRONOMER 1	*Inst Astronomy*	*Planetary Nebulae, H II Regions*	*Basic*
ASTRONOMER 2	*Inst Astronomy*	*Planetary Nebulae, Spiral Galaxies*	*Basic*
ASTRONOMER 3	*Inst Astronomy*	*Modern Astronomy (eg.Infrared Astron.,Stellar & Nebular Photometry & Spectroscopy,Stellar Formation & Rotation, Nuclear Activity in Galaxies)*	*Basic/ Appl*
GEOSCIENTIST 1	*Inst Eng*	*Seismic Engineering*	*Applied*
GEOSCIENTIST 2	*Inst Geophy*	*Seismology, Geophysical Engineering*	*Applied*
GEOSCIENTIST 3	*Inst Geophy*	*Motion Seismology*	*Applied*

[1] Has potential clinical application
[2] This research contains a strong local element as native Mexican plants are studied
[3] Before Sept 1988 Fac Chemistry

The description of their research areas as theoretical, basic or applied is also shown in Table 8-2. This varied according to discipline with the physicists carrying out mainly theoretical and basic research, with the chemists and geoscientists focussing on more local or applied aspects. The explanation for the different research interests can be defined in terms of the conditions and priorities of research in a developing country, such as Mexico. Two of the biomedical scientists were working in neurophysiology, a research field which has attained certain recognition in Mexico, and the third on cysticercosis, a common disease of developing countries. The chemists were all working in the study of natural products which has remained the main research area of the Institute of Chemistry since its founding over 50 years ago. This is the result of an interest both nationally and internationally in the isolation and composition of metabolites from Mexican plants and insects commonly used in native medicine since pre-colombian times.

Little experimental physics is carried out in Mexico due to the lack of appropriate apparatus and facilities and the few Mexican experimental physicists usually have to make do with outdated equipment. Astronomy is by nature a basic science; the applied aspect of Astronomer 3's work is related to the development of instrumentation. All three geoscientists are seismologists, one of whom is working on structural engineering aspects, monitoring the propagation of seismic waves particularly in relation to local topographical and geographical conditions. Institutional interest in this particular line of research resulted from the 1957 earthquake in Mexico City and Acapulco and the need to establish standards and procedures for the construction of earthquake resistant buildings and structures. Geoscientist 2 specialises in earthquake modeling, prediction and simulation, while Geoscientist 3 focuses on seismic activity in the Mexican Republic.

8.5 Research Environment (Internal Research Structure)

8.5.1 *General Background*

During the second round of interviews Biomedic 1 made some general comments on the differences between how science is done in industrialised countries and how it works in developing regions, such as Latin America. In his opinion whereas in the USA a group leader has a team of several postdocs who carry out the research, in Mexico junior scientists normally hold associate research posts. The category of postdoc does not form an integral part of the Mexican research system and consequently little provision of funds is made for this type of position. Nonetheless, Astronomer 1 felt that the figure of the postdoctoral student is emerging in Mexico. His institute has been offering three or four of these positions for the last three years that were created with foreigners in mind. It was his opinion that Mexican postdocs would be more interested in a tenure track post. Geoscientist 1 mentioned four postdoctoral students from Spain, Japan and France who are part of his group. However, none of these is based in Mexico.

Biomedic 2 referred to the figure of the associate researcher as being relatively new in her institute, although this is not perhaps the case of other institutes within the UNAM. She feels that the older senior researchers need this type of help, but perhaps not the younger senior scientists. Older scientists have more obligations and are less willing to show students how to do the laboratory work, for instance. She also mentioned differences in the number of associate researchers that senior scientists from different institutes are allowed to have. In some institutes a senior person could have up to five associates, some of whom might be considered leaders making these groups obviously more productive.

Another important consideration, according to Biomedic 1, is that the smallness of the Mexican scientific community implies that senior scientists often have to make do with the staff they have. He mentioned that the Mexican National System of Researchers has only about 6,000 members whereas for a country the size of Mexico there should be more like 20,000. This explains, he said, why in Mexico, unlike the USA for instance, there is little mobility and true competition between groups.

Physicist 2 also commented on the group structures of scientists in other countries. There are two styles, he maintained. The first is when the group is made up of a single researcher with his/her doctoral students and postdocs, sometimes collaborating with two or three other researchers. The golden rule, he believes, is mobility with the doctoral students and postdocs moving to other laboratories. Sustained collaboration with students and colleagues is not the norm. The second refers to the case of researchers who work with a large number of colleagues forming very productive groups. These, he believes, are the true research groups.

Others mentioned the endogamy inherent in many Mexican groups. In the opinion of Chemist 3's co-worker, unlike the US where doctoral and postdoctoral students move on to other institutions, in Mexico these tend to stay within the same group that formed them, a situation which does not allow them to become truly independent researchers.

Biomedic 1 also commented that in his experience, there is a different work philosophy in Mexico than in the States where productivity and efficiency are paramount. In countries like Mexico, scientists are less pragmatic, with sentiment forming part of the academic arena, this being considered detrimental to scientific work. Mexicans tend to be more emotional than cerebral in their personal relationships. Also the temperament of the Mexican people make it difficult for two senior scientists to work together because of professional jealously (an opinion also expressed by Biomedic 3 and Chemist 1 during the first interviews, see section 12.2.1). For this reason he believes that small groups work better in Mexico although they are generally less productive than larger groups.

Biomedic 1 went on to remark that many young scientists do not want to join established groups as they believe the merit of their work will always be identified with the better known members of the group. Consequently they usually prefer to form their own groups as soon as possible. Individual groups still exist in Mexico and evaluation of research activity is essentially focussed on individual effort. He believes that evaluation schemes are too rigid, not allowing for multidisciplinary ventures although this kind of collaboration is now being activity encouraged by Mexican funding bodies.

Geoscientist 2 commented that in general research groups in Mexico are rivals and are highly critical of each other. They are cordial on the surface but competitive beneath with lots of in-fighting and squabbling occurring between groups. Groups tend not to share information which he considers is one of the major weakness of Mexican scientific community (see also comments by Astronomer 3 in section 8.5.2 and by other scientists in section 12.2.1).

8.5.2 *Composition and Dynamics*

The basic composition of the internal research structures of the 15 UNAM scientists are summarised in Table 8-3. Details of the individual structures as given to me by 13 of the scientists, Chemist 3's co-worker and Astronomer 2's PhD student during the second round of questions are presented below.

Table 8-3

Basic composition of the internal research structures of the 15 scientists

	RESEARCHERS		***TECHNICIANS***	***STUDENTS***		
	Senior [a]	Associate	assigned to group	PhD	M.Sc.	B.Sc.
BIOMEDIC 1	2	2		4/5		
BIOMEDIC 2		1	2	2	2	6
BIOMEDIC 3		3	4	4	2	4
CHEMIST 1	1				1	2
CHEMIST 2		1	1	1		1
CHEMIST 3	1			2	2	1
PHYSICIST 1	4			2	2	1/2
PHYSICIST 2	2			1	3	1
PHYSICIST 3		2		4	1	2
ASTRONOMER 1 [b]	1 [c]	2 postdocs		1		
ASTRONOMER 2	3		1	1		
ASTRONOMER 3	1/2	2/3 [d]				
GEOSCIENTIST 1 [e]		4 postdocs		5	1	1
GEOSCIENTIST 2	3	1		1		
GEOSCIENTIST 3 [b]	2/3			2	3	

[a] Does not include the 15 scientists all of whom hold senior positions
[b] No fixed group
[c] Plus a series of US scientists
[d] Postdocs and/or graduate students
[e] International network of students and postdocs

Biomedic 1

Biomedic 1's core group, of which he is the leader, consists of four scientists who work in his laboratory and four or five doctoral students from the UNAM. Two of these scientists hold senior research positions and two are associate researchers. All are younger than Biomedic 1 and he considers it is his experience, contacts and reputation that give him the leadership of the group. His wider group also encompasses three senior scientists who are working in other laboratories within the Faculty of Medicine of the UNAM where Biomedic 1 is currently assigned, with their respective PhD students. Some of these are his former research students who went on to do postdocs abroad. The extended group consists of about 16 people, all of whom are encouraged to have their own projects as well as collaborating in joint research.

Ideas are forthcoming from the different members of the group unlike while the group was forming when ideas would be furnished mainly by himself. He now sees his role as promoting and facilitating the work of his group both materially and intellectually. He mentioned that there is a wide range of abilities with regard to writing papers within the group even when writing in Spanish and more so with English. Papers that bear his name are always checked and corrected by him before being sent out for publication. He does the final revision of both the scientific content and the English style. He also suggests the journal to which the papers should be submitted. Members of the group also publish independently although he considers the core group as tightly knit with well-defined goals. Resources that are hard to come by are pooled for maximum advantage.

He believes that there is good group communication. Interactions between the members of the core group take place during weekly seminars when students present the progress made on their projects or when relevant new articles in the field are discussed. Members of the wider group often attend these seminars. When funding is forthcoming students are encouraged to attend one national and one foreign meeting each year. They are also encouraged to write their own papers. Each member of the group is responsible for his/her own literature searchers and for keeping up-to-date in their respective topics.

Doctoral students often go to the US for six months, usually to learn new techniques. He believes that this can be counterproductive as it sometimes causes them to become disillusioned with the situation in Mexico. For this reason he prefers them to graduate in Mexico and then go abroad for a postdoc. Some of the researchers in his group have their own contacts abroad where they often send their own doctoral students, often where they themselves had studied.

Biomedic 2

Biomedic 2 belongs to a small group comprising of herself as the leader, an experienced associate researcher with a postgraduate degree from abroad, two technicians assigned to the group plus 10 students at the present time (two PhD students, two masters' students and six Biology undergraduates). The number of students varies but she usually has at least one from each level. She has had an associate researcher in her group for the last three years although this person has been more years at her Institute. The good associates stay in the group for a few years before they become independent and ready to form their own groups. Institutional guidelines stipulate that the associate researchers cannot stay for more than five years within her Institute.

Biomedic 2 sets the research agenda of the group and is always the one to obtain resources. She no longer does any practical work and does not even have time to write up all the results that come out of the lab. However, she always writes the creative part of the articles while the associate researcher writes the methods, prepares the graph, etc. She goes to the lab everyday and discusses results from the previous day with the people involved. Every Friday the group meets to organise the work for the following week. These sessions also serve to plan and evaluate projects. Biomedic 2 pointed out that ideas are forthcoming not only from herself and her associate researcher but that she has always had at least one PhD student who contributes ideas. The group has weekly seminars where projects are presented one week and recent articles analysed the next.

The students carry out their own literature searches. Biomedic 2 keeps up with the latest developments in her field in order to write up the articles. She is the main contact with other groups of scientists. Contacts abroad are useful to facilitate access to particular techniques. The associate researcher also has his own project which is relevant to the research interests of the group. She described this as unusual as senior scientists do not normally like their junior researchers to have independent projects.

She confirmed that she does not have any particular problems writing the articles in English. The first author of an article, she believes, should be the person who understands perfectly the work, who took on the project, who has expertise in the subject and who is familiar with the literature. She is the first author only in review papers bringing together the results of the different projects that the group has carried out. People from outside the group also participate as co-authors such as researchers from other institutes who have helped with techniques. Her doctoral students appear as first authors whereas undergraduate students do not unless they are exceptionally bright. It is the rule in her lab that an article in the international literature has to be forthcoming from every thesis, undergraduate as well as postgraduate.

Recently only her postgraduate students participate in nationals meetings due to lack of money. Only the most advanced doctoral students go to international meetings and they must have a sufficient grasp of English to make their attendance worthwhile. Student attendance at meetings abroad is usually combined with some other academic activity such as course attendance or a stay in a foreign lab. She herself rarely goes to meetings these days and only when they invite her to take part in a seminar and pay all her expenses. When her associate researcher wants to attend meetings he uses the funding from his own project.

Biomedic 3

Since Biomedic 3 has been at the Faculty of Medicine her group consists of herself, three associate professors (previously there were four but one resigned), four technicians and 10 students (four PhD students, two Master's students and four undergraduate from different faculties within the UNAM). Two of the associate professors are her former students. Up until five years ago when she was working at the Institute for Biomedical Research she had fewer people in her group as her laboratory was smaller and lack of space limited the number of people she could have working in her group.

Each member of the group has their own project and is in charge of literature searching, experimental design, standardisation and implementation of techniques, carrying out the research, presenting the results and usually writing up the work in article form. This latter activity usually happens with Biomedic 3´s help. Articles have been written from the results of almost all thesis projects. Thesis projects invariably fall within the research interests of the group which are basically those of Biomedic 3.

Weekly seminars are held at which all group members are present. All members have to present their work at some point. The atmosphere is informal, hierarchies do not exist and everybody addresses Biomedic 3 by her Christian name. Students practise presenting their work during the seminars which prepares them for participation at scientific meetings.

The strongest group interactions are towards the interior of the group. Biomedic 3 sometimes suggests that other members interact with people and institutions outside the UNAM but this role falls mainly to her. She believes there to be a strong group identity and encouragement to behave and act as a group. Nonetheless, each member is allowed to have their own contacts and activities outside the group. However, as she pointed out, this is more difficult at international level as language is the limiting factor. She encourages other members of the group to go to international meetings although traditionally this has fallen to her or past members of the group. The constraint is usually financial as there are always results to present. She usually finds the means for the students to attend national meetings.

Biomedic 3 sees her role as coming up with ideas, directing the research and finding resources. In an environment where resources are scarce it falls to the most senior member of the group to apply for funding and international grants. Like Biomedic 2, she mentioned that she does no longer does any practical work herself. She actually attributed her high productivity to having a large group that carries out the experimental work. She believes that perhaps her most important attribute is her ability to carry out multidisciplinary projects with other groups both nationally and internationally.

Chemist 1

Chemist 1´s present group consists of himself, one other senior researcher, one master's student and two undergraduate students. Technical support is shared by all researchers at his institute. He has never had any associate researchers and few doctoral students, none of whom have become permanent members of the group. He feels that the students are motivated by working as part of a team, particularly as there is little hierarchy within the group.

Until five or eight years ago and during a period of 10 to 12 years, the group also included two other senior researchers. However, as he mentioned, groups disintegrate or split up due to changing interests. He feels that the group was more productive when there were four senior members rather than two mainly due to a richer exchange of ideas.

Members of the group do not have other projects outside the group. Chemist 1 is the main contact with researchers from other groups although one of the former senior scientists also had his own contacts with other groups.

There is a certain division of labour in his present group although each member does their own literature searching. Chemist 1 tends to do much of the lab work although the postgraduate students do the experimental work for their thesis projects which form part of the research agenda of the group. Chemist 1 also does the interpretation of results and writes the articles. The other senior researcher does a lot of editorial work on a bulletin that the group produces.

It tends to be the senior scientists who go to international meetings but students are encouraged to present their work in meetings, especially at national and regional levels. Funding is an important limitation for students as well as personal considerations. Students have to present their projects in front of the group and rehearse presentations for their final exam or for congresses.

With regard to the order of names on the papers produced by the group, the names of the two senior researchers normally appear first, followed by the student(s) plus the technician(s) who have made important contributions to the work. Order of names is not usually a problem, as he feels everyone contributes to the work. It is usually the person who writes the paper who is the first author because this task falls to the person who has been in charge of the project.

Chemist 2

Chemist 2 described his group as small but stable consisting of one associate researcher and one technician whose role is more like that of a researcher. Also calls on the help of the technical staff that are shared by all the research groups in the Institute. At the present time he has one doctoral and one undergraduate student. The group structure between the three researchers, he described as pyramidal. Projects are communal, with the topics suggested by Chemist 2, discussed by the group and modified as a result of these discussions.

The group has not changed much in recent years except for the presence of a few of his doctoral students who had stayed on in his laboratory for a while after graduating. Also there was a Mexican researcher who spent two years there on sabbatical. He mentioned the sporadic collaboration of other senior researchers from his Institute. He himself does very little experimental work at present as he is the Academic Secretary of the Institute.

Literature searching is done mainly by the technician and perhaps the associate researcher. The associate researcher presents the draft of the papers in English to Chemist 2, and he corrects them. He mentioned that scientific papers have a natural structure that makes the writing easier. The technician got her masters in the US so she is competent in English.

All members of the group have contact with other groups, these having been set up by Chemist 2. He is also responsible for securing funding because he is better known in scientific circles.

The three members of the group share the credits as co-authors. The order varies and it is very often the associate researcher who appears as the first author and Chemist 2 as the last because he "organises the work". First author position is rotated between Chemist 2 and the associate researcher. Technicians usually appear in the acknowledgements except when their contribution is essential to the work and then they appear as co-authors. Chemist 2 is always cited as the person to write to for reprints (which he interprets as his being responsible to the editors for the work).

Chemist 2 goes mainly to international meetings as the other two members do not particularly like going. It is difficult to get money for student participation. Each year the Institute of Chemistry organises a seminar in which all students, both undergraduate and postgraduate, affiliated to groups within the institute present their thesis work. A book of abstracts is published as a result of this seminar.

<u>Chemist 3</u>

Chemist 3's co-worker mentioned that that prior to 1995 Chemist 3's group consisted of herself and two other senior researchers when a disagreement occurred and the more senior of the two senior scientists broke off to form his own group. The co-worker (who is the senior scientist who continued in the group) also publishes with other researchers in the Institute because of his expertise in magnetic resonance. At the moment there are two PhD, two masters and one undergraduate student supervised by the group. As mentioned also by Chemists 1 and 2 who work in the same institute, technicians are not assigned to any one group or project but rather lend support where and when it is needed. He considers this kind of group formation is typical of the Institute of Chemistry.

Chemist 3 did not like to assume the role of leader. She believed that the Institute of Chemistry had an inverted pyramidal structure, "too many generals and not enough soldiers and students". It was this attitude which caused the friction with the senior scientist who left the group. She saw her role as providing ideas but with each member of the group making contributions in their respective areas of expertise.

Chemist 3 had several links with scientists abroad. She did not take sabbaticals anymore but rather went to foreign laboratories for stays of about three months. She took one just before she became ill. The senior researcher of the group who was interviewed mentioned that he does not have his own contacts abroad as he is very introverted although he believes that the researcher who left the group does. There is little contact with national groups as they generally do not have the expertise that the group is looking for or, sometimes, they are just not interested.

With respect to the writing of papers, each member wrote up their part. The students, for instance, wrote up the laboratory methods and results. Chemist 3 had the habit of writing which she did easily in Spanish and in English. The names of two or three students were likely to appear in each article and sometimes these appeared as first authors.

All senior researchers helped to resolve the doubts of the undergraduate students. Masters students were helped less. Chemist 3 used to spend some afternoons at the library looking up information although students were expected to do their own literature searching.

Chemist 3 attended international meetings but usually to present a global picture of the findings of the group rather than any specific project. Students tended to go to national meetings rather than events abroad.

<u>Physicist 1</u>

Physicist 1 has a group of people with whom he has on-going collaborations, not continuously but rather intermittently, in the form of joint projects or in a series of joint projects. He still works sporadically with another senior researcher who had been his principal collaborator from the time they had been doctoral students together. This scientist is now director of his institute.

His principal collaborator at the moment is an ex-doctoral student. Another ex-student is also present in the group plus a Dutch scientist who arrived at the Institute about four years ago and who is an important member of the present group working directly with Physicist 1. A recently arrived Russian researcher is beginning to work with the group. All four are senior researchers. Foreign students have come to work with the group intermittently and they are about to hire an associate researcher (a Chinese postdoc) to work directly with the group.

One PhD student associated with the group has just graduated and another is about to finish his thesis. In addition there is another PhD student plus two masters students and the possibility of one or two undergraduate students in the near future. This is the normal student configuration of the group that has not changed much over the last few years. Notwithstanding, he lamented the serious lack of Physics' students in Mexico.

The group does not have obvious hierarchies and he believes the group to be democratic, even with regard to the students. Because of Physicist 1's experience, he perhaps could exert more influence in the initial direction of a piece of research. He also mentioned that he has more contacts abroad and that each researcher participates equally in the projects. The money, for instance, is shared out equally. He recognised that the students have a slightly less independent role to play within the group, but when they are enthusiastic and hard working, their contribution to the group goes beyond that of their thesis projects.

It varies as to whether other group members also have their projects outside the group. However, of his two closest collaborators, one does (the Dutchman) and one does not. Interactions and discussions within the group lead to ideas but anyone can come up with ideas for discussion. There are no fixed roles in the group but a certain work division exists due to the particular talents and preferences of the individual members. Physicist 1, for instance, takes an analytic approach to problems and uses this ability to look for precise solutions and to generate methodologies. He does not work much with computers but leaves this activity to the two group members he is working most closely with at the moment.

Physicist 1 considers he plays an important role at the interface between internal and external interactions of the group. He cited the example of their important collaboration with a Spanish group that resulted from his sabbatical in Spain. At the present time they are establishing a joint project with MIT which he initiated. He also mentioned that the Dutchman came to work in Mexico as the result of the contacts he made while a postdoc at Yale.

Physicist 1 secures the resources or, at least, he initiates the process but has the help of everyone else to write the research proposals. Research papers go through various draft stages. Sometimes the writing up is divided between the various co-authors and the draft seen by everybody involved. Nonetheless, Physicist 1 always does the final revision as he is the most experienced. He mentioned that he has no trouble writing the articles or communicating in English and indicated that the whole group has good ability in English. The person who makes most contribution to the work normally appears as the first author. However, sometimes the junior person is invited to be the first author to help them gain recognition. In theoretical physics he believes that the first author position is not so meaningful as in other fields, such as astronomy, for instance, although the tendency is now for the first author to be the major person involved in the work.

There are no formal group seminars, rather they get together for two to three hours almost daily to discuss work. He believes the dynamics of the group correspond to genuine team work. Everybody comes across information, references and citations of interest in the normal course of their work. Literature searches are carried out rather chaotically, no one person being in charge of this.

Although all members of the group participate in international events, Physicist 1 has perhaps attended more of these meetings in the last two years than the others. Students have also attended meeting but less perhaps than the group would like. Their attendance has depended very much on the availability of funding which is getting more and more scarce.

Physicist 2

Physicist 2´s group is small consisting of himself and two other senior researchers, one of whom moved with him in 1988 from the Faculty of Chemistry to the Institute of Physics. The other is from the UNAM's Institute of Chemistry. There are normally perhaps three or four undergraduate and postgraduate students associated with his group. At the moment there is one PhD student in the group, plus three masters and one undergraduate. Normally student progress is much slower than his own.

Physicist 2 tends to come up with the original ideas but this is not always the case. He attributes this to the fact that he is the person who keeps up most diligently with the literature. He receives information from his many contacts abroad, selects it and disseminates it among local colleagues. He also decides on the research agenda of the group but this does not mean that his collaborators do not develop their own projects. He admitted to being dominant and to the existence of a pyramidal hierarchy in his group. However, he considers the senior researcher from his own institute as his equal. Although she is well connected with external groups both nationally and internationally, Physicist 2 is more involved in international activities receiving more invitations to participate in foreign meetings, or to contribute to special issues of journals.

He does not have as many collaborative projects as some other researchers do. He does occasionally collaborate with other researchers in the Institute of Physics but this is not the norm. He also has sporadic collaborations with foreign scientists and is the sole author in some of his papers. The problem is that there are few doctoral students in Physics and many researchers. In his whole career he has supervised only four doctoral theses. His experience is that the students contribute to work that he is doing rather than having their "own" projects.

He nearly always writes the research papers. This is not only because of his ability in English but also because he knows what is happening in the field and can put the work in appropriate context, thus making his group competitive internationally. Physicist 2 mentioned that he has more trouble writing papers in Spanish than in English because he is more accustomed to writing in English.

At present the group has no formal seminars but rather Physicist 2 gets together individually with the other group members, especially with his main collaborator. He tends to be rather informal in his interactions with his colleagues and students and the frequency of these will depend on his involvement in other activities and the urgency of discussing a research problem with another member of his group.

The participation of students in national and international meetings has depended very much on the availability of funding which has varied throughout the years. His collaborators attend their own meetings. However, it is easier for him, as the most senior member of the group, to get invited with all expenses paid.

Physicist 3

Physicist 3's internal research group consists normally of himself, usually two associate researchers and several students. At the moment he has two associate researchers, one of whom was his PhD student, the other with a doctorate from the US, four PhD students, one master's and two undergraduate students. He recognised that he is "lucky" to have so many PhD students. Before, he pointed out, the best students were attracted to physics, but this is not the case anymore as other careers such as economics or molecular biology promise young people a brighter future. He mentioned one brilliant student with whom he still collaborates but who now has his own research team.

His goal is always for the associate researchers to gradually become researchers in their own right and to leave the group to form their own research team. The two at present have other projects, their own contacts and their own undergraduate and postgraduate students. He does not tell them what to do, rather they discuss their ideas with him. He normally has simultaneous collaborations with other senior researchers within his own institute and outside. He recognises that the group is known as his group but he does not consider it as such. He feels that there are no hierarchies in the group except that because he is the oldest and most experienced, he is the one who applies for funding and other resources. For the same reason his name often appears as the project leader.

He usually writes the first draft of the papers which are then discussed with the other members of the group involved in the project and changes made. He has no problem with writing papers in English. In his opinion the first author is the person who has done most work on the project. Authors never appear in alphabetical order. The names of his PhD students always appear first on papers resulting from their thesis projects. When his contribution has been to comment on and make suggestions, he appears as the last author.

With regard to keeping up with the literature, he believes that this is changing. Before it used to be a matter of going to the library together, but now younger members of the group tend to use the new information services available on the Internet. The group meet for weekly seminars in which work in progress on the different projects is reported and discussed.

Attendance of the group at meetings depends on the money available. There is one important event every March in the US where he likes the group to be represented. Doctoral theses are presented by the students but only when their English is good enough, if not Physicist 3 presents the work. The students themselves present their work at national meetings.

Astronomer 1

Astronomer 1 described three periods in his research career of 30 years. During the first he published with his professor at the University of California. In the second he worked with his wife, also a senior researcher at the Institute of Astronomy and with recent PhD graduates. A third period corresponding to the last few years is characterised by his collaboration with researchers from different countries. At the moment his research activity is a combination of the last two periods. When asked with whom he is working at the present time, he mentioned his collaboration with two foreign postdocs and with a series of US scientists, projects in which his astronomer wife is also involved.

Astronomer 1 referred to a certain division of the work. For instance he mentioned that his wife, who is also a senior scientist, is better at mathematics and complex computer programmes whereas he is often the one to come up with the problems to be solved. He considers his wife to be of equal scientific standing as himself and mentioned that she has research projects and collaborators other than those she has with him.

He has only one student at the moment, at doctoral level. In his research career he has supervised only about 10 theses, very few of which have been at undergraduate level. He mentioned that in the biological fields, for instance, researchers have many more students. On the other hand, he has worked with 30 or 40 young researchers. He also mentioned that the policy of his Institute is that a student who has done his/her PhD in Mexico, should then go abroad for at least a year's postdoc.

He does not consider himself the leader of the group in the sense that he is the boss although the fact that he is often the most experienced member of the team especially when working with young scientists, makes him the obvious person to suggest and offer advice. He says he sometimes does the routine work that gives him first author status. When working with young scientists, the projects carried out will correspond to his research interests. When he works with older scientists, it is because of mutual interest in certain topics.

Astronomer 1 works with foreign scientists when their skills complement his own forming multinational and very often mutligenerational groups. These are not necessarily multidisciplinary except within astronomy. For projects that involve requesting experimental time in the space telescope, it is convenient to have in the team an experimentalist, a theoretician and an expert in the field to produce a balanced application that has more chance of being approved. Sometimes there are so few people working in any particular topic that it is difficult to put together a complete team from one country, particularly in a scientifically small country such as Mexico.

He described certain constant trends in his relationship with collaborators, such as the fact that each member assumes a certain responsibility and there are no hierarchies. However, when he works with young researchers he usually suggests the topic of the research and is more likely to write a larger part of the article. He also often directs the research but the actual work is carried out by the younger scientist. At the beginning the young scientists will have just the one project with Astronomer 1. After two or three years they will perhaps continue to work with Astronomer 1, but also do work on their own or with other researchers.

There are two rules for the ordering of names on papers in his subject area. The first is that the person who did the most work appears as first author, the second author position is assigned to the person who did the next most work, and so on. The second case applies when everybody has done about the same amount of work or when the order cannot be decided on and then the co-authors appear in alphabetical order. However, every co-author on a paper assumes part of the responsibility for the work.

A weekly colloquium is held in his Institute given by one of the researchers or sometimes a foreign visitor. Smaller seminars are also held on select topics that are sometimes given by his group. Astronomer 1 is often invited to give lectures at international meetings of specialists.

Astronomer 2

The information on the present structure of Astronomer 2's research group provided by her doctoral student by email indicated the presence of three other senior scientists, one other of whom is also from the Institute of Astronomy of the UNAM and two from different Spanish institutions. Also forming part of the group is one technician and the doctoral student (herself).

She described all senior members as "collaborators", the hierarchy depending on who has been involved the longest in the project, who was responsible for the main ideas and who has carried out the bulk of the work. However, she remarked that Astronomer 2 is normally the one who comes up with the main ideas for projects thus setting the research agenda of the group, and making her the natural leader. She mentioned that the group composition has changed over the last few years. For instance, one of the doctoral students is now a researcher within the group. Other factors are changes in institutional hierarchy causing some people to participate more and others less in group projects.

The experimental observation is carried out by one of the senior scientists depending on who has physical access to the observatory, the funding and the time. Reduction of data is normally done by the PhD student herself. Literature searching and the writing up of the work as a scientific article are joint efforts involving all members of the group. She mentioned that Astronomer 2 is the first author on papers, the other members of the group appearing as co-authors.

All senior members of the group have independent contacts and projects at national and international level. It is also mainly the senior scientists who attend meetings but it really depends on the availability of travel money. In certain occasions there is also funding for technicians and the students to go to meetings.

Astronomer 3

Astronomer 3 remarked in his email that his group usually consists of one or two senior scientists and two or three junior ones. Included in the later category are postdocs and graduate students. He has had very few undergraduate students due to the fact that over the past few years he has been based in areas where there are few or no candidates. However, there is little group structure and, in essence, anybody can work with his group as long as they are willing and get along well with the rest of the people. Notwithstanding, one person is assigned the leadership of each project who could be a young scientist or even a PhD student. He sees his own role as overseer of the work of the group, ensuring completion of the projects and offering constructive criticism.

The changes in his group are, he believes, intrinsic to every research group. He likened the group to a flock of sheep where the young grow up and begin to challenge the elders and then it is often time for them to move on. However, he pointed out that this does not mean that the group is not willing to listen to ideas forthcoming from their younger members.

Astronomer 2 remarked that he is very careful with the observations he carries out and with the reduction of data, activities that he never entrusts to anybody else. The junior members of the group tend to be the ones who do the literature searching although all members need to keep up with the most recent information in the field which is discussed in group seminars. The preparation of articles for publication is done by the person in charge of each project. In his group everybody who has worked on the project and only those who have worked on the project, appear as authors.

Relationships with other groups with similar research interests are established mainly through contact at scientific meetings which Astronomer 3 believes is the most important function of these events. This is an aspect of his work that he does not particularly enjoy. Conference attendance depends on the time and money available and the enthusiasm of the members of the group to go. Anyone from the group can do depending on the availability of funding.

He mentioned that all group members participate equally in both internal and external interactions. All have independent contacts with other groups both inside and outside the country although they are cautious as to what information they give to national colleagues because of professional jealousy and piracy. For this reason he stated that any member of the group is free to communicate what they want as long as the project is in the final stage of preparation for publication.

Geoscientist 1

Geoscientist 1 described himself as the engine of an international group or network of students and postdoctoral scientists who have a common research interest in a little studied and difficult topic of dynamic elasticity. The lack of specialists in Mexico or the lack of interest in this particular topic means that he has had to look abroad for collaborators. In spite of graduating doctoral students he has not found anybody to commit themselves to this line of research in Mexico.

At the moment he has five doctoral students, including one from Greece and two working in industry. He also has one master's student from Italy and one undergraduate student. He considers that four postdoctoral scientists (one from Spain, one from Japan and two from France) also form part of his group. In each case he was involved in the supervision of their doctoral theses abroad and two of them actually spent time in his laboratory at the UNAM. The original contacts were established during his many visits to foreign scientists.

During the interview he drew a schematic representation of the roles played by his two sabbatical leaves of absence in 1982 to France and Italy, and in 1990 to France through which he was able to trace the snowballing effects of his contacts. He described these as a "transitory or temporal network". He mentioned that he continues to explore ideas and interests with postdoctoral scientists with a view to possible collaboration involving exchange visits in both scientific and technological research. The foreigners, he commented, are the ones who usually have the resources.

The integration of his group and the way it works has not changed fundamentally over the years except that individual students have come and gone. He often comes up with ideas that he transmits to the most appropriate person in the group to apply them. The interactions of the group take various forms, some people have the ideas, some people work hard, some are communicative, etc. He sees his role as animator, enthusiast, spiritual adviser, comedian and entertainer. He is the most experienced member of group, the main force within the group and the central node of all interactions. He recognised that without him there would be no group.

Interactions occur via email, visits and encounters in congresses. He considers that email plays a very important role in his activities. Students concentrate on the research for their theses while the postdocs have independent activities such as teaching, their own projects, etc. These collateral activities reduce the number of opportunities to collaborate with Geoscientist 1. He has ideas that he wants to develop and is always looking for students to do the routine work. The projects of the foreign postdocs are derived from the main research interest of the group or are extensions or applications of these. He procures the resources for his doctoral students but believes his work suffers from lack of both time and resources. His public appointment (since 1997) does not allow him as much time for research as he would like. He is always looking for ways to work more efficiently.

He has found that his knowledge of English, French and Italian has helped his relationships with his foreign colleagues. Geoscientist 1 nearly always writes the articles for publication but sometimes he is given a draft to review by another member of the group. His papers are always written up in English and this is not a problem for him in practical terms.

Geoscientist 2

Geoscientist 2 referred to his present group structure as interdisciplinary due to the presence of physicists from the UNAM's Institute of Physics. The group, he explained, is really one from the Institute of Physics and consists of three other senior scientists, one associate researcher, himself and his PhD student. Both Geoscientist 2 and the group of physicists had been working on different aspects of the same problem for over 10 years but recently their interests have converged. The associate researcher is a recent PhD graduate who, although a physicist, got his PhD less than two years ago from an Earth Sciences department in the US. Geoscientist 2 arranged his appointment. He thinks that the group will split up soon due to changing interests.

This is the first time that Geoscientist 2 has worked in a team and he has had very few doctoral students during his career. His earlier collaborations have been mainly with foreign scientists. The fact that the present project is focussed on a theoretical aspect of seismology makes Geoscientist 2 the natural leader of the project. The physicists would be looked upon as outsiders. Most of the contribution of the physicists has been in the weekly brain storming sessions. He considers there is true collaboration within the group but the roles are not evenly distributed.

The group holds weekly meetings to discuss the project. The first paper which has just been accepted for publication in a US seismology journal, was written by Geophysicist 2 after going through several draft versions seen by all members of the group. He is the first author and the junior man the last. The student does not appear as he joined the project later. He believes that the author who contributes the most to the work should be the first author. He thinks that being first author means something, especially with regard to Mexican evaluation criteria.

Each scientist in the group keeps up with the literature in his own field and shares articles of interest to the project with the other members. All have independent contact with researchers abroad. Geoscientist 2 likes to consult foreign scientists about recent literature. The associate researcher is the one who normally performs tasks related to looking up literature, taking photocopies of papers etc. The senior scientists also have other projects in process.

He presented a seminar on the work during the weekly seminars of the Department of Seismology and Vulcanology (where Geoscientist 3 is the head of department) and so did his student. Geoscientist 2 is already on the programme of an important international meeting to present the results at the end of the year.

Geoscientist 3

Geoscientist 3's department has 10 scientists (plus students and technical staff belonging to the National Seismology Network which is housed in the Department) who are specialists in different aspects of seismology and vulcanology, each with their own research groups and agendas. However, Geoscientist 3 does not have a fixed group but rather looks for colleagues to help him with particular projects. It is most likely that these collaborators will not be from his institute, but rather from other institutes and faculties within the UNAM. He is usually the one who comes up with the ideas for projects in accordance with his own research agenda but sometimes other scientists both Mexican and foreign come to him with suggestions. He first looks at the feasibility of the projects in terms of who can help him carry them out, resources etc. This has always been his style of working.

He probably works with two or three other scientists in most projects either senior or associate, some of which might be postdocs. He normally has two doctoral and probably three master's students at any one time. Geoscientist 3 stressed the problem of attracting students, particularly good ones, to his area of seismology. Doctoral students will participate in projects related to their thesis but their progress is slow and does not keep pace with Geoscientist´s 3 rhythm of work (a opinion previously expressed by Physicist 2).

He mentioned that he is the motor behind the projects. He keeps up-to-date with the literature to have the necessary elements to plan the projects and to write the papers which he always does himself. The person doing most of the work appears as the first author, which would be student in the case of their thesis project. The role of the other scientists is usually with respect to the acquisition of data and sometimes, their analysis. Even his fellow researchers do not work fast enough for his liking. He experiences little problem in writing in English. When other people approach him with ideas for projects, his role would be more as a critic and guide.

It happens more and more that the younger generation want to pursue work with foreign scientists, especially those recently returned from abroad. He is more and more reluctant to collaborate internationally as he believes the priorities are different. He sees his role in this context as an adviser on whether these international proposals are realistic in the Mexican context and especially in terms of how long they will take to get publishable results.

Geoscientist 3 is getting more selective in the meetings he attends. He encourages his students to present their own projects especially at national level. Most of them are not well prepared to attend international meetings except to present posters. His department is one of the larger and better integrated of the Institute. Students present progress reports on their projects during the weekly departmental seminars. Each person gets one or two opportunities a year to present their work.

8.6 Academic Awards

The recognition enjoyed by the 15 scientists as members of both the local and international scientific communities is shown in Table 8-4. Twelve had received at least one national prize of importance, eleven of whom had been given the highest award of their own institution, the UNAM. These prizes are given annually in two distinct categories, for young researchers under 40 years of age, and for more established scientists, this award often coming at the end of a long and successful career. Each of these prizes is given either for research, or for teaching within eight different general areas that make up the knowledge system. In all 15 prizes are awarded each year in both categories. Astronomer 1 was the recipient of the greatest number of awards including foreign membership of the US Academy of Sciences, an honour bestowed on only a few Mexican nationals. He was also the only one of the 15 elected to the Mexican National College (Colegio Nacional,) an elite society of Mexican intellectuals. All 15 reported being members of national and international evaluation boards and committees with the exception of Chemist 1 who mentioned participation of this type only at national level. Furthermore all 15 reported invitations to give special courses and conferences both at home and abroad.

All 15 scientists had reached the highest position in the salary scale for researchers within the UNAM. Astronomer 2 became an emeritus researcher in 1981 and Biomedic 2 in 1997. Without exception the scientists had become members of the National System of Researchers (SNI) in 1984, the year of its creation and all had reached the highest category (level III) by 1994.

8.7 Academic Links with other Institutions

The connections that all 15 scientists have with other institutions and other countries as a result of personal history, higher education or research visits are seen in Table 8-5. In all cases researchers had established links with scientists in other countries, in many cases with research groups from the scientific centre. Five of the scientists had done their doctorates in Mexico but all had since spent sometime in institutions abroad. Four of these graduated from the UNAM and one from the National Polytechnic Institute (IPN). All had been undergraduates in the UNAM except the three who were foreign born and had arrived in Mexico as PhDs to work in research. Five of the 15 had gained their PhDs from universities in the US, one from Canada, two in the UK, one in France and one in Turkey, her country of birth.

Table 8-4

Academic awards of the 15 UNAM scientists

SCIENTIST	PRIZES				ELECTED MEMBERSHIP	
	UNAM[1]	*AIC*[2]	*Nacional*[3]	*OEA*[4]	*Colegio Nacional*[5]	*US Nat Acad Sci*
BIOMEDIC 1	✓*(1988)*		✓*(1987)*			
BIOMEDIC 2	✓*(1991)*					
BIOMEDIC 3						
CHEMIST 1	✓*(1996)*					
CHEMIST 2	✓*(1987)*	✓*(1968)*				
CHEMIST 3	✓*(1997)*					
PHYSICIST 1	✓*(1991)*[6]	✓*(1989)*		✓*(1991)*		
PHYSICIST 2		✓*(1983)*		✓*(1985)*		
PHYSICIST 3						
ASTRONOMER 1	✓*(1988)*		✓*(1981)*		✓*(1992)*	✓*(1987)*
ASTRONOMER 2	✓*(1989)*[7]					
ASTRONOMER 3						
GEOSCIENTIST 1	✓*(1998)*		✓*(1994)*	✓*(1988)*		
GEOSCIENTIST 2	✓*(1997)*		✓*(1995)*			
GEOSCIENTIST 3	✓*(!995)*					

[1] Institutional recognition [2] Peer recognition for young scientists [3] Recognition by Mexican government
[4] Regional recognition for young scientists [5] Highest national honour for Mexican academic
[6] Category of young academics (<40yrs old) [7] Teaching category

Table 8-5

Academic links of the 15 UNAM scientists with research institutes In different countries

SCIENTIST/ACTIVITY	COUNTRY	INSTITUTION	YEAR
BIOMEDIC 1 *County of birth*	MEXICO		
Undergraduate	MEXICO	UNAM	
Masters	USA	Northern Illinois Univ	
PhD	CANADA	Univ Saskatchewan	1971
Postdocs/Sabbaticals/Prolonged Visits [1]	USA	Univ California-Irvine	1973-4
	USA	Univ California-Los Angeles	1980-1
BIOMEDIC 2 *Country of birth*	MEXICO		
Undergraduate	MEXICO	UNAM	
Masters	MEXICO	UNAM	
PhD	FRANCE	Univ Louis Pasteur, Strasbourg	1973
Postdocs/Sabbaticals/Prolonged Visits	FRANCE	Univ Paris VI	1975-6
	USA	Inst Basic Res Developmental Disabilities, NY	1983-4
	DENMARK	Panum Inst, Copenhagen	1987-9
BIOMEDIC 3 *Country of birth*	MEXICO		
Undergraduate	MEXICO	UNAM	
Masters			
PhD	MEXICO	Instituto Politécnico Nacional	1978
Postdocs/Sabbaticals/Prolonged Visits	UK	Imperial College, London	1987-
	UK	Natl Inst Med Res, Mill Hill	1988
CHEMIST 1 *Country of birth*	MEXICO		
Undergraduate	MEXICO	UNAM	
Masters			
PhD	MEXICO	UNAM	1973
Postdocs/Sabbaticals/Prolonged Visits	USA	Lousiana State Univ	1978-9
			1982-3
			1988-9
CHEMIST 2 *Country of birth*	MEXICO		
Undergraduate	MEXICO	UNAM	
Masters			
PhD	MEXICO	UNAM	1960
Postdocs/Sabbaticals/Prolonged Visits	USA	Florida State Univ	1962-3
CHEMIST 3 *Country of birth*	SPAIN		
Undergraduate	MEXICO	UNAM	
Masters			
PhD	UK	Imperial College, London	1962
Postdocs/Sabbaticals/Prolonged Visits	CHILE	Catholic Univ Chile	1970
	FRANCE	Univ Scient Med, Grenoble	1977-8

[1] Includes visits of more than 3 months during UNAM appointment

Table 8-5 cont.

<u>PHYSICIST 1</u>			
Country of birth	MEXICO		
Undergraduate	MEXICO	UNAM	
Masters	MEXICO	UNAM	
PhD	MEXICO	UNAM	1979
Postdocs/Sabbaticals/Prolonged Visits	USA	Yale Univ	1985-
	USA	Brookhaven Natl Lab	1986
	SPAIN	Univ Seville	1991-2
<u>PHYSICIST 2</u>			
Country of birth	MEXICO		
Undergraduate	MEXICO	UNAM	
Masters			
PhD	UK	Univ St Andrews, Scotland	1975
Postdocs/Sabbaticals/Prolonged Visits	UK	Univ Oxford	1978-
	USA	Cornell Univ	1979
	FRANCE	College de France	1985-
	USA	New York Univ	1986 [2]
	BELGIUM	Kath Univ Leuven	1992-3
<u>PHYSICIST 3</u>			
Country of birth	MEXICO		
Undergraduate	MEXICO	UNAM	
Masters			
PhD	USA	Univ Illinois	1971
Postdocs/Sabbaticals/Prolonged Visits	GERMANY	Univ Frankfurt	1972-3
	USA	Georgia Inst Technology	1981-
	BRAZIL	Univ Fed Fluminense	1982
	MEXICO	Instituto Politecnico Nacional	1986
	MEXICO	CONDUMEX	1990
<u>ASTRONOMER 1</u>			
Country of birth	MEXICO		
Undergraduate	MEXICO	UNAM	
Masters			
PhD	USA	Univ California-Berkeley	1967
Postdocs/Sabbaticals/Prolonged Visits	USA	Univ California-Berkeley	1967-8
	USA	Kitt Peak Natl Observ, Tucson	1975-
	UK	Univ College, London	1976
	JAPAN	Univ Tokyo	1986
<u>ASTRONOMER 2</u>			
Country of birth	TURKEY		
Undergraduate	TURKEY	Univ Istanbul	
Masters			
PhD	TURKEY	Univ Istanbul	1937
Postdocs/Sabbaticals/Prolonged Visits	USA	Harvard College Observ	1938-42
	USA	Univ Princeton	1946-51
	USA	Univ Chicago	1947
	TURKEY	Middle East Technical Univ, Ankara	
	SPAIN	Univ Laguna, Tenerife	1985
<u>ASTRONOMER 3</u>			
Country of birth	MEXICO		
Undergraduate	MEXICO	UNAM	
Masters	USA	Univ California-Berkeley	
PhD	USA	Univ California-Berkeley	1972
Posdocs/Sabbaticals/Prolonged Visits	USA	Kitt Peak Natl Observ, Tucson	1972-3
	USA	Univ Arizona, Lunar/Planet Lab	1974
	GERMANY	Univ Heidelberg	1980
	ITALY	Osserv Astron Merate, Milan	1992

[2] 1 month visits to both the UK amd Puerto Rico during the sabbatical

Table 8-5 cont.

GEOSCIENTIST 1 *Country of birth*	MEXICO		
Undergraduate	MEXICO	UNAM	
Masters	MEXICO	UNAM	
PhD	MEXICO	UNAM	1979
Postdocs/Sabbaticals/Prolonged Visits	FRANCE	Univ P & M Curie, Paris	1982-
	ITALY	Milan Polytechnic	1983
	USA	Univ So Calif	1985-7
	JAPAN	Univ Kyoto	1988-94[3]
	FRANCE	Univ Joseph Fourier, Grenoble	1990
	FRANCE	Univ P & M Curie, Paris	1990
GEOSCIENTIST 2 *Country of birth*	GERMANY		
Undergraduate	CHILE	Univ Chile	
Masters	USA	Univ Harvard	
PhD	USA	Cal Inst Tech	1955
Postdocs/Sabbaticals/Prolonged Visits	USA	Cal Inst Tech	1955-7
	UK	Imperial College, London	1979-80
	INDIA	Ctrl Water/Power Inst, Pune	1982
	BRAZIL	Univ Fed Bahia	1986-7
	JAPAN	Univ Kyoto	1987
	GERMANY	Univ Kiel	1990
GEOSCIENTIST 3 *Country of birth*	INDIA		
Undergraduate	INDIA	Indian Sch Mines, Dhanbad	
Masters			
PhD	USA	Columbia Univ	1971
Postdocs/Sabbaticals/Prolonged Visits	USA	Scripps Inst Oceanography, Univ Calif-San Diego	1980-81
	USA	Univ Wisconsin	1983
	ITALY	Univ Rome	1987
	NORWAY	Univ Bergen	1990-1

[3] Several short visits <2 months each, total of 9 months

All disciplinary groups showed a variety of links with respect to institutions, countries and regions. Two astronomers had doctorates from the University of California, Berkeley. The total numbers of institutional links with the USA/Canada and with Western Europe were equally balanced. Links with the US were often with universities in the southern part of the US, such as California. Two of the chemists and one of the biomedics had links only with the USA/Canada, and one biomedic had links only with Western Europe. Chemist 3 had made visits to Western Europe and to Latin America (LA). The remaining 11 researchers had links with both North America and with Western European countries; three also reported stays in Asia and two in LA.

Of the 53 postdocs/sabbaticals/prolonged visits reported in the CVs of the 15 scientists, 22 were to European institutions and 20 were to institutions in the US. European links were mainly with the UK and France. In Astronomy and Geosciences three visits were reported to Japan. Physicist 3 was the only one of the 15 scientists to report a sabbatical spent in Mexico.

The geoscientists had the highest number of separate links with foreign institutions, 18 with four different regions of the world (North America, Europe, LA, Asia), followed by the Astronomers with 15 institutional links covering three regions (North America, Europe, Asia), the physicists with 13 links also covering three regions (North America, Europe, LA), the biomedics with 10 links to two regions (North America, Europe), and the chemists with four links to three regions (North America, Europe, LA) .

Connections had been made almost exclusively with institutes of higher education or research institutes. Only Physicist 3 reported a sabbatical spent in the private sector (Condumex in Mexico).

8.8 Discussion

The 15 scientists came from different research groups, areas and institutes within the UNAM. However the profiles of these highly productive scientists are consistent with those of researchers considered highly successful in their local environment, recognised as such by the national scientific community and fully integrated into the research and teaching activities of their respective institutes, centres or faculties.

Research groups are presently considered as the minimum unit of analysis of the research issue (Bordons 1995). As pointed out by Ziman, it is easy to understand in the present climate of increased personal mobility and interpersonal communication, that scientists are becoming more cosmopolitan as individuals. However the organisational units of modern science are not individuals but groups (Ziman 1994). Funding, as an example, favours research projects backed up by groups of scientists to avoid isolation both inside and outside the country and the scattering of research efforts among individual projects (Gómez et al. 1995).

Meadows believes that research groups also form the basis of scientific communication. Quoting work by Diana Crane in rural sociology (Crane 1969; Crane 1972). he mentions that the position of high producers as the central foci of collaborative activity can best be seen in the appearance of research groups in the field. Groups were formed as a result of the emergence of the high producers and their acquisition of a band of colleagues and research students (Meadows 1974).

Bordons, using a combination of bibliometric techniques and expert opinion, looked at the structure and research performance of teams in two biomedical fields in an attempt to identify group features linked to good scientific performance. Results showed a relationship between high production and high visibility with the most productive groups in both fields showing a higher tendency to publish in the top, high impact journals. An inverse relationship was found between productivity and team size which the authors attribute to the greater number of organisational problems associated with large groups. According to this same author, previous studies had shown conflicting views on the relationship between productivity and team size with no clear evidence available on the optimal size for research groups. However, results from the Spanish biomedical study suggest that the group size of eight to nine might be a basic unit of research activity in different scientific fields. Results also showed that steady collaboration with foreign colleagues was linked to publications in higher expected impact factor journals than those without foreign intervention (Bordons 1997).

In his model for the reason, form and effect of research collaboration, Melin lists four forms of collaboration: verbal exchange, division of labour, teamwork and team-team interaction. He believes that collaboration takes different forms depending on the tradition and culture of the discipline, and more specifically on the field that the collaborators belong to. The academic and intellectual background and its environment play a significant role (Melin 1998).

In the present study there were some notable differences with regard to the composition of the internal research groups. Some of these could be linked to the type of research being carried out while others seemed to be associated with individual differences between scientists working in the same area. The biomedical scientists, for instance, tended to have the larger research groups which included exclusive technical support and a large number of students at both undergraduate and graduate levels Technical support for the chemists was shared with other researchers in their institute but was available when required. Theoretical areas, as in the case of the physicists, did not require this type of support.

Biomedic 1 talked about his extended group within the UNAM with which he collaborates from time to time. The large number of UNAM research institutes and faculties in the biologcial and medical sciences (see section 4.3.2) coupled with a significant number of government research institutes and hospitals, implies a wide range of potential institutional and national partners for researchers in these areas.

Although from very different disciplinary backgrounds, Astronomer 1 and Geoscientist 1 were the two scientists who did not have fixed internal groups but rather created their own collaboration networks embracing scientists and postdocs both in Mexico and abroad. As Geoscientist 1 pointed out, without him there would be no group. This ties in with Melin's idea that the team or possibly an individual working within a network, is relevant producer of ideas and discoveries in today's world rather than the sole researcher (Melin 1997b).

All 15 scientists had at least one other senior or associate researcher, or postdoctoral student as members of their groups. Most had at least one other senior researcher as a group member. As pointed out by several of the scientists, Mexican postdoctoral students usually occupy associate researcher positions.

During the interviews differences between disciplines were mentioned in respect to the number of potential students available. Notwithstanding there were also obvious individual differences with respect to the 15 scientists in their abilities to attract students to their groups. For instance, all three physicists referred to the fact that there is a lack physics' students in Mexico, nonetheless, all three had an important number of students associated with their research. Among the astronomers there was a tendency to recruit foreign students and postdocs which they were able to do this partly because astronomy is an international science. Nonetheless. Geoscientist 1 was also able to look abroad for his students and his postdocs in spite of the fact that seismology is an applied field. This was a conscious strategy on the part of this scientist due to a lack of specialists in Mexico in his subject. All 15 scientists had at least one PhD student presently associated with their group except for Chemist 1 who mentioned he has had few doctoral students and Astronomer 3 who is based in Baja California.

All mentioned the importance of student participation in internal seminars and group discussions and some the importance of ideas coming from creative students. In the experimental sciences it is often the students, together with the technicians, who carry out the routine laboratory work. Two of the biomedics commented that they no longer carry out any experimental work. Productivity, in the opinion of some of the respondents, was associated with the presence in the group of a large number of senior scientists and/or a large number of students. In this first instance, more ideas will be forthcoming from a greater number of senior scientists, coupled with the fact that these will have their own students and perhaps contacts. Student members, on the other hand, contribute their thesis projects to the production of the group, especially when, as remarked by some of the UNAM scientists, articles must be forthcoming from every student project.

In his study on the community of science in Europe, Franklin found that seniority has the expected association with the number of subordinates: senior researchers work with more subordinates than do junior researchers. Those with a lesser degree than a PhD have fewer subordinates and more students than those with at least the equivalent of a doctorate. The research environment of women scientists looks very much like that of the non-PhD scientists in that they have fewer subordinates and more students than male scientists without a PhD (Franklin 1988). In the present study no obvious disadvantages in group structure could be seen with respect to the four female scientists in comparison with their male colleagues. On the contrary, Astronomer 1 had the highest number of senior scientists assigned to her group and Biomedic 3, the largest number of total groups members (including students and technicians).

Franklin also found substantial differences between groups of disciplines with the largest departments being found in the engineering sciences and the smallest among the more theoretical mathematical and physical sciences. Research teams engaged in specific projects were generally much smaller than the group of individuals with whom the scientists work on a daily basis comprising about five persons on average, as opposed to 16 (Franklin 1988). In the present study a few of the scientists remarked on the projects that they were engaged in at the time of the interview which in agreement with Franklin's findings, often involved only certain of the members of what they had identified as their research groups. This was particularly notable in the case of Physicist 1 who referred to his on-going but intermittent collaborations with a group of people in joint projects or a series of joint projects.

In Franklin's study on the European community of science there was considerable variation between country and in the case of Spain, for instance, the research teams seemed to be identical to the group of people with whom researchers work on a daily basis. Although the size of the research team is generally very different from that of the larger group with whom respondents work on a daily basis, its hierarchical structure is similar (Franklin 1988).

In the present study, some of the researchers pointed out the lack of hierarchical structures in their groups although the distinct standings as scientists of the different members of the groups meant that varying roles fell naturally to each category of researcher or student. Only two scientists reported a pyramidal structure. Nonetheless, due to the experience and natural seniority of the 15 scientists, their role within the groups corresponded to that of leader, particularly in those having fixed groups. They were the ones who came up with ideas (but not necessarily the only ones), that secured funding, tended to co-ordinate, promote and facilitate the projects, and in general were the members of the group (or one of the members) with most contact with the national and international scientific communities. They also tended to set the research agenda for the group, especially when working with younger scientists. In other words they formed the central core of their groups and were the main players linking the internal and external group actions. Many of the scientists interviewed acknowledged themselves to be or thought they were considered by others to be, the leaders of their respective groups.

Differences in the internal science policy of the different institutes within the UNAM was commented on by one of the biomedics with respect to the number of associate researchers allowed within each group. There were also different opinions expressed by the 15 scientists as to whether the tendency is for postdocs to stay within the same groups or eventually to move on and form their own groups. Perhaps this discrepancy can be explained by the general lack of mobility between groups in the small scientific communities of DCs such as Mexico. Perhaps the better scientists leave to form their own groups while the not so talented or the less ambitious ones remain where they are as long as they are able.

With regard to their English language skills, the respondents told me that they had an important hand in writing the papers in English and preparing them for publication. None acknowledged any practical difficulty in this area. Eight of the 15 had gained their doctoral degree in English-speaking countries and the other seven had spent a visit of at least a year's duration in these countries. It was therefore to be expected that they should have little problem in communicating with scientists in almost any part of the world considering that English is the international language of science. Geoscientist 1 pointed out that his language skills in several European languages including English helped his relationship with foreign collaborators. Some of the scientists mentioned learning or perfecting a language as a benefit obtained from sabbaticals spent abroad (see section 10.6).

From the contact I had with the scientists during the interviews, the only two scientists whose English language skills I could not personally vouch for were Chemist 1 and Chemist 2. Both these scientists were rather reserved and, unlike the other respondents, did not speak to me in English from time to time during the interviews. The 15 scientists were also the group members who tended to present the papers at international meetings suggesting certain language ability and the ones most likely to get funding. A common denominator was an increasing lack of funding to attend meetings particularly in the case of the students.

The fact that all 15 had spent at least one year in universities or research institutes in scientifically advanced countries, over and above time spent as doctoral students, suggests that they have developed important links with researchers abroad. The frequency with which many of these scientists have paid visits of more than three months to foreign institutions in different countries points to the existence of a variety of links with colleagues abroad.

Shiva and Bandyopadhyay in their analysis of the Indian scientific community, found that a distinctive feature of the scientists who had achieved a high degree of recognition, was the greater amount of personal contact with the leading centres of research in Western countries (Shiva and Bandyopadhyay 1980).

In his study on Third World scientists Gaillard found that researchers who had completed all their studies at home were relatively more apt to work alone on their research and were the last to take sabbatical leaves (Gaillard 1991). Equally, researchers who had never studied abroad were less likely to be in contact with foreign researchers, except at international scientific meetings. He relates the frequency of communication with researchers in other countries to the time spent studying abroad.

In the present study there were no clear differences in the patterns of visits abroad between those scientists who had received their doctorate from Mexico and those who had gone abroad for their PhD. Although more of the 15 UNAM scientists had done their doctoral studies in the USA or Canada than in European countries, the visits that they had carried out during the subsequent years were equally balanced between European and US institutions. Visits to LA and other countries were relatively infrequent.

Herzog agrees that scientists from peripheral countries who have earned their highest degree abroad are more likely to report foreign employment or an extended research sabbatical abroad (Herzog 1983). According to this author, about 62% of physical scientists and mathematicians from Ireland had been employed abroad versus about 40% of the remaining scientists in the country. He suggests that researchers in the more applied sciences, such as the biological and agricultural sciences, are less likely to travel abroad than their conationals working in fields characterised by a relatively high degree of paradigm development, where we would expect freer international exchange. Low paradigm fields, he suggests, tend to give rise to distinctive national research traditions with little international co-operation. All 15 researchers in the present study appeared to be working on topics of relevance to scientists in other countries independent of the basic or applied nature of their work.

The integration of this group of scientists into the international scientific community is illustrated by the fact that all but one reported membership of international evaluation boards or committees, principally as members of the editorial boards of international journals.

It is unlikely that gender differences will affect the results of the present study. With the exception of Biomedic 3 who was 36 in 1980, the starting year for the analysis, the other three female scientists were all over 40 (Astronomer 2 was already 72), suggesting the absence of any significant effects due to gender during the 15 years of the study. The only possible effect could, perhaps, be attributed to accumulative disadvantage due to gender restraints on their earlier career development. All four had spent time abroad from 1980 to 1994, with the exception of Chemist 3 who had been abroad from 1977-8.

The fact that the group of UNAM scientists, selected on the basis of a high production of articles in SCI, should exhibit a wide spectrum of ages, would suggest that age is not an important variable in this study, at least with respect to total production. However, the possibility exists that age might affect other aspects of the individual research activities of this group of scientists, such as the number of visits made abroad.

In the present analysis of highly productive Mexican scientists it would be expected that these senior scientists are likely to have few superiors, as was apparent from the interviews . However, as pointed out by Franklin, asking the scientists themselves about their research environments, is likely to produce subjective views of group hierarchies. The fact that the European senior scientists that he interviewed purported to have few superiors does not mean that, from an objective point of view, there were few individuals in a position to direct the work of others (Franklin 1988). However it must be remembered that according to authors such as Dedijer, research in developing countries is, or was at the beginning of the 60s, essentially a pre-research culture lacking the institutional and motivational elements present in the scientifically advanced communities. In an advanced country the scientific community is large enough to permit differentiation with sufficient members in each field to permit complex interactions with each other whereas in developing countries scientists are relatively few in number (Dedijer 1963). Some of the scientists in the present study referred to this and other important differences between the structure and dynamics of the scientific communities of developing and industrialised countries. This situation might go a long way to explaining why in the present study different group structures and interactions were found even within some of the same disciplines.

Chapter 9

Bibliometric Profiles of the UNAM Scientists

9.1 Production of Papers

9.1 1 *Overall Production*

The 15 scientists produced a total of 797 papers from 1980-1994. Individual production ranged from 34 to 68 (from 2.3 to 4.5 papers per year) (Figure 9-1).

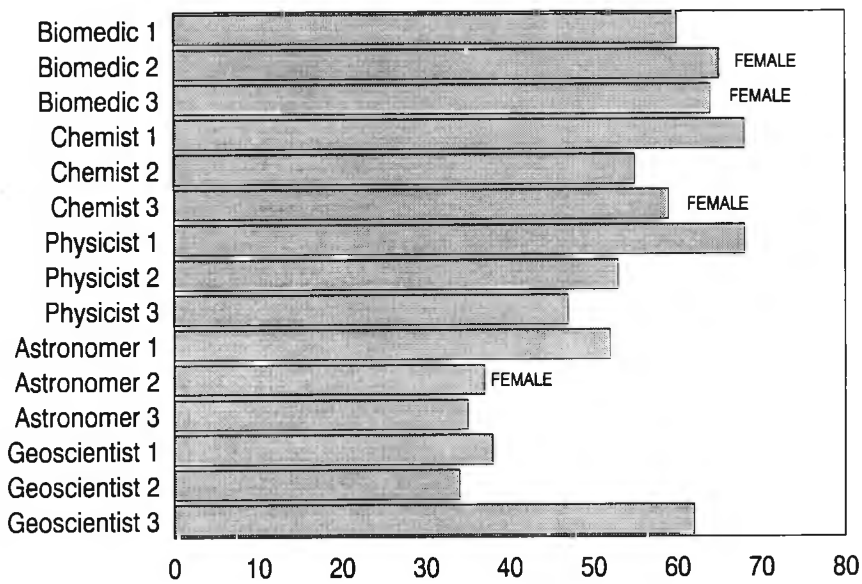


Figure 9-1. 1980-1994 production of papers of the 15 scientists

9.1.2 *Production and Gender*

The four female scientists published 37, 59, 64 and 65 papers, figures that are comparable with their male colleagues (Figure 9-1).

9.1.3 *Annual Production Levels*

Annual production levels increased from 1980 to 1987 followed by a sharp decline reaching in 1992 a comparable figure to 1980 (Figure 9-2). Production showed an upward trend in 1993 and 1994.

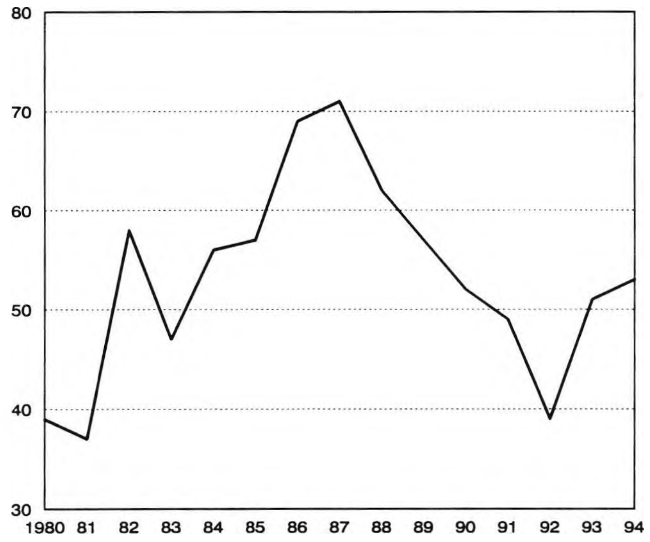


Figure 9-2. Annual production of papers of the 15 scientists

9.1.4 *Annual Production Levels of the 15 scientists compared with those of Mexican Science and World Science*

The decline in papers of the 15 scientists as a group from 1987 is not reflected in the trends of the total UNAM and Mexican productions (see Figure 7-1) nor in the Mexican production in any of the five general disciplines of the 15 scientists (Figure 9-3). Nor is this drop reflected in the global trends of the specific disciplines of the 15 scientist as registered by the SCISEARCH database (Figures 9-4 and 9-5). This indicates that the steep decline in production of the 15 scientists from 1987 to 1992 does not follow national or international trends.

9.1.5 *Production and Scientific Age*

The relationship between the years since the award of the PhD degree (scientific age) and total production of papers is seen in Figure 9-6. When applying a correlation coefficient analysis on the total data for the 15 scientists, $t=1.88$ and $r=0.46$ which is just significant or merely suggestive of a negative relationship between the two variables at 5% on a one-tailed test. The negative relationship is most obvious in the case of the two older scientists (Astronomer 2 and Geoscientist 2) but Astronomer 3 and Geoscientist 1 seem to be counterexamples.

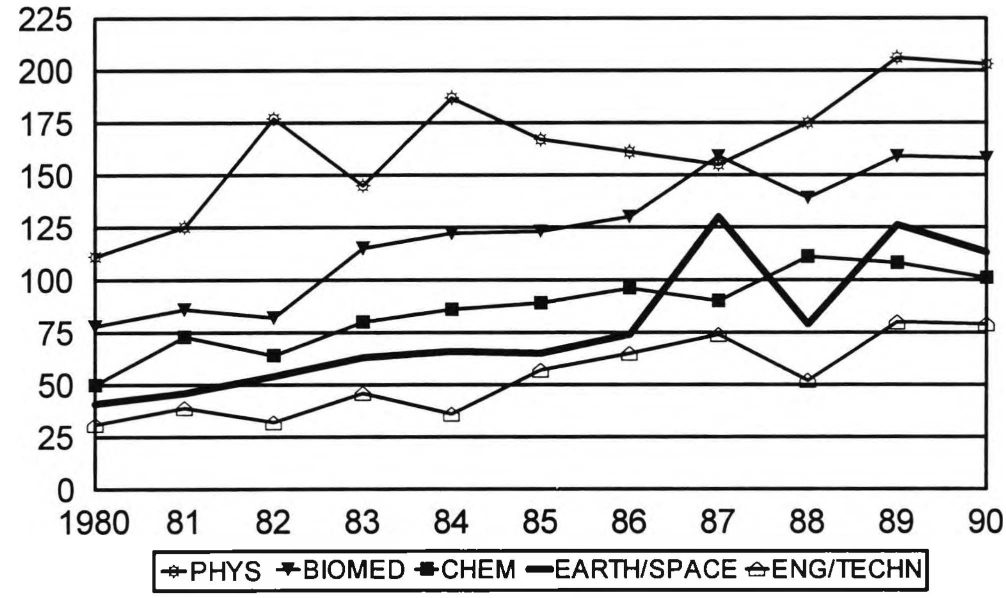


Figure 9-3. Trends in Mexican production of papers in the general disciplines of the 15 scientists

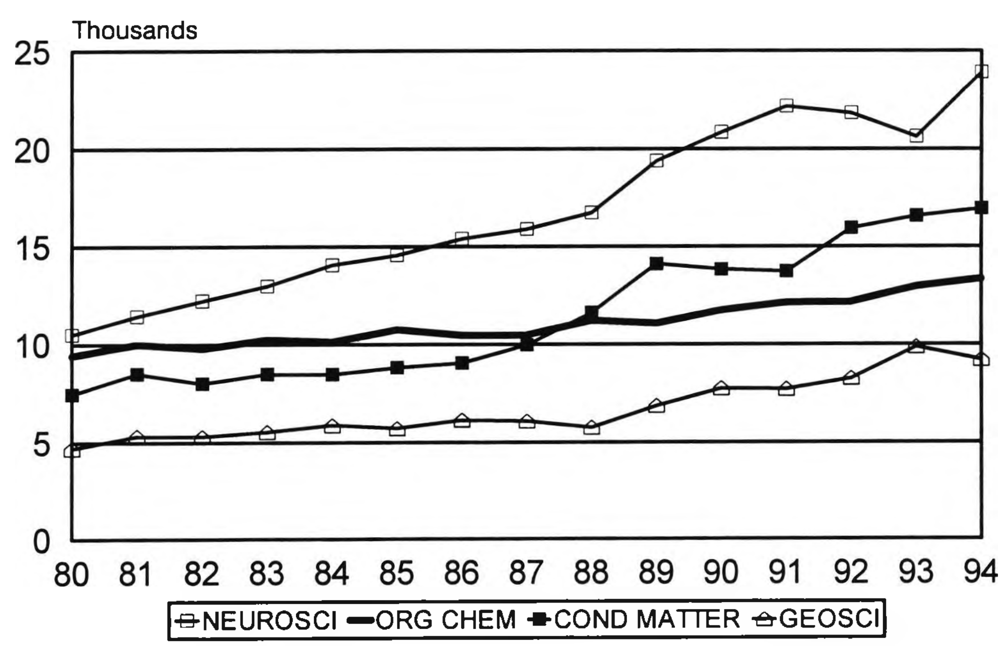


Figure 9-4. World trends in the annual production of papers in neurosciences, organic chemistry, condensed matter physics and geosciences (Source: SCISEARCH)

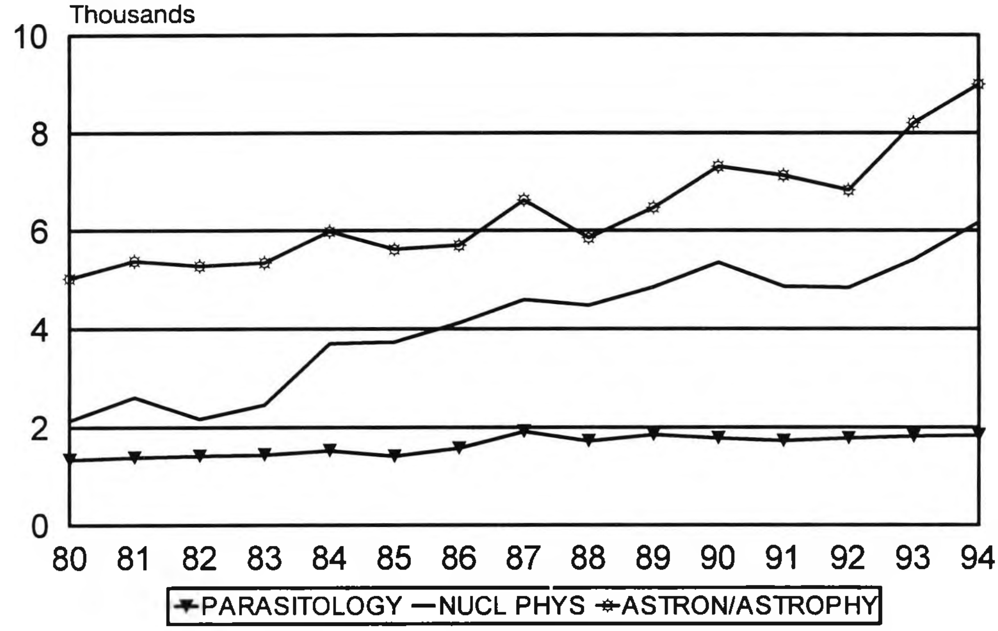


Figure 9-5. World trends in the annual production of papers in parasitology, nuclear physics, and astronomy and astrophysics (Source: SCISEARCH)

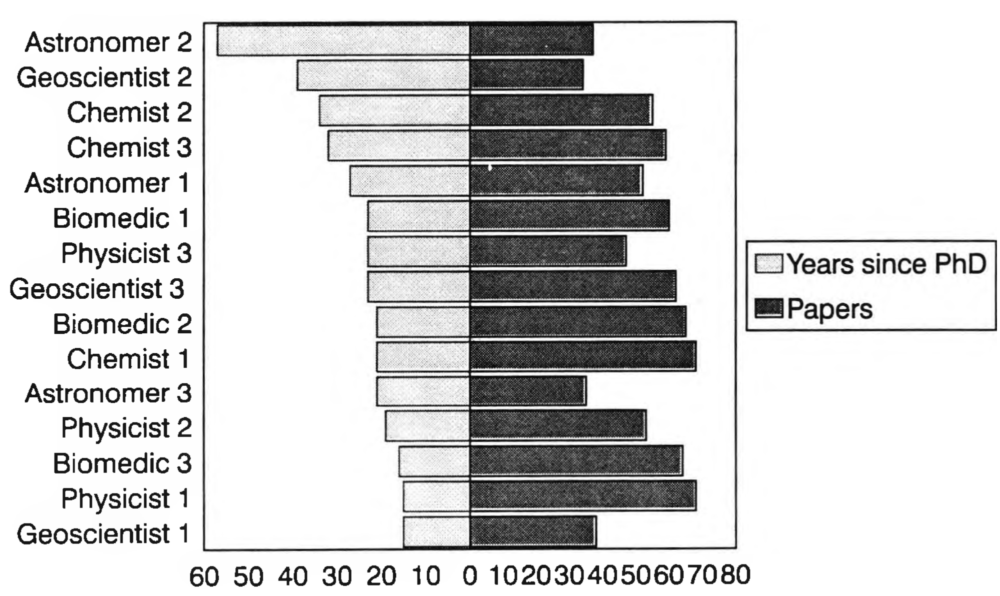


Figure 9-6. 1980-1994 papers and years since PhD in 1994 of the 15 scientists

Dividing the scientists into three groups according to scientific age (>25 years, from 19-23 years, and 15-16 years) and looking at their three year moving average of papers, the oldest group shows a steady increase in production up to 1986. Thereafter production begins a sharp decline to approximately two papers per year. Maximum levels reached were between four and five papers published annually per scientist (Figure 9-7). The middle age group shows a more consistent pattern in the production of papers over the 15 years studied (between three and four papers annually per scientist). The younger scientists show a marked rise in production from 1981 to1988 (maximum values of five to six papers), followed by a sharp decline with production returning to around three papers a year in 1993.

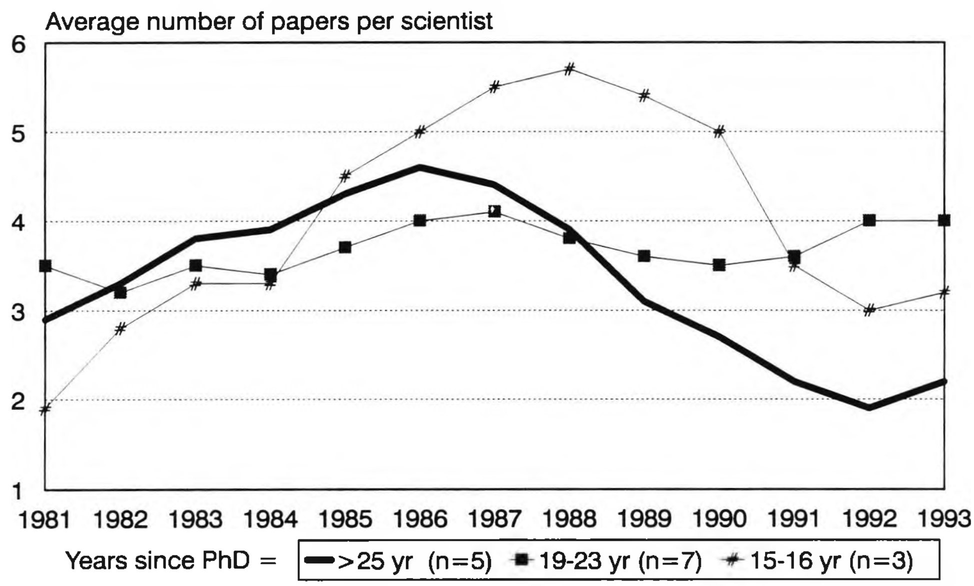
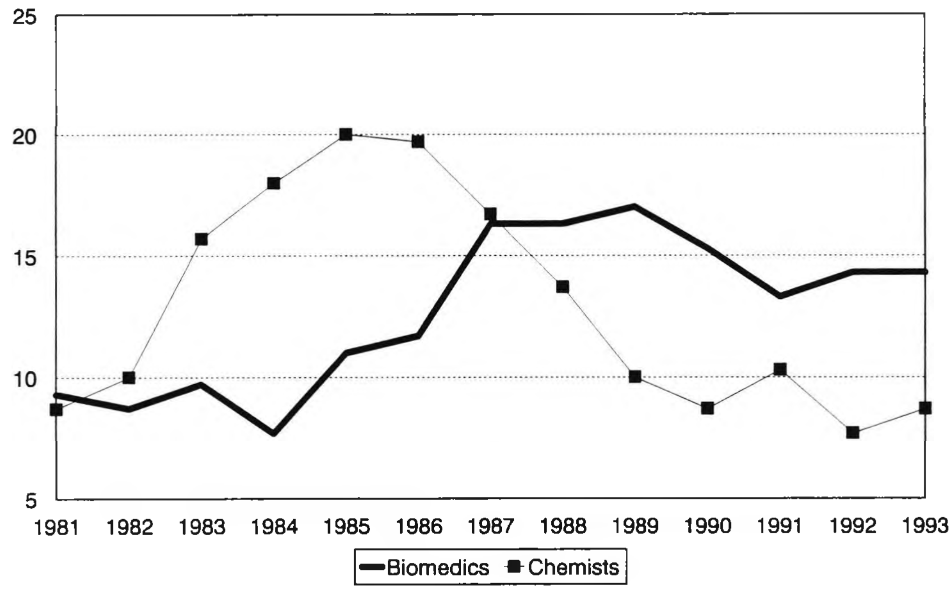


Figure 9-7. Annual production (3yr moving average) of papers and years since PhD

9.1.6 *Production and Disciplines*

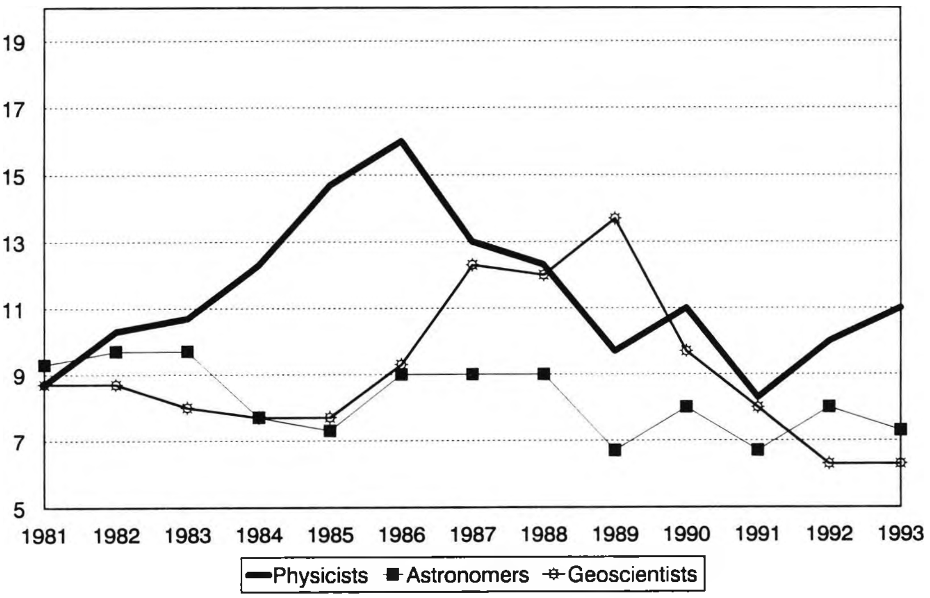
The group of three biomedical researchers had the highest total production of 189 papers, followed by the chemists with 182, the physicists with 168, the geoscientists with 134, and the astronomers with 124.

The annual production (expressed in terms of three year moving averages) of papers of all five groups of scientists peaked in the middle to late eighties (Figures 9-8 and 9-9). The astronomers had a earlier peak in production at the beginning of the eighties. The biomedical researchers were the only group whose publication counts did not thereafter return to lower levels of production similar, in most cases, to those seen at the beginning of the 80s.



Total production: Biomedics=189 Chemists=182

Figure 9-8. Annual production (3yr moving average) of papers by the biomedical scientists and the chemists



Total production: Physicists=168 Astronomers=124 Geoscientists=134

Figure 9-9. Annual production (3yr moving average) of papers by the physicists, astronomers, and geoscientists

9.1.7 *Comparison with Production Levels of other Mexican Scientists*

The rankings with respect to the 1980-1990 production of papers of the 15 UNAM scientists compared to their national colleagues working in the same fields are shown in Table 9-1. In all instances the 15 scientists occupied one of the top five places in the national rankings, with two of the biomedical scientists, one of the physicists, one of the astronomers and the three geoscientists being the most productive in the country. Biomedic 3, all three chemists and Physicist 2 were the most productive of the UNAM scientists while Physicist 3 occupied position number 4. All astronomers in the present sample were from the UNAM except one whose production was below the median value.

Table 9-1

Comparison between the production of 1980-1990 papers of the 15 scientists and other Mexican scientists

	RESEARCH FIELD	NO. OF PAPERS	MEDIAN	RANKING
Biomedic 1 Biomedic 2	Biology and Medicine/Neurophysiology	32 38	7.5	2-3/20 1/20
Biomedic 3	Parasitology	28	4.5	2/18
Chemist 1 Chemist 2 Chemist 3	Organic Chemistry	35 38 34	13	3/23 2/23 4/23
Physicist 1	Nuclear Physics	38	8	1/23
Physicist 2	Statistical Mechanics	28	11	4/19
Physicist 3	Physics of the Solid State	25	10	4/25
Astronomer 1 Astronomer 2 Astronomer 3	Astronomy/Astrophysics	27 18 21	10	1/19 5/19 3-4/19
Geoscientist 1	Civil Engineering	20	0	1/16
Geoscientist 2 Geoscentist 3	Seismology /Tectonics	19 32	3	2/23 1/23

9.1.8 *Comparison with Levels of International Papers of other Mexican Scientists*

The comparative patterns in international papers between the UNAM scientists and their national colleagues were less consistent than with respect to overall production levels (Table 9-2). All three biomedics, one physicist, one astronomer and two of the geoscientists were ranked in the top two positions in relation to production of international papers within their respective fields. Four of the 15 scientists (Chemist 1, Physicist 2, Astronomer 2 and Geoscientist 2) had levels equal to or below the median for all Mexican scientists in the present sample.

While all three chemists had been the most productive in the UNAM in the organic chemistry field, five other Mexican scientists had higher numbers of papers published in international co-authorship, three of which were from the UNAM and two from other institutions.

Table 9-2

Comparison between the 1980-1990 levels of international coauthorship of the 15 scientists and other Mexican scientists

	RESEARCH FIELD	NO. OF INT COAUTHORSHIPS	MEDIAN	RANKING
Biomedic 1 Biomedic 2	Biology and Medicine/Neurophysiology	4 8	1	2/20 1/20
Biomedic 3	Parasitology	7	0	1/18
Chemist 1 Chemist 2 Chemist 3	Organic Chemistry	0 4 4	0	12-23/23 6-7/23 6-7/23
Physicist 1	Nuclear Physics	16	3	2/23
Physicist 2	Statistical Mechanics	1	2	11/19
Physicist 3	Physics of the Solid State	9	1	3-4/25
Astronomer 1 Astronomer 2 Astronomer 3	Astronomy/Astrophysics	6 3 11	4	4-8/19 12/19 1/19
Geoscientist 1	Civil Engineering	6	0	1/16
Geoscientist 2 Geoscentist 3	Seismology /Tectonics	1 15	1	12-14/23 1/23

9.1.9 *Discussion*

The annual production of papers of the 15 scientists is well above the national average for Mexican researchers which is reported to be 0.33 (José Yacamán 1994). However, this figure includes scientists from all fields of knowledge and presumably covers the approximately 6,000 members of the National System of Researchers.

An annual production of two articles a year on average was found for 28 researchers from the Institute of Physics at the UNAM (Liberman, Seligman et al. 1991). Between 10 and 15% (3-4 scientists) of these physicists published between three and four articles annually; a figure much more in keeping with the figure of 2.3 to 4.5 papers per year found in the present study. According to Liberman, this group constitutes the academic spearhead of the institute. The two physicists in the present study who work at this particular institute produced 3.5 and 3.1 papers per year, respectively which puts them in the academic spearhead group described by Liberman and co-authors.

A general falloff in the number of papers published annually starting in or during the late eighties seen in the group as a whole (Figure 9-2), and with respect to the different disciplinary groups (Figures 9-8 and 9-9) is not reflected by the trends in production of other Mexican scientists in the same general fields (Figure 9-3) or by global trends (Figures 9-4 and 9-5). There are two possible explanations for the drop in the production of the group of 15 scientists. One is related to the implementation in 1984 of the National System of Researchers. All 15 scientists were members of the SNI from its creation and would have been re-evaluated three or four years later, depending upon the category of membership assigned to them. This implied a need for high production of papers from 1984 to 1987 or from 1984 to 1988. On the other hand, all 15 scientists were well established before the implementation of the programme and, as previously mentioned, were assigned to the highest category from the first evaluation.

The second explanation which is perhaps more convincing, is that the decline in production is an artifact of the sampling technique. The 15 scientists were selected on the basis of the numbers of papers published between 1985 and 1989. This five-year span could well have coincided with a period of high productivity which may have been difficult to sustain in the years immediately following this period. The yearly production of papers by individual scientists or by groups of scientists can suffer considerable variations. As Fox pointed out, it is difficult to separate the performance of individual scientists from their social and organisational contexts (Fox 1991). In DCs institutional, political and economic conditions are less stable than in industrialised countries making it more difficult for scientists to maintain a certain level of publication. In their study on Brazilian scientists Fonseca and co-workers found that scientists give more weight to human factors than material conditions as the main driving force behind scientific productivity. They considered this finding surprising in a country where material conditions for research are less than ideal (Fonseca , Velloso et al. 1997).

With respect to her sample of physicists, Liberman also mentions that the few older scientists did not maintain their publication rhythm for more than 25 years (Liberman, Seligman et al. 1991), suggesting that production declines with age. In the present study the five scientists whose scientific age in 1994 (years since awarding of the PhD) was >25 years showed a decline in production from 1987-1992 that began to recover only slightly from 1993 to 1994. While this group had the highest production on average for the first eight years of the study, from 1988 onwards, annual production levels were well below the other two age groups (Figure 9-7). From these two experiences on limited samples of Mexican scientists, it does seem possible that a negative effect of age on scientific productivity could occur after 20 years or so in the research field. Decreased international contact and in the number of visits abroad could possibly explain the decline in production of papers with age seen in the present study.

In spite of numerous studies carried out on the relationship between age and productivity in scientific research, there seems to be little consensus on this point. Some authors suggest that this is due to field differences. Older scientists, they argue, are less likely to be able to keep up in disciplines with rapid technology progress (either a technological field itself or one where technology plays an important role) or where concepts are rapidly changing. Their decreased production is due, not to a decline in their intellectual abilities and skills, but rather because of obsolete ideas and training (Kyvik 1990; Levin and Stephan 1991).

In fields where knowledge production occurs at a slower pace, such as the social sciences and the humanities, faculty members may be productive throughout their careers. Further support is provided for this explanation by differences between the various natural and medical science disciplines. Older faculty members in physics are less productive than older researchers in mathematics, and older scientists in biomedicine are less productive than their counterparts in social medicine (Kyvik 1990). The five oldest scientists in the present study were two astronomers, two chemists and one geoscientist. According to Kyvik's results, production in both chemistry and geosciences declined with age. Although astronomers were not studied by Kyvik, the analogy with the physicists and the fact that astronomy is highly dependent on instrumentation, suggests that in this field also, productivity is likely to decline with age.

The four female scientists analysed in the present study had overall production rates comparable with their male colleagues. Taking into consideration that the scientists were chosen according to their production levels in the mainstream scientific literature irrespective of the gender, the result is not suprising. Two of the female scientists were among the five oldest scientists and the remaining two were in the productive biomedic group. It is thought unlikely that gender will have had any effect on the production results of the present study.

Results of the comparative production levels of the 15 scientists with their national peers with similar periods of research activity confirm that this group are indeed among the most highly productive scientists in the country in their respective fields.

The low median levels of production of papers with respect to the two fields where the three geoscientists were working could be explained by the applied nature of the research of these scientists. Especially in civil engineering results are much more likely to be reported in technical or institutional reports (Rosas Gutiérrez and Escalante Vargas 1995). The fact that the three geoscientists were chosen for the present study on the strength of their mainstream production of research papers, accounts for their dominant position in any ranking based on this variable.

In contrast, not all the 15 UNAM scientists were among those scientists showing the highest levels of international co-authorships, suggesting that research performance should not be explained solely in terms of this activity. Of the four scientists showing median or below median values for their levels of international papers, two were the oldest members of the group of 15 UNAM scientists (Astronomer 2 and Geoscientist 2) who also had the lowest production of papers found in the group of 15 scientists. Another was Chemist 1 who had spent three sabbaticals between 1978 and 1989 at the same US university and the fourth was Physicist 2 who had taken two sabbaticals abroad between 1979 and 1986 with little resulting co-authorship, suggesting high international activity. However, it should be remembered that the database used to analyse the co-authorships did not include papers written by Mexican scientists reporting institutional affiliations outside Mexico.

9.2 Publishing Patterns and Coauthorships

9.2.1 *Document Types*

The scientific article was the most frequently used document type occurring in 80.5% of the total production of papers (9-10)). Notes showed lesser importance (13.7% of the total) with reviews and letters showing the same level of occurrence (2.9%). The biomedical researchers and the chemists showed a greater tendency to publish notes than the other groups of scientists, especially in documents without foreign co-authorship. The group of geoscientists published a greater percentage of their national papers as letters than did the other groups. However, this was due to Geoscientist 2 who published 29.4% of his papers as letters, contributing to 43.5% of the total production of letters of the 15 scientists[1]. Greater use was made of articles in international papers (88.8% of the total) than in national papers (77.2%), with all other document types showing lower levels of importance in international as compared to national papers.

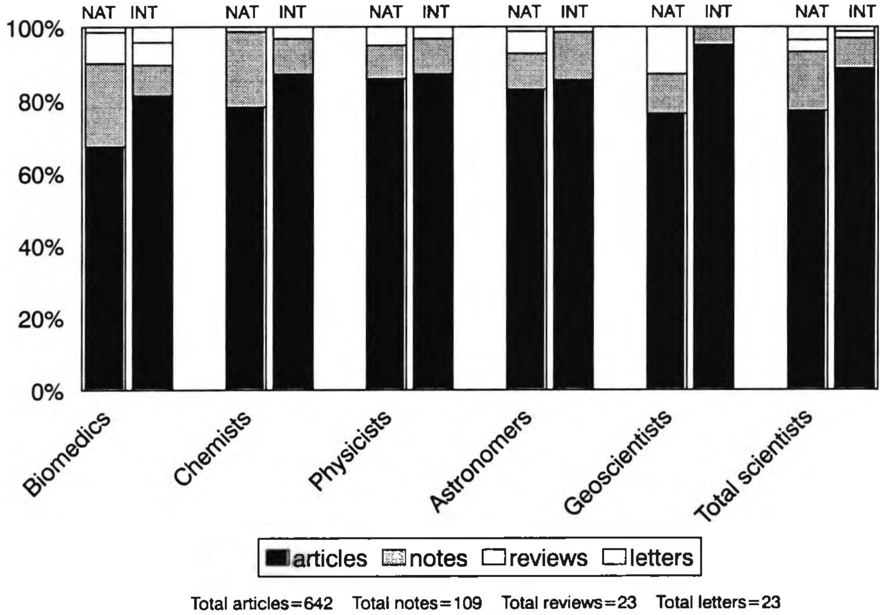


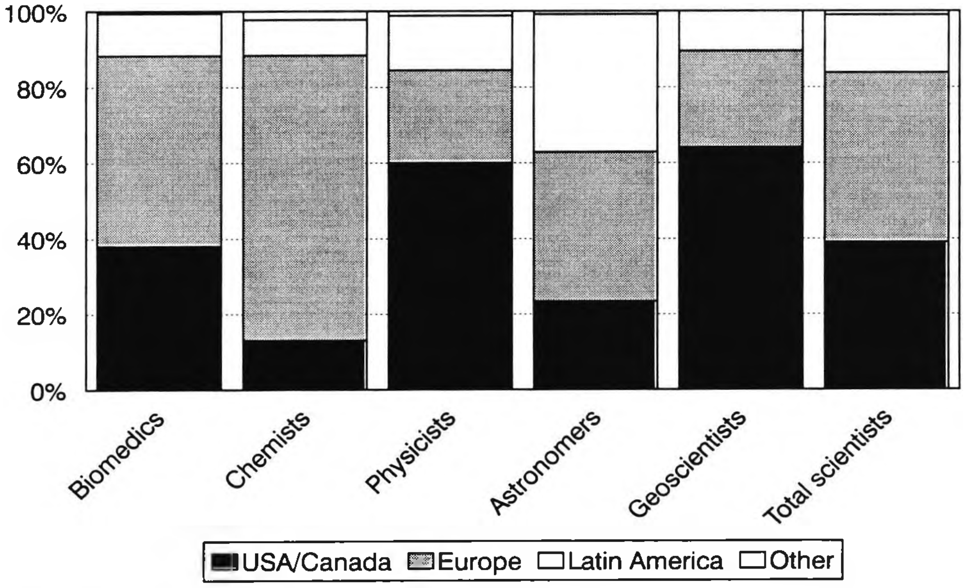
Figure 9-10. Document types in national and international co-authored papers

[1] When I asked Geoscientist 2 during the interview why he had published so many letters, he explained that he used to be more argumentative which he believes is not very productive. Now he says he has "settled down".

9.2.2 *Publication in Journals from Different Regions*

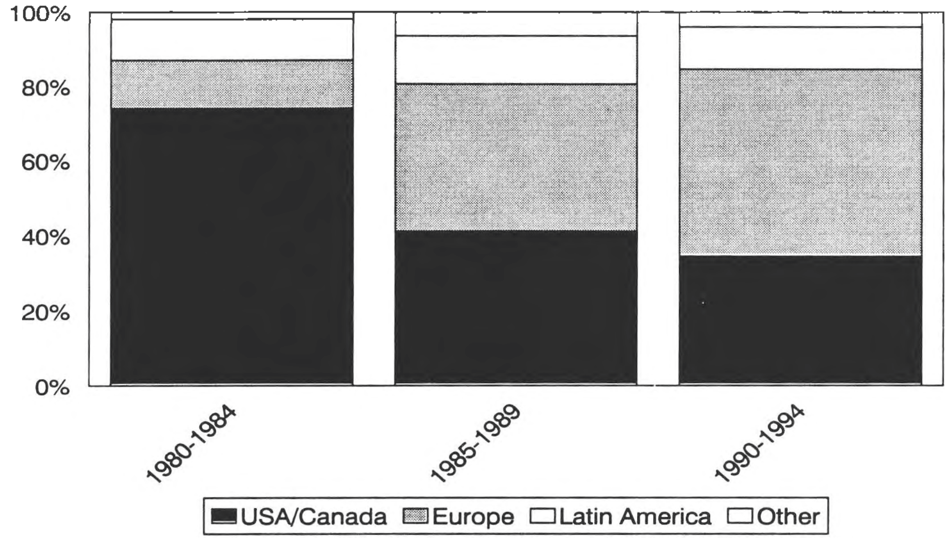
A greater number of papers were published in European than USA/Canadian journals (44.7% and 39.1%, respectively) (Figure 9-11). Approximately 15% of papers were included in Latin American titles. Three-quarters of the production of the chemists was published in European journals, principally the UK journal *Phytochemistry* where 30.2% of the total appeared. The physicists showed a 60.1% preference for USA or Canadian titles, 45.8% of total production was disseminated through the US Physical Review series. The astronomers published 36.2% of their papers in Latin American journals, 93.3% of which were in the *Revista Mexicana de Astronomla y Astrofísica*, a SCI journal, and the rest in *Revista Mexicana de Física* (a SCI journal from 1991 onwards). The biomedical researchers showed a more even distribution between USA/Canadian and European titles, with an 11.1% publication in Latin American titles. This group of scientists published in a far wider range of titles than other groups.

From 1980 through to 1994, there was an increase in the percentage of papers published in European journals at the expense of Latin American titles (Figure 9-12). The percentage of papers published in European titles increased from 35.0% in the five-year period from 1980-84, to 45.3% from 1985-89, to 53.3% from 1990-94. The percentage of papers published in USA or Canadian journals suffered only small variations.



Total papers in journals from USA/Canada=312, Europe=356, Latin America=121, Others=8

Figure 9-11. Percentage of papers published in journals from different regions of the world



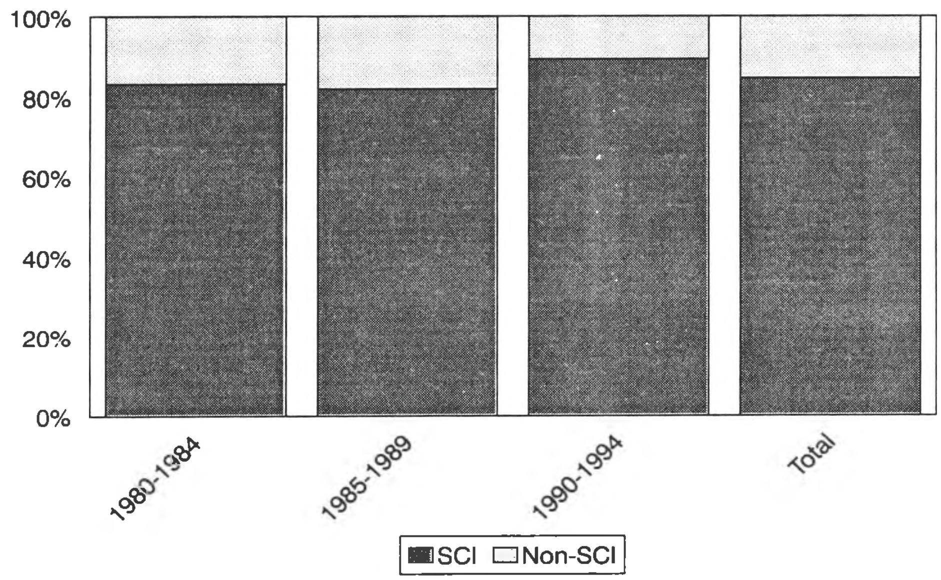
Total papers 1980-84=54, 1985-89=109, 1990-94=123

Figure 9-12. Changes in the percentage of papers in journals from different regions of the world

9.2.3 *Publication in Journals covered by **Science Citation Index***

Approximately 85% of the total of 797 research papers reported for 1980-1994 were published in SCI journals (Figure 9-13). The percentage of papers published in non-SCI journals decreased from 16.9% in 1980-84, to 10.7% in 1990-94.

When taking into consideration only those papers written in international collaboration, the percentage of papers in SCI journals increases to 89.6% compared to 82.7% for papers without foreign collaboration (Figure 9-14). In all groups there was a higher percentage of non-SCI journals with respect to papers involving only national institutions.



Total papers 1980-84=237, 1985-89=316, 1990-94=244

Figure 9-13. Changes in the percentage of papers in SCI and non-SCI journals

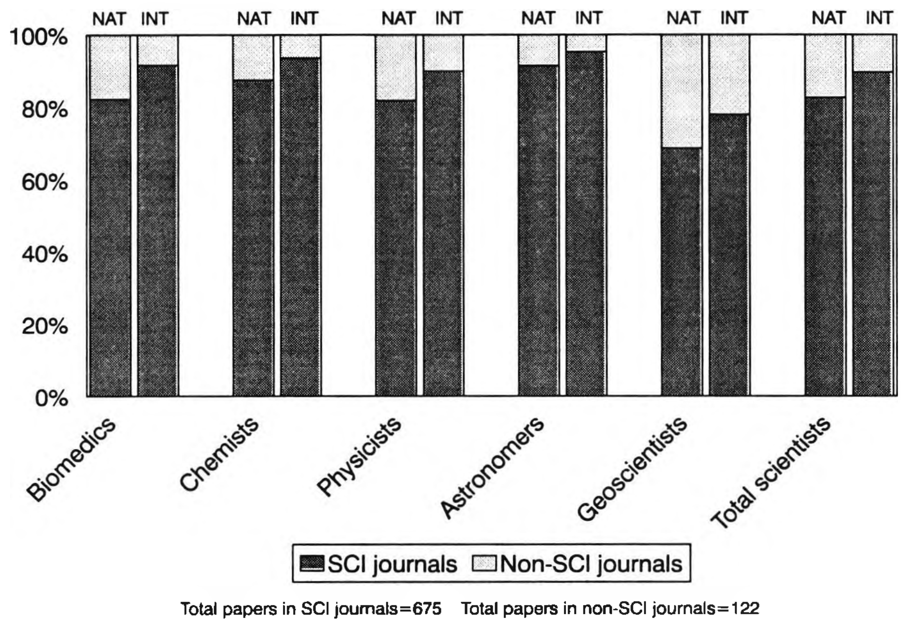


Figure 9-14. Percentage of papers published in journals indexed in **Science Citation Index**

The geoscientists were the group to make most use of non-SCI journals (28.4% of total papers). This is partly due to publication in the specialist journals, *Earthquake Spectra*, and *Soil Dynamics and Earthquake Engineering*, published in the US and UK, respectively, neither of which is covered by the SCI.

Detailed analysis of the non-SCI journals used by the UNAM researchers showed that almost 50% of titles were Latin American, with 13% more European titles being used than those published in US/Canada (Table 9-3). Almost 80% of the Latin American titles were Mexican. With respect to the number of papers published in non-SCI journals from different regions, over 60% were published in Latin American titles, with almost 90% of these appearing in Mexican journals.

Table 9-3

Regional distribution of non-SCI journals and papers

	TOTAL	USA/CANADA	EUROPE	LATINAMERICA	OTHER
Journals	69	12 (17.4%)	21 (30.4%)	34 (49.3%)*	2 (2.9%)
Papers	122	20 (16.4%)	26 (21.3%)	74 (60.7%)**	2 (1.6%)

* 27 Mexican journals (79.4% of LA titles)
** 66 papers in Mexican journals (89.2% of papers in LA titles)

When looking only at internationally co-authored papers, the percentage of Latin American journals decreased to under 40% (Table 9-4). The same number of papers in international collaboration was published in non-SCI USA/Canadian journals, as in non-SCI European journals. The number of institutional collaborations from these regions was also found to be the same.

Table 9-4

Regional distribution of internationally co-authored studies in non-SCI journals and papers

	TOTAL	USA/CANADA	EUROPE	LATINAMERICA	OTHER
Journals	18	4 (22.2%)	6 (33.3%)	7 (38.9%) *	1 (5.6%)
Papers	24	6 (25.0%)	6 (25.0%)	11 (45.8%) **	1 (4.2%)
Collaborations	27	9 (33.3%)	9 (33.3%)	8 (29.6%)	1 (3.7%)

* 4 Mexican journals (57.1% of LA titles)
** 7 papers in Mexican journals (63.6%) of papers in LA titles)

There was a slightly higher chance of papers published in international collaboration being published in journals from the region where the foreign institute is located. For example, 48.4% of papers published with US or Canadian institutions were published in USA/Canadian titles, as opposed to 43.8% in European journals. In the case of European collaboration, the corresponding figures were 50% for European journals and 42% for USA/Canadian titles. Overall 45.6% of internationally co-authored papers were published in journals edited within the regions where the collaborating institutions were located.

9.2.4 *Number of Authors per Paper*

Sixty-eight papers had only one author equal to 8.5% of the total. Eight of the 15 scientists published between 0 and 2 papers without co-authors, two scientists between 3 and 5, and four scientists between 6 and 10. Geoscientist 2 had an exceptionally high level of one-author papers compared to the rest of the group with a total of 22, representing 65% of his total production. Astronomer 2 also showed a much higher percentage (27%) of one-author papers than the other 13 scientists who averaged 5.0%.

There was a significant increase in the number of authors per paper overall, from 3.1 in the period 1980-84, to 4.0 between 1990 and 1994 (Figure 9-15). The chemists and the astronomers showed the greatest number of authors per paper, 4.6 in both groups in the latter period. The astronomers showed the greatest increase over the periods studied, from 2.5 to 4.6 authors per paper. With the exception of the astronomers in the most recent of the five-year periods, the biomedical scientists and the chemists displayed much higher levels of co-authorship than the other three groups.

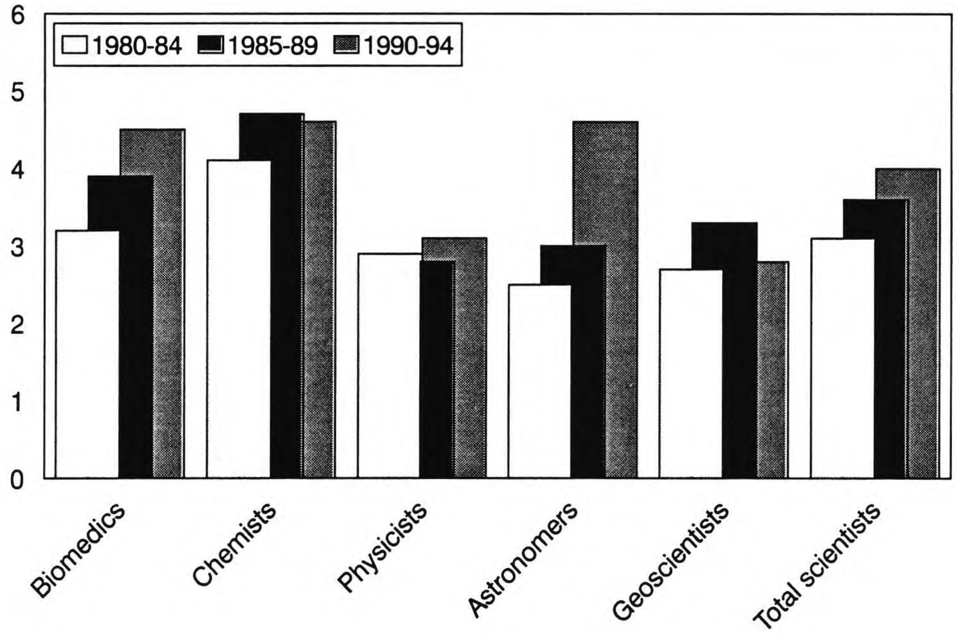


Figure 9-15. Changes in the number of authors per paper of the 15 scientists over five-year periods

When comparing these patterns with other Mexican scientists in the same general disciplines of the 15 UNAM scientists for the years 1980, 1985 and 1990, increases are also apparent in the number of authors per paper from 1980 to 1990 (Figure 9-16). However the sharp increase in the number of authors per paper in the period from 1990-1994 seen for the three astronomers in the present study is not reflected in the figure for all Mexican papers in earth and space sciences in 1990. The largest numbers of authors per paper were again seen in biomedicine and chemistry.

The 1980-1994 papers of the 15 scientists co-authored internationally had a larger number of authors per paper than those published with no foreign collaboration (Figure 9-17). The international papers published by the astronomers and the physicists had the highest and lowest numbers of authors per paper (5.2 and 3.4, respectively) while the chemists and the biomedical scientists showed the highest level of co-authorships with respect to papers written with national colleagues (4.4 and 3.8, respectively).

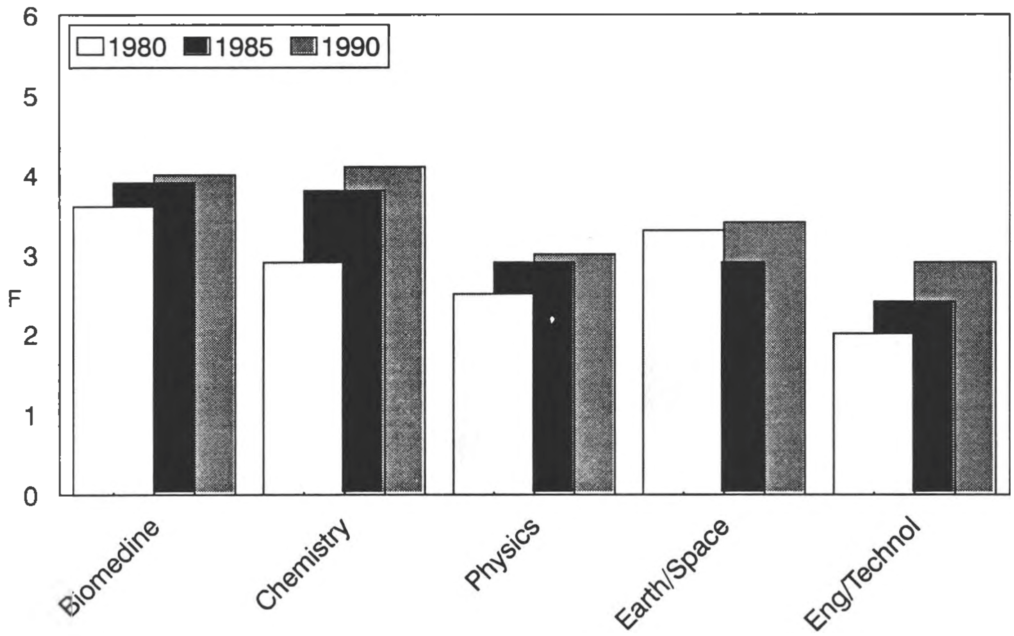


Figure 9-16. Changes in the number of authors per Mexican paper in the general disciplines of the 15 scientists from 1980-1990

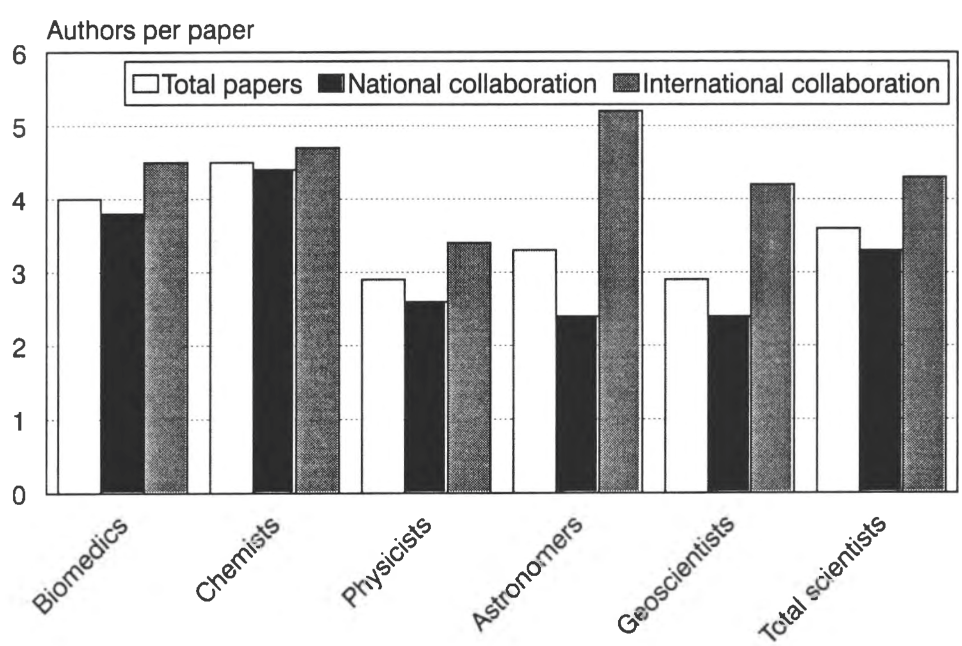


Figure 9-17. Number of authors per paper of the 15 scientists in national and international collaboration

Higher numbers of authors per paper in those written with foreign colleagues were also seen in respect to the 1980-1990 papers of their national colleagues in the same general disciplines (Figure 9-18). Papers in biomedicine and chemistry showed the greatest number of authors per paper both with respect to papers written with national colleagues and those co-authored internationally. Papers in the earth and space sciences also showed a high number of authors per paper in international collaboration.

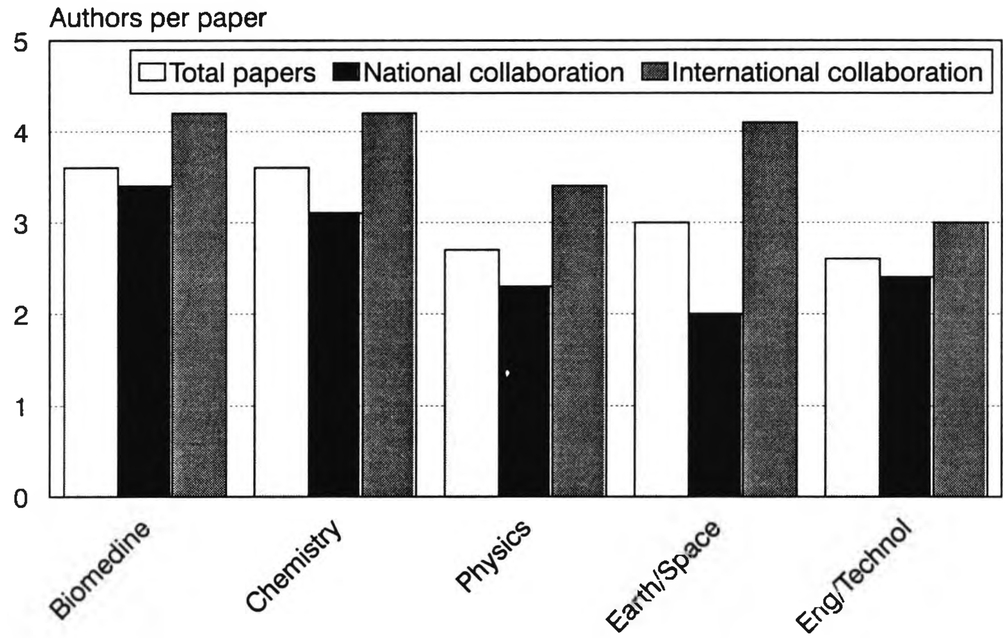


Figure 9-18. Number of authors per 1980-1990 Mexican paper in national and international collaboration in the general disciplines of the 15 scientists

9.2.5 *Frequency of Co-authorship with Individual Co-authors*

Almost 45% of all the 15 scientists' co-authors were from their own institutions while approximately another quarter were from foreign institutions outside Latin America (Table 9-5).

The presence of a large number of institutional co-authors in the case of the Biomedics and more particularly in the case of the Chemists is apparent from the analysis. Physicist 2 and Geoscientist 3 showed frequent co-authorship with a group of colleagues from other UNAM institutions in relation to their total numbers of co-authors. Biomedics 1 and 3, and Physicist 3 had a significant number of individual co-authors from other national institutions while almost 30% of Biomedic 2's co-authorships were with foreign (non Latin American) colleagues. A lesser internationalisation of their research activity with respect to the frequency of co-authorship (as a percentage of total co-authorship) with non Latin American scientists is apparent for Biomedics 1 and 3, the three chemists and Physicist 2. Only Physicist 3 and Geoscientist 3 tended to co-author to any extent with Latin American scientists.

The three physicists and the three geoscientists showed different patterns of collaboration while the astronomers showed similar tendencies, co-authorships being distributed between the internal and foreign levels. The large number of international partners for Physicist 1 and Geoscientist 3 is consistent with results found in other parts of the thesis. Astronomer 3 also showed an important number of co-authors both at institutional and foreign levels.

Table 9-5

Number of individual co-authors [1] of the 15 scientists at different levels from 1980-1989

	Level 1- own institute	Level 2- other UNAM	Level 3 – other national	Level 4 - other LA	Level 5- other foreign	Total
Biomedic 1	25	2	16	1	6	50
Biomedic 2	19	1	3	0	9	32
Biomedic 3	22	6	32	1	11	72
3 X BIOMEDICS	**66**	**9**	**51**	**2**	**26**	**154**
Chemist 1	25	0	5	0	5	35
Chemist 2	36	10	7	0	6	59
Chemist 3	34	1	3	0	4	42
3 X CHEMISTS	**95**	**11**	**15**	**0**	**15**	**136**
Physicist 1	5	6	1	1	25	38
Physicist 2	10	5	3	0	1	19
Physicist 3	6	0	9	5	9	29
3 X PHYSICISTS	**21**	**11**	**13**	**6**	**35**	**86**
Astronomer 1	9	0	1	2	11	23
Astronomer 2	7	0	0	0	4	11
Astronomer 3	19	0	0	3	19	41
3 X ASTRONOMERS	**35**	**0**	**1**	**5**	**34**	**75**
Geoscientist 1	7	5	3	0	9	24
Geoscientist 2	7	0	0	0	6	13
Geoscientist 3	14	23	0	5	22	64
3 X GEOSCIENTISTS	**28**	**28**	**3**	**5**	**37**	**101**
ALL 15 SCIENTISTS	**245**	**59**	**83**	**18**	**85**	**552**

[1] No adjustment was made for individual co-authors who might have published with more than one of the 15 scientists

When looking at the frequency with which the 15 scientists co-authored with individual scientists, the most consistent in her choice of co-authors was Chemist 3 with > 5 co-authored papers with 23% of her collaborators (Figure 9-19). As a group the chemists were the most consistent with respect to the presence of certain co-authors.

All three chemists, all three physicists and Astronomer 1 showed the presence of a strong partnership with at least one other member of their own institutions with >15 co-authored publications in the ten-year period from 1980-1989. The three biomedics showed a slightly lower level of collaboration with members of their own UNAM institutions while Chemist 3 and Geoscientist 3 showed a important link with a member of another UNAM institution. The distribution of the total number of co-authors with 5-9 co-authorships was spread over the different levels of collaboration with Biomedic 1 and Chemist 2 showing significant co-authorship with a scientist from other national institutions, Physicist 3 with a Latin American scientist, and Chemist 1 and Physicist 1 with members of a foreign institution where they had spent sabbaticals.

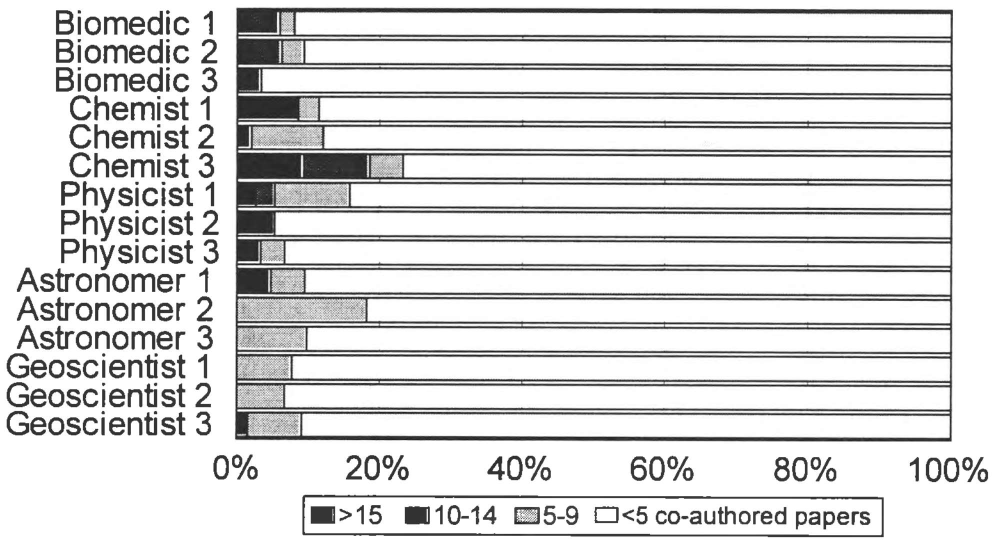


Figure 9-19. Frequency of 1980-1989 co-authorship of the 15 scientists with individual co-authors

9.2.6 *Author Position*

There was a slightly higher tendency for the UNAM scientists to be the co-author in papers written with foreign colleagues than with respect to national papers (45.9% and 35.9% of papers, respectively) (Figure 9-20). Only in the case of the astronomers or the geoscientists was there a notable difference in author position between the two groups of papers. Astronomers published 69.5% of their national and 28.6% of their international papers as first or sole authors. The corresponding figures for the geoscientists were 62.4% and 39.0%. The chemists were the only group where a greater tendency was found to publish as first author in international collaboration than with respect to national papers. In the biomedical group no differences were found.

Looking at the frequency with which the authors' names were found to be in alphabetical or non-alphabetical order in the 15 scientists' papers, shows little difference between those papers where only Mexican institutions were involved and those reporting foreign collaboration (Table 9-6). In both cases around 80% of papers had the authors' names registered in non-alphabetical order. The biomedics and the chemists showed a larger percentage of papers in non-alphabetical order, particularly with regard to national papers, probably due to the greater number of authors per paper in these fields (Figure 9-17). Seventy-one percent of national papers with author names in alphabetical order had only two authors and 34% of internationally co-authored papers. The fact that papers with foreign collaboration tended to have a greater number of authors per paper (Figure 9-17), might suggest that the authors of papers with foreign colleagues are more likely to be listed in alphabetical order than those involving only national institutions. However in both cases the overall tendency is for authors to be listed in non-alphabeical order.

The results for the individual scientists will be affected by the position in the alphabet of the first letter of their surnames and that of their most frequent collaborators. In the present study, five of the 15 scientists had their surnames in the first quarter of the alphabet, one in the second and the remaining nine in the third quarter. Only in case of the chemists were all three surnames in same quarter of the alphabet, in this case in the third quarter. However, only 13% of their total papers had only two authors

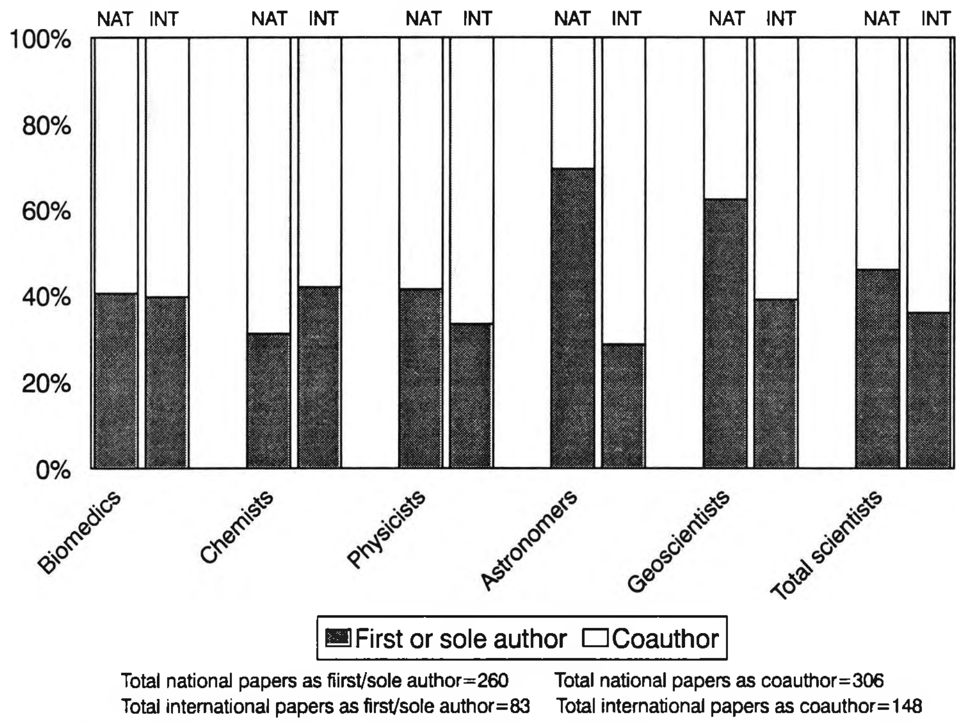


Figure 9-20. Author position in national and international papers

Table 9-6

Percentage of nationally and internationally co-authored papers with names in alphabetical and non- alphabetical order

	National		International	
	ABC	Non-ABC	ABC	Non-ABC
BIOMEDICS	9.2%	90.8%	14.6%	85.4%
CHEMISTS	7.9%	92.1%	6.5%	93.5%
PHYSICISTS	40.0%	60.0%	23.0%	77.0%
ASTRONOMERS	35.4%	64.6%	24.3%	75.7%
GEOSCIENTISTS	14.9%	73.1%	9.5%	90.5%
ALL 15 SCIENTISTS	**20.0%**	**80.0%**	**16.7%**	**83.3%**

9.2.7 *Discussion*

Even though the scientists analysed in the present study published predominantly in SCI journals, a significant percentage of research papers were published in non-SCI journals. The fact that almost 40% of the non-SCI journals were domestic titles in which exactly half of the non-SCI papers were published, suggests a commitment on behalf of these elite scientists to disseminate at least some of their results at local level. Nonetheless, the percentage of papers published in non-SCI journals decreased over the 15 years studied. A contributing factor could be the creation in 1984 by the Mexican government of a national system of researchers which entitles participating scientists to an income additional to their institutional salary (Malo and Rojo 1996), and where mainstream publication is one of the most important evaluation criteria. A steady increase in the number of SCI publications by authors from Venezuela has been attributed to the implementation of a similar incentives programme in this country (Pericchi 1996).

Many authors from DCs have stressed the importance for the development of science in their countries, of adequate coverage of their journals by the SCI and other ISI services. With regard to Latin America, only 49 journals from this region were covered in 1994 by the ISI database which contains approximately 7,000 titles in all knowledge areas.(Krauskopf and Vera 1995a; Krauskopf and Vera 1995b). Only 12 of these titles are published in Mexico. As mentioned earlier only two Mexican scientific journals are currently covered by the SCI; the *Revista Mexicana de Astronomía y Astrofísica*, and *the Revista Mexicana de Física*, both of which were used by all scientists in these fields in the present study. The Mexican medical journals, *Archivos de Investigación Médica* which was covered until the mid 90s, and the *Revista de Investigación Clínica* covered until 1986, had few articles published by the sample of biomedics.

As previously suggested by Nora Narváez-Berthelmot, papers published by Latin American scientists in co-authorship with colleagues from other countries are published predominantly in SCI journals, increasing their visibility at global level (Narvaéz-Berthelemot 1995a). The present results indicate that the papers co-authored with institutions from abroad are more likely to be published in SCI journals than those not involving international co-authorship, even in the case of Mexican scientists with an important production of papers in the mainstream literature involving only national institutions.

In his study on the community of science in Europe, Franklin refers to the central position occupied by the US which is seen in the virtually unanimous first place given by respondents from different European countries to American publications both as sources of information and as vehicles for the publication of results. European journals occupied second place (Franklin 1988). Considering the central position of US science and the geographical proximity of Mexico with the rest of North America, it was, perhaps at first sight, surprising to find more papers published in European journals than those from the USA and Canada. However, on examining the list of journals by country, covered by the 1994 *Science Citation*

Index [1], I found that more European titles were included than those published in the USA and Canada, 54.1% and 40.3% of the total, respectively [2]. However, analysis of the relationship between region of co-authorship and the region publishing the journal, suggests that internationally co-authored research was almost as likely to be published in journals from outside the region where the foreign partners are located as they were to be picked up by publishing houses from the same region. This suggest that considerations concerned with reaching the right audience are at least equally as strong as the possible concerns of the foreign partners of publishing in journals edited in their own regions (Russell 1997).

Nonetheless, European journals, defined in both Franklin's and in the present study as those published in one of the countries of European continent, are not necessarily representative of European science. This is especially true of those titles published in English which also attract contributions from other geographical areas. Also scientists from European countries, as is clear from Franklin's study, often publish in US journals. Such is the internationalisation of science that the presence of a strong journal publishing industry in certain European countries, such as Switzerland or Holland, is not in keeping with their relative positions in the world scientific order. Many European journals, therefore, have editors from the US. Members of editorial boards are chosen for their expertise and trajectory in their particular fields, and not necessarily for considerations of their country of origin or residence (Russell 1997).

Results from the present study on the frequency of co-authorship of the 15 scientists showed the importance of internal collaborations with almost half of the total number of co-authors affiliated to their own institutes within the UNAM. Frequent co-authorship (as a percentage of total co-authorship) with these internal colleagues was particularly notable with respect to the chemists, the physicists and Astronomer 1 (Figure 9-19) suggesting the presence of stable internal groups or at least, the presence of a continued collaboration or collaborations at this level. The large number of one-off collaborations with respect to all 15 scientists can be explained partially by the presence of students in the papers resulting from their thesis projects. All 15 reported at least one graduate student as part of their presence group structure (see Table 8-3).

When comparing these bibliometric results with the information on their research group structures obtained from the scientists themselves (section 8.5.2) certain similarities are apparent. For instance, the presence of important internal collaborators in the case of the chemists coincides with the fact that their groups are characterised by sustained collaborations of at least some of their members, The physicists when interviewed also alluded to ongoing collaborations with members of their own institutions. Astronomer 1 mentioned his continued collaboration with his wife. The fact that the group of biomedics also

[1] Institute for Scientific Information (1994) Science Citation Index (1994) . Source Publications arranged by Country of Origin.. Philadelphia, p 138-150.

[2] Increasing collaboration with European countries reported for these 15 scientists (see results in section 9.4.2 of this thesis) could have contributed to a preference for publication in European journals.

had a large number of internal co-authors and also group members particularly in the case of Biomedics 2 and 3, could imply lower co-authorship frequencies with any one collaborator. The fact that Physicist 2 has a group member from the Institute of Chemistry (see section 8.5.2) and that Geoscientist 3 referred to an important collaboration with colleagues at the Institute of Engineering (see section 12.2.1) explains their co-authorship with other UNAM colleagues.

Bibliometric analysis of co-authorship patterns nonetheless reveals only a partial picture of what is happening at group level. Although we might be able to trace the basic group structure of scientists or fields through bibliometric analysis of co-authorship frequencies with certain individual scientists and institutions, it tells us little or nothing about other aspects of group interactions, particularly with scientists outside the group and with auxiliary personnel who do not necessarily appear as co-authiors. For this reason Bordons and collaborators emphasise the importance of combining bibliometric techniques with expert opinion in the description of research groups.

In their study on Spanish research in the medical sciences Bordons and her colleagues mention the difficulties attached to the delimitation of groups which do not necessarily correspond to the formal structure of departments, units or centres. For this reason they believe there is a lack of bibliometric studies at research group level. The three methodologies that have been used for defining research groups are: i) the identification of scientists belonging to the same institutional department ii) the identification of partners in research projects and iii) co-authors in scientific publications. The advantage of the latter approach is that no previous knowledge is required of the field or area to be studied such as institutional affiliations or project partners. However, research groups defined in terms of co-authorships do not necessarily correspond to any administrative or institutional reality (Bordons et al. 1995).

In their preliminary study on the identification of Spanish research teams using bibliometric tools team leaders were automatically identified on the basis of high productivity and the group members recognised according to the frequency of co-authorship with the team leaders. Two levels of application were analysed: at field level in the sub-field of pharmacology and pharmacy and at institutional level in a Spanish hospital. Results in the fields were compared to those attained using cluster analysis techniques which were then validated by insider expert opinion. The identification of groups using the two distinct bibliometric approaches turned out to be quite similar, with both methods yielding meaningful results as validated by experts opinion. Nonetheless, they conclude by pointing out that because the automatic procedures for the identification of group structures are not without flaws, expert assessment of results becomes an essential stage in the identification of research groups using bibliometric techniques (Bordons et al. 1995).

In the present study the information on group structures was sought not from experts in the fields of the 15 scientists but from the scientists themselves. A certain subjectivity with respect to the dynamic and interactions of the group among themselves and with other scientists may have occurred but, perhaps, no more than would be expected in any expert evaluation whether it be internal or external. The advantage of asking the scientists themselves for information relates to their intimate knowledge of their own research activities, including the historical perspective.

The processes underlying the assignation of credit for multi-authored papers follow a variety of conventions that seem at least partially related to the culture of the particular research fields (Harsanyi 1993). Authorship order is not entirely a function of just individual attitudes but is also a reflection of differences in disciplinary practices (Bayer and Smart 1991). However, as Meadows points out, the custom in most branches of science is for the authors to be listed in the order of importance of their contributions to the reported research but practices vary. When the contributions of each individual co-author are indistinguishable, such as in some team research, then the authors may be given in alphabetical order. In some subject areas, alphabetical listings is the norm whether or not it is possible to estimate individual contributions to the work (Meadows 1974).

Subramanyam also mentions in his article on research collaboration that the name of the principal researcher almost always appears first while the order in which the remaining authors are listed is sometimes alphabetical (Subramanyam 1983). Stokes and Hartley maintain that when the order of names is not alphabetical then the convention is that the experimental work was performed by the first author, superintended by the last and with the assistance of those between (Stokes and Hartley 1989). A more recent study in the certain fields of chemistry concludes that authorship and ranking of co-authors could be determined mainly by research activity shares done by the co-authors although in some circumstances, the names of non-contributing authors might appear. The institutional as well as the disciplinary contexts are mentioned as possible influence factors (Vinkler 1993).

The weight or prestige associated with being first author is illustrated by Zuckerman's classic study on the co-authorship patterns of Nobel prize laureates. She argued that, assuming that authors' names are listed in the order of the value of their contributions, then first author status should be more frequently assigned to the laureates than other scientists. Instead, she found that the laureates exercise *noblesse oblige* by giving credit to less eminent co-workers increasingly as their eminence grows. However, this has its limits with the laureates' contributions to prize-winning research being more visible than those to other research (Zuckerman 1968).

A paper published in Mexico by a researcher in the natural sciences on ethical considerations with regard to the assignation of credit to authors in scientific publications mentions that the order of names is assigned in accordance with the relative contributions made to the work by the different authors (Santana 1989). The information gathered during the interviews carried out with the 15 scientists in the present study, pointed towards a general agreement that the first author is the person who has contributed most to the work (see sections 8.5.2 and 12.4.2 of the thesis). This will normally correspond to the person who writes the paper (or at least who co-ordinates the writing up), who has been in charge of the project, who is most familiar with the literature of the subject and who is the expert in the field. When the project relates to thesis work then the student will normally be the first author, especially in the case of doctoral students. However, a few exceptions were mentioned. For instance, Physicist 1 commented that sometimes a more junior person is named first in order to advance their career, again indicating the value of first author position. Alphabetical ordering of names was mentioned by Astronomer 1 but only as an alternative when everybody does the same amount of work or when the order cannot be decided (see section 8.5.2). Astronomer 3 also mentioned this possibility (section 12.4.2). [3]

The exceptions mentioned by the physicist and the astronomers can be associated with the findings in Table 9-6 where these two groups of scientists showed the highest tendencies for the names of the authors to be in alphabetical order in papers involving national colleagues as well as those in international co-authorship. Nonetheless the chances that the authors of their papers were listed in alphabetical rather than non-alphabetical order was about 2 to 1 in national papers for the astronomers, about 3 to 2 for the physicists, and 3 to 1 for both groups in internationally co-authored papers. This suggests that any analysis of Mexican science based on the assumption that first author position corresponds to the scientist who contributed most to the work will most likely have less relevance for groups of physicists and astronomers than it would for groups of scientists in the other fields analysed in the present study.

A general belief exists in certain sectors of the scientific community that authors from DCs, are more likely to be the junior partners in joint projects with colleagues abroad. In her study on joint research programmes established between Brazilian scientists at the Amazonia National Research Institute and institutions from the scientific centre, Lea Velho found that the foreign scientists were much more likely to appear as first authors and that, in many cases the Brazilian counterparts did not achieve co-authorship status in the resulting papers. She concludes that the partnerships resulting from these international co-operation projects failed to produce the expected co-authored output of initiatives traditionally deserving the name (Velho 1995).

Results from the present study suggest that, at least in the case of this small group of productive Mexican scientists, first author status is frequently assigned to them when collaborating with foreign authors. An increase in the number of first author papers published in international co-authorship was associated with the maturing of Mexican biomedical research groups in a study on the creation and development of the Institute for Biomedical Research of the UNAM where Biomedic 3 was working during the years analysed in the present study (Lomnitz, Rees et al. 1987).

An increase in the number of authors per paper was seen both with respect to the 15 scientists analysed in the present study and to their Mexican colleagues working in the same

[3] My three year experience (1991-4) as a member of the scientific research board of the UNAM (as the elected academic staff representative of my institute) gave me insight into how UNAM researchers are evaluated by the directors of their institutes. Researchers were not considered to have achieved independence and to be worthy of promotion from associate to senior researcher unless they had published papers in the international literature in which they appeared as first authors.

general disciplinary areas. The trend towards increased multiple authorship of scientific papers shown by Mexican researchers is a reflection of what has been reported for scientific communication generally. Bridgstock, for instance, wrote that many researchers have chronicled the steady increase in the number of scientific papers published with more than one author, following the work of Derek de Solla Price (Bridgstock 1991). This phenomenon has also been documented for the social sciences (Oromaner 1975). Although the rate of increase in multi-authorship varies with subject area, Meadows referred to the consistent trend towards increased collaboration in all major branches of science during the present century (Meadows 1974). Notwithstanding the degree of collaboration and hence the incidence of multiple authorship tends to be low in the humanities and high in big science areas for which large technical teams are required (Subramanyam 1983).

The 15 Mexican scientists in the present study maintained a high profile in the mainstream literature both in journals from USA/Canada and from Europe and frequently had first author status assigned to them in internationally co-authored papers. The increase in the number of their co-authors with time is consistent with national and global trends. These high visibility profiles at international level are consistent with science policy initiatives of DCs and are in accordance with the criteria laid down by the Mexican scientific evaluation bodies.

9.3 CITATION LEVELS

9.3.1 *Overall Citations*

The citations (excluding self citations) given to 1985-1989 papers published by the 15 scientists in 1985 to 1993 papers are given in Figure 9-21. The total number of citations received was 1,966 (range from 547 for Biomedic 1 to 4 for Astronomer 2), and the average number of citations per paper, 6.24. Biomedic 1 had two highly cited papers (342 citations in seven years, and 110 citations in six years). This researcher also had the highest number of citations given to a paper in any single year, 85 citations three years after publication. Only two other papers received >40 citations; Biomedic 2 with a paper receiving 52 citations in five years, and Astronomer 1 whose paper received 43 citations in six years. The percentage of papers cited was 72.1% (range from 100% for Biomedic 2 to 17% for Astronomer 2).

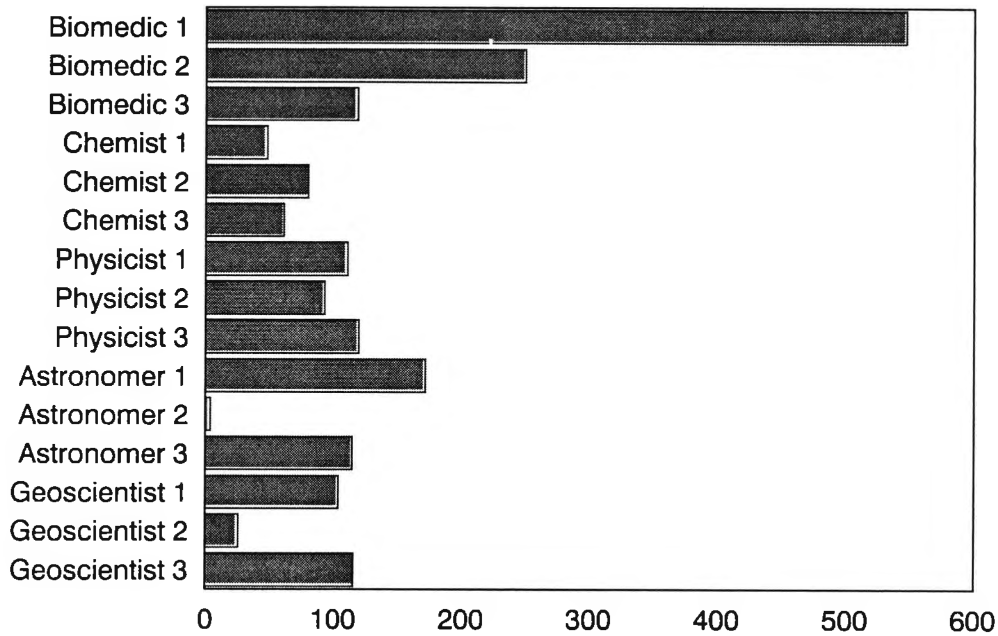


Figure 9-21. 1985-1993 citations to 1985-1989 papers of the 15 scientists

9.3.2 *Annual Citation Levels*

Annual citation levels for the 15 scientists are shown in Figure 9-22. Citations showed a steady increase from 1985 to 1990 when they began to descend. The two highly cited, innovative papers of Biomedic 1 were published in 1987 and 1988 which explains the increase in growth rate of the citations in 1987.

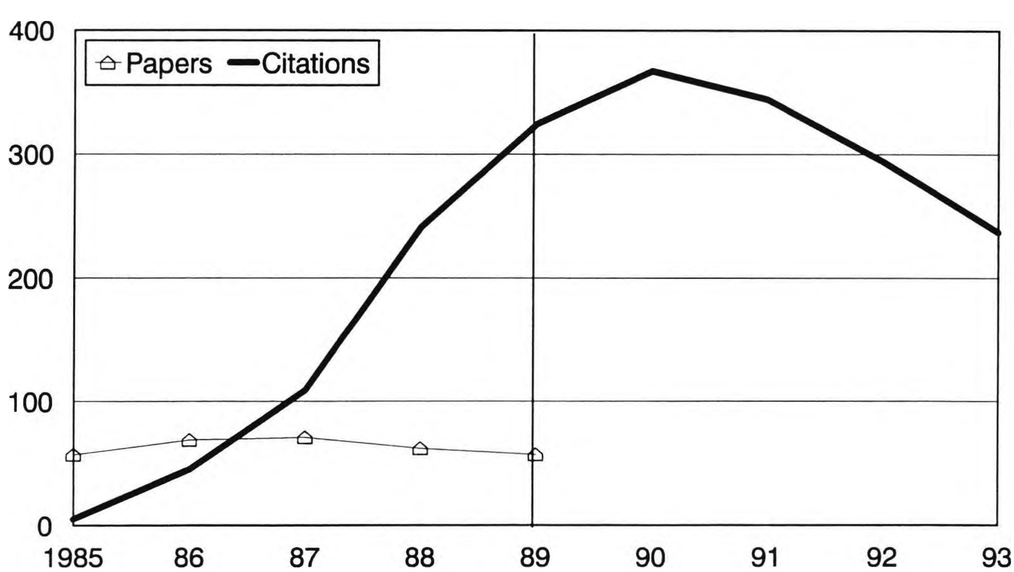


Figure 9-22. Annual citations to the 1985-1989 papers of the 15 scientists

9.3.3 *Citations as First Authors and as Co-authors*

Table 9-7 gives the figures for the five year citation rates of the 294 papers published between 1985 and 1989 of 14 of the 15 UNAM scientists according to author position. Data for Biomedic 1 were not included as the presence of two highly cited papers during this period (294 and 98 citations in five years, respectively) would have skewed results.

The number of citations per paper overall was greater when the UNAM scientists were either the only author or occupied first author position, than when they appeared as co-authors, 4.4 and 2.9 citations per paper, respectively. This was also the case with respect to 8 of the 14 individual scientists and all groups with the exception of the chemists.

Table 9-7

Effect of author position on five-year citation rates of 14 UNAM scientists *

	First or Sole Author			Coauthor		
SCIENTIST	Cites	Papers	Cites/ paper	Cites	Papers	Cites/ paper
Biomedic 2	129	9	14.3	56	9	6.2
Biomedic 3	56	15	3.7	49	18	2.7
2 x BIOMEDICS	185	24	**7.7**	105	27	**3.9**
Chemist 1	23	8	2.9	16	10	1.6
Chemist 2	11	6	1.8	52	19	2.7
Chemist 3	11	11	1.0	36	24	1.5
3 x CHEMISTS	45	25	**1.8**	104	53	**2.0**
Physicist 1	53	15	3.5	18	14	1.3
Physicist 2	53	11	4.8	18	12	1.5
Physicist 3	7	4	1.8	56	15	3.7
3 x PHYSICISTS	113	30	**3.8**	92	41	**2.2**
Astronomer 1	90	9	10.0	30	7	4.3
Astronomer 2	0	8	0.0	4	4	1.0
Astronomer 3	17	3	5.7	63	8	7.9
3 x ASTRONOMERS	107	20	**5.4**	97	19	**5.1**
Geoscientist 1	43	9	4.8	35	11	3.2
Geoscientist 2	8	8	1.0	13	3	4.3
Geoscientist 3	50	9	5.6	37	15	2.5
3 x GEOSCIENTISTS	101	26	**3.9**	85	29	**2.9**
ALL 14 SCIENTISTS	551	125	**4.4**	483	169	**2.9**

* Biomedic 1 was eliminated due to the presence of two highly cited papers

9.3.4 *Citations of Nationally and Internationally Co-authored Articles*

Internationally co-authored papers were found to be more highly cited overall than those published in institutional or national collaboration (Table 9-8). However, this was true at individual level for only half of the 14 scientists and only with respect to the groups of biomedics, astronomers and the geoscientists. National collaboration proved beneficial for citation rates in the case of Chemist 2, and also for both Physicist 1 and Geoscientist 3 whose single papers co-authored with colleagues from other national institutions received an important number of citations. However, the general trend was for the institutional environment to be more favourable for citations than collaboration with national colleagues.

Table 9-8

Effect of level of institutional collaboration on five-year citation rates of 14 UNAM scientists *

	Institutional**			**National**			**International**		
SCIENTIST	Cites	Papers	Cites/ paper	Cites	Papers	Cites/ paper	Cites	Papers	Cites/ paper
Biomedic 2	70	10	7.0	0	0	0.0	115	8	14.4
Biomedic 3	42	11	3.8	29	14	2.1	34	8	4.3
2 x BIOMEDICS	112	21	**5.3**	29	14	**2.1**	149	16	**9.3**
Chemist 1	17	4	4.3	0	1	0.0	22	13	1.7
Chemist 2	39	19	2.1	23	5	4.6	1	1	1.0
Chemist 3	46	32	1.4	1	1	1.0	0	2	0.0
3 x CHEMISTS	102	55	**1.9**	24	7	**3.4**	23	16	**1.4**
Physicist 1	18	8	2.3	11	1	11.0	42	20	2.1
Physicist 2	61	22	2.8	0	0	0.0	10	1	10.0
Physicist 3	34	5	6.8	20	6	3.3	9	8	1.1
3 x PHYSICISTS	113	35	**3.2**	31	7	**4.4**	61	29	**2.1**
Astronomer 1	89	11	8.1	0	1	0.0	31	4	7.8
Astronomer 2	1	10	0.1	0	0	0.0	3	2	1.5
Astronomer 3	16	3	5.3	0	0	0.0	64	8	8.0
3 x ASTRONOMERS	106	24	**4.4**	0	1	**0.0**	98	14	**7.0**
Geoscientist 1	33	8	4.1	12	6	2.0	33	6	5.5
Geoscientist 2	13	10	1.3	0	0	0.0	8	1	8.0
Geoscientist 3	31	11	2.8	9	1	9.0	47	12	3.9
3 x GEOSCIENTISTS	77	29	**2.7**	21	7	**3.0**	88	19	**4.6**
ALL 14 SCIENTISTS	510	164	**3.1**	105	36	**2.9**	419	94	**4.5**

* Biomedic 1 was eliminated due to the presence of two highly cited papers

** Includes papers as sole author or in collaboration with colleagues from the UNAM

9.3.5 *Citations to Papers published in SCI and Non-SCI Journals*

As would be expected, papers published in SCI journals received a much higher number of citations than those appearing in non-SCI titles in all but one case (Table 9-9). The only exception was Geoscientist 1 whose three articles published in the non-SCI journals, two in *Earthquake Spectra* and one in *Soil Dynamics and Earthquake Engineering* received 12, 10 and 8 citations, respectively, in the five years following publication. Geoscientist 3 also had two papers in *Earthquake Spectra* that received 9 and 7 citations. Only 26.8% (19 of 71) of papers published in non-SCI journals were cited at least once in the five year period analysed compared to 74% (182 of 246) of papers published in SCI titles.

Table 9-9

Effect of publication in SCI journals on five-year citation rates of 14 UNAM cientists *

	SCI journal			Non-SCI journal		
SCIENTIST	Cites	Papers	Cites/ paper	Cites	Papers	Cites/ paper
Biomedic 2	185	18	10.3	-	-	-
Biomedic 3	101	23	4.4	4	10	0.4
2 x BIOMEDICS	286	41	**7.0**	4	10	**0.4**
Chemist 1	39	18	2.2	-	-	-
Chemist 2	56	21	2.7	7	4	1.8
Chemist 3	43	30	1.4	4	5	0.8
3 x CHEMISTS	138	69	**2.0**	11	9	**1.2**
Physicist 1	71	25	2.8	0	4	0.0
Physicist 2	71	20	3.6	0	3	0.0
Physicist 3	63	16	3.9	0	3	0.0
3 x PHYSICISTS	205	61	**3.4**	0	10	**0.0**
Astronomer 1	120	15	8.0	0	1	0.0
Astronomer 2	4	12	0.3	0	0	0.0
Astronomer 3	80	10	8.0	0	1	0.0
3 x ASTRONOMERS	204	37	**5.5**	0	2	**0.0**
Geoscientist 1	43	13	3.3	35	7	5.0
Geoscientist 2	21	9	2.3	0	2	0.0
Geoscientist 3	66	16	4.1	21	8	2.6
3 x GEOSCIENTISTS	130	38	**3.4**	56	17	**3.3**
ALL 14 SCIENTISTS	963	246	**3.9**	71	48	**1.5**

* Biomedic 1 was eliminated due to the presence of two highly cited papers

9.3.6 *Effect of Place of Publication on Citation Rates*

Papers published in international journals were more highly cited than those published in national journals or in regional journals (Table 9-10). However, the small number of papers published in regional journals (n=4) makes it impossible to draw any valid conclusions from these data. With the exception of Chemist 2 whose sole paper published at regional level attracted four citations and Astronomer 1 whose six national papers received a total of 62 citations, all other cases showed higher citations for papers appearing in journals published outside the Latin American region. However all six of Astronomer 1's national papers were published in the journal *Revista Mexicana de Astronomía y Astrofísica* which is a SCI journal.

Table 9-10

Effect of place of publication of the journals on five-year citation rates of 14 UNAM scientists *

	National			Regional			International		
SCIENTIST	Cites	Papers	Cites/ paper	Cites	Papers	Cites/ paper	Cites	Papers	Cites/ paper
Biomedic 2	0	0	0.0	0	0	0.0	185	18	10.3
Biomedic 3	2	6	0.3	0	2	0.0	103	25	4.1
2 x BIOMEDICS	2	6	**0.3**	0	2	**0.0**	288	43	**6.7**
Chemist 1	0	0	0.0	0	0	0.0	39	18	2.2
Chemist 2	3	3	1.0	4	1	4.0	56	21	2.7
Chemist 3	4	4	1.0	0	0	0.0	43	31	1.4
3 x CHEMISTS	7	7	**1.0**	4	1	**4.0**	138	70	**2.0**
Physicist 1	0	4	0.0	0	0	0.0	71	25	2.8
Physicist 2	0	3	0.0	0	0	0.0	71	20	3.6
Physicist 3	0	2	0.0	0	1	0.0	63	16	3.9
3 x PHYSICISTS	0	9	**0.0**	0	1	**0.0**	205	61	**3.4**
Astronomer 1	62	6	10.3	0	0	0.0	58	10	5.8
Astronomer 2	0	7	0.0	0	0	0.0	4	5	0.8
Astronomer 3	4	3	1.3	0	0	0.0	76	8	9.5
3 x ASTRONOMERS	66	16	**4.1**	0	0	**0.0**	138	23	**6.0**
Geoscientist 1	0	1	0.0	0	0	0.0	78	19	4.1
Geoscientist 2	0	0	0.0	0	0	0.0	21	11	1.9
Geoscientist 3	1	3	0.3	0	0	0.0	86	21	4.1
3 x GEOSCIENTISTS	1	4	**0.3**	0	0	**0.0**	185	51	**3.6**
ALL 14 SCIENTISTS	76	42	**1.8**	4	4	**1.0**	954	248	**3.8**

* Biomedic 1 was eliminated due to the presence of two highly cited papers

9.3.7 *Discussion*

While individual production levels of papers of the 15 scientists varied exactly twofold, citation rates showed a much larger variation, mainly due to the presence of two highly cited papers by Biomedic 1 and low citation levels by the two oldest scientists in the group, Astronomer 2 and Geoscientist 2. The two highly cited of papers of Biomedic 1 published in the *New England Journal of Medicine*, were co-authored with other national institutions and reported a controversial technique for transplanting adrenal medulla to patients with Parkinson's disease.

The annual citation curve from 1985 to 1993 for the 1985 to 1989 papers showed the normal pattern of gradual rise, as more papers were taken into consideration, up to 1990 when the citation rates began to descend. Preliminary results suggest, that in the case of the 14 highly productive scientists considered in this analysis, that being the sole or first author favoured five year citation rates. Overall findings also suggest that papers written in international cooperation have higher citation rates. This relationship has previously been reported with respect to co-authorship between European countries (Lewison 1991) and with respect to Dutch science (Moed, De Bruin et al. 1995). It has also been shown to hold for certain Latin American countries. The citation rate for 1982 to 1991 internationally co-authored Brazilian papers in ISI indexed journals was four times that of non collaborative papers (Meneghini 1996).

Because of the very nature of the *Science Citation Index*, it is obvious that papers published in journals covered by the SCI will have a greater opportunity for citation irrespective of their merit or relevance. Nonetheless, the fact that five papers published by one of the geoscientists in two non SCI international journals received a considerable number of citations, indicates that coverage of the journal by SCI is not an absolute prerequisite for citation.

The fact that internationally co-authored papers by DC scientists are published predominantly in SCI journals would increase their citation rates over those international studies published in national journals. Irrespective of the type of collaboration involved, papers published in national journals covered by SCI will have more opportunity to receive citations than those appearing in the less visible non-SCI national publications. Coverage by SCI increases the visibility of national journals from DCs and increases their scientific prestige. In the opinion of Spagnolo, a Brazilian researcher, the number of international journals produced in a country seems to be, in itself, an indicator of maturity in the national scientific apparatus (Spagnolo 1990).

Arunachalam believes that knowing the limitations of using SCI data techniques to answer questions concerning Third World science and understanding the special features of peripheral science, there is no better way to measure the international impact of the work done in these countries than by using citation-based quantitative techniques (Arunachalam and Manorama 1989)

9.4 Patterns of Links Established with Co-Authors

9.4.1 *Papers in National and International Collaboration*

The 15 scientists as a group published 232 papers between 1980 and 1994 in collaboration with authors from overseas, representing 29.1% of total production (Figure 9-23). The physicists showed the highest level of international co-authorship (41.1%), followed by the astronomers (33.9%), and the geoscientists (30.6%). The biochemical researchers and the chemists showed lower levels (25.4% and 17.0%, respectively).

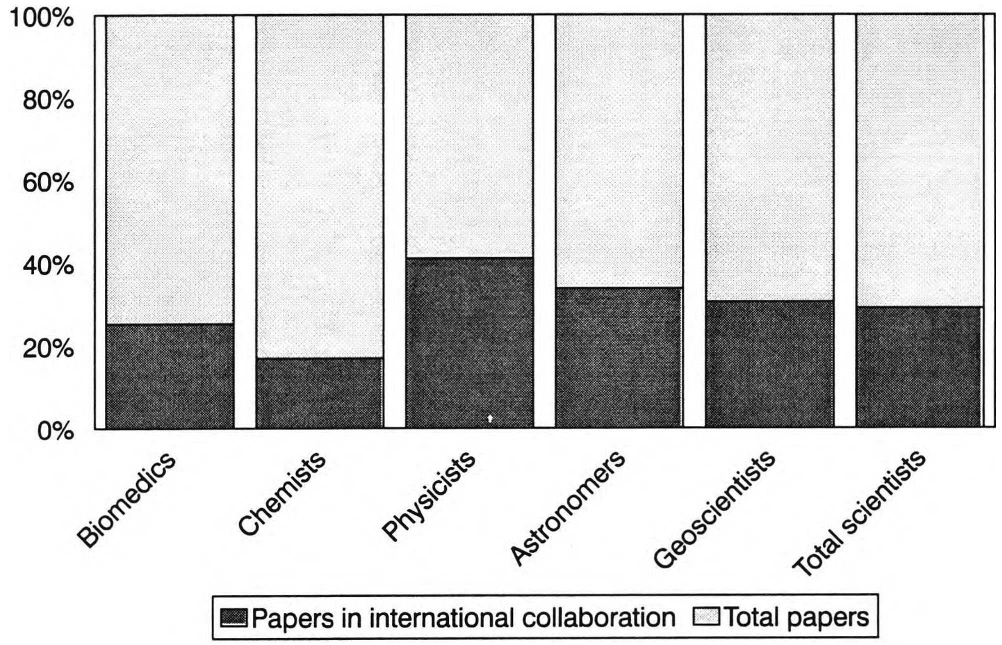


Figure 9-23. Papers in international collaboration of the 15 scientists in different disciplines

Individual production of papers in international collaboration ranged from 1 to 34 (Figure 9-24). The chemists and the biochemists also had the highest individual and group levels of papers published without foreign co-authorship. Two of the physicists, one astronomer and one of the geoscientist showed a balanced production of national v. international papers.

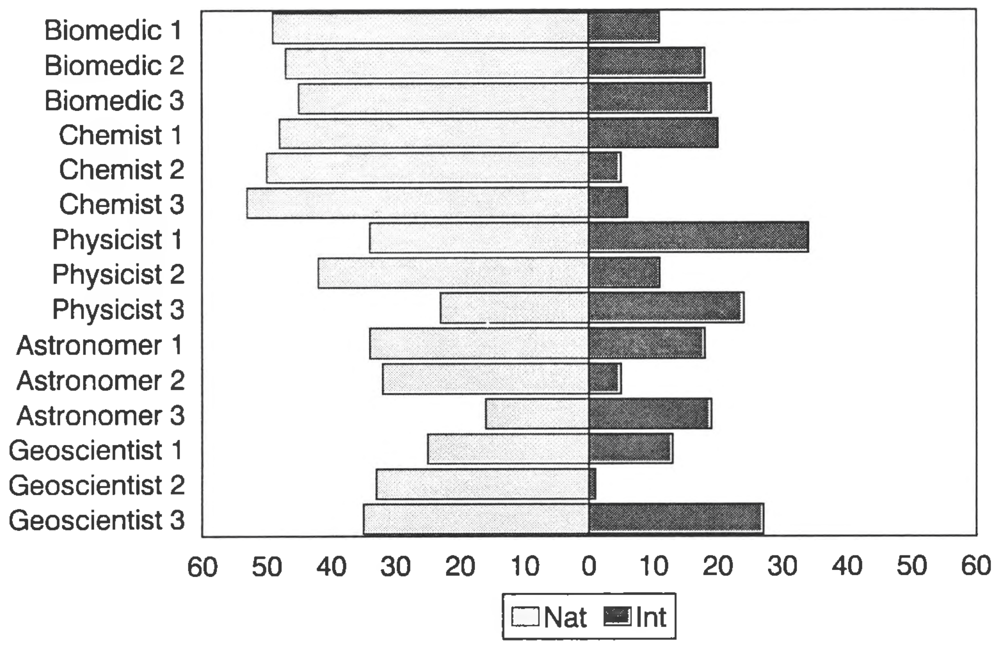


Figure 9-24. Production of national and international co-authored papers of the 15 scientists

While the number of papers written either as the sole author or in collaboration with national colleagues fell from 1988 onwards, the number of papers co-authored with colleagues from foreign institutions showed a definite upward trend (Figure 9-25). In 1980 25.6% of papers were international, a percentage which reached 35.8% in 1994. Figures peaked in 1986 and again in 1993, year in which the number of international papers surpassed those published alone or with national counterparts.

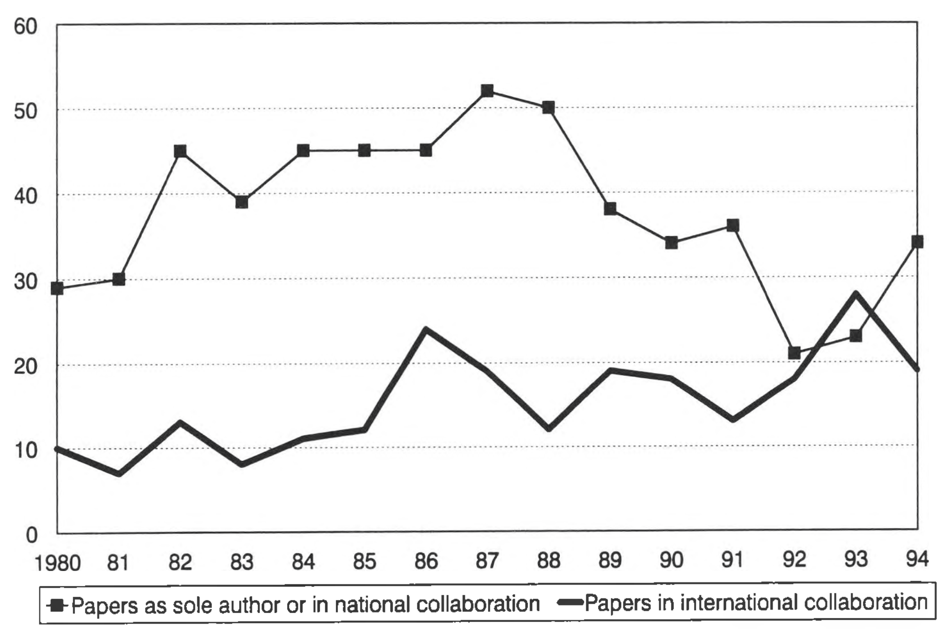
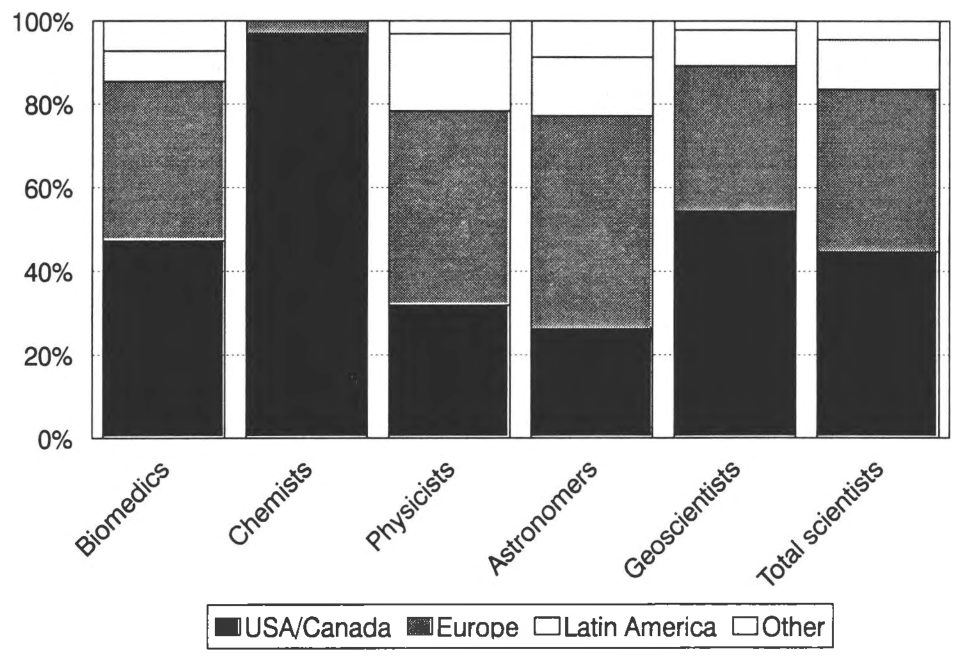


Figure 9-25. Annual production of papers in national and international institutional collaboration of the 15 scientists

9.4.2 *Papers in International Collaboration with Different Regions*

The main international partners of the group of scientists as a whole were institutions in the USA and Canada, 44.6% of international papers involved collaboration with these two countries (Figure 9-26). However, co-authorships with European colleagues occurred almost as frequently, in 39.0% of the total of 232 international papers. Co-authorships with fellow Latin American institutions were apparent in 11.8% of the total. Few co-authorships took place with countries other than those in North America, Europe, or Latin America. The highest numbers were found for the astronomers, biomedics and physicists, 5, 4 and 3 papers, respectively.

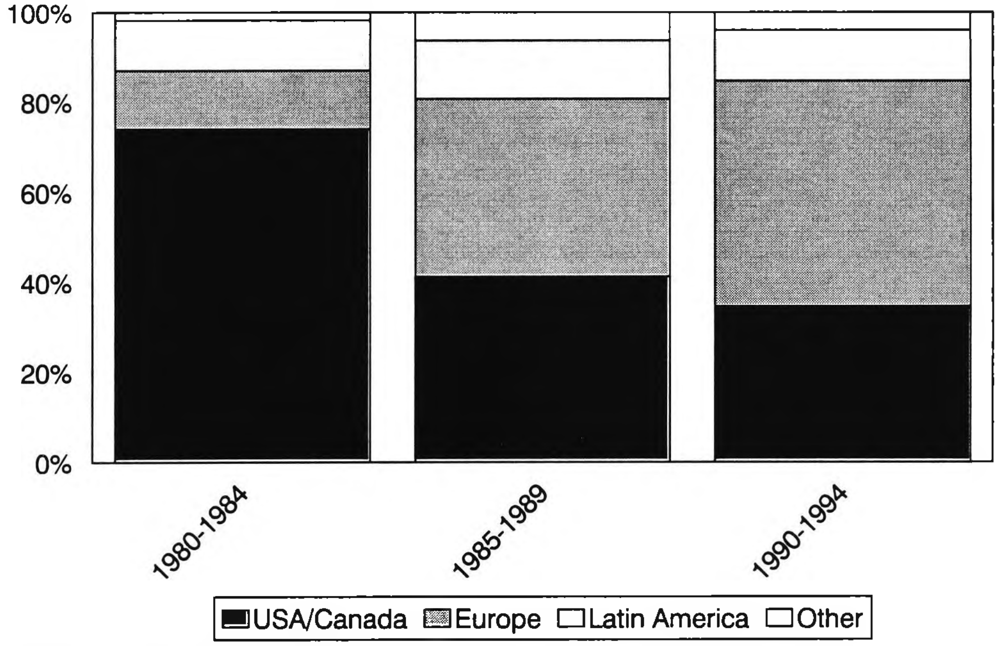
With the notable exception of the Chemists where only a single collaboration was found with European institutions, other disciplinary groups showed significant levels of co-authorship with colleagues from this region. In the case of the physicists and astronomers there were more papers in collaboration with European institutions than with those from North America, 46.4% and 50.9% of all internationally co-authored papers, respectively. Collaborations with Latin American institutions were also greater in these two groups of scientists.



Total papers with USA/Canada=128, Europe= 112, Latin America=34, Others=13

Figure 9-26. Percentage of papers in international collaboration with different regions of the world

The percentage of papers co-authored with European institutions showed a gradual increase from 13% in the period 1980-1984 to 50.4% in 1990-1994 (Figure 9-27). Although the percentage of papers co-authored with the USA or Canada showed an important decline, the actual numbers of papers in the three five-year periods showed little change, 40, 45, and 43, respectively, while the figures for Europe increased from 7 in the first period, to 43 in the second, and 62 in the third. The number of papers with other Latin American countries showed little percentage change but increased from 7 in the first five years to 14 in both the second and third periods.



Total papers 1980-84=54, 1985-89=109, 1990-94=123

Figure 9-27. Changes in the percentage of papers in international collaboration with different regions of the world

While collaboration with European colleagues was consistently important to the astronomers, this increased considerably from the first five-year period (1980-1984) to the last from 1990 to 1994 in the case of the biomedical researchers, the physicists, and the geoscientists (Figure 9-28). Co-authorship with Latin American institutions showed no consistent patterns among groups.

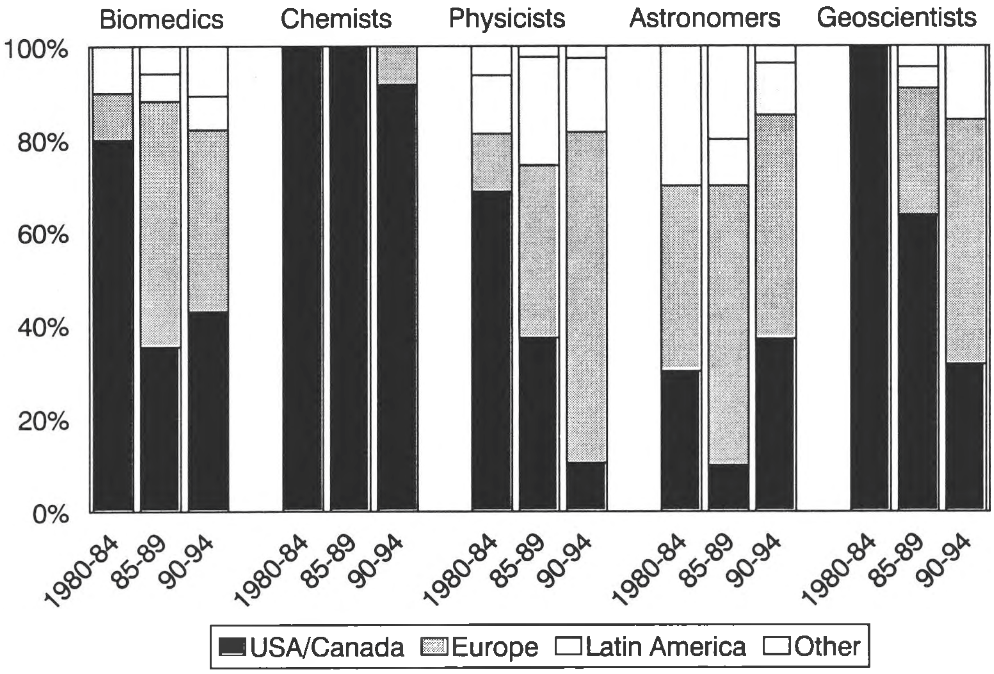
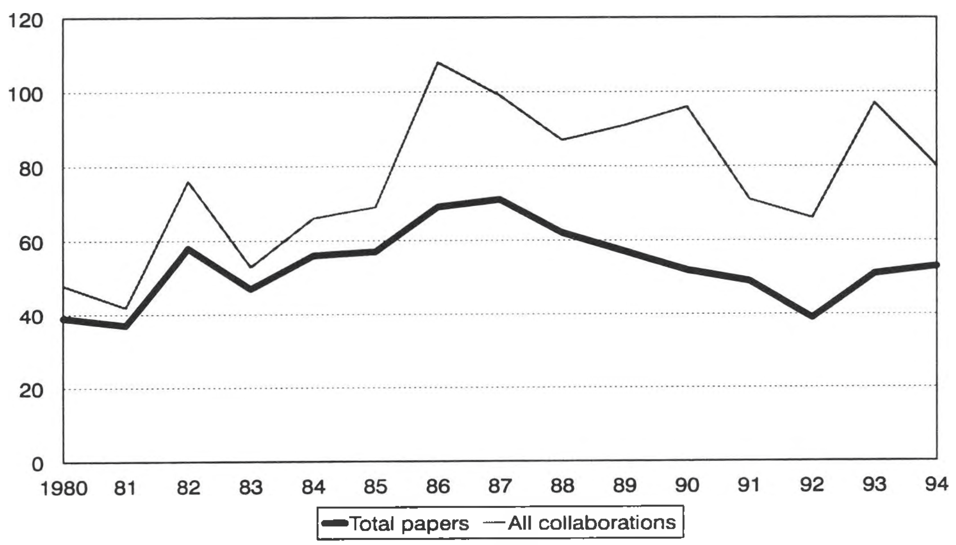


Figure 9-28. Changes in the percentage of internationally co-authored papers with different regions of the world in different disciplines

9.4.3 *Institutional Collaboration and Production*

The number of institutional co-authorships in relation to the annual production of papers for the 15 scientists as a whole, is shown in Figure 9-29. The total number of institutional collaborations was 1,159 which included collaboration with other institutes or faculties within the UNAM.



NB Figures refer to institutional coauthorships. In the case of the UNAM collaborations with both the author's own institute and with other UNAM institutes are included.

Figure 9-29. Institutional collaboration and annual production of the 15 scientists

A marked rise in the number of collaborations per paper is apparent from the divergence of the two lines in Figure 9-29. In 1980 the average number of collaborations with other institutions per paper was 1.2, a figure which increased to 1.5 for 1994. In 1990 and in 1993 respective figures were 1.8 and 1.9.

The highest number of institutions collaborating in any one paper was nine. Two papers by Biomedic 3 involved this number of institutions with the following distributions: in the first, two UNAM institutes, two other national institutes, and five foreign institutions from three different countries; in the second, three UNAM institutes and six other national institutes. Physicist 1 collaborated with seven international institutions from four different countries in one paper.

Institutional co-authorships at UNAM level followed closely the annual production of papers indicating the important role of colleagues from the same institution in the research task (Figure 9-30). Collaboration with foreign institutes took on increasing importance during the 15 years studied, surpassing the level of UNAM collaboration in 1993. The peak in production seen during the mid 80s was associated with a peak in the number of international institutional collaborations. However, while the production of papers began to drop thereafter (picking up again from 1992), co-authorships with institutions abroad continued to rise. Collaboration with other national institutes was less significant and show no well-defined pattern.

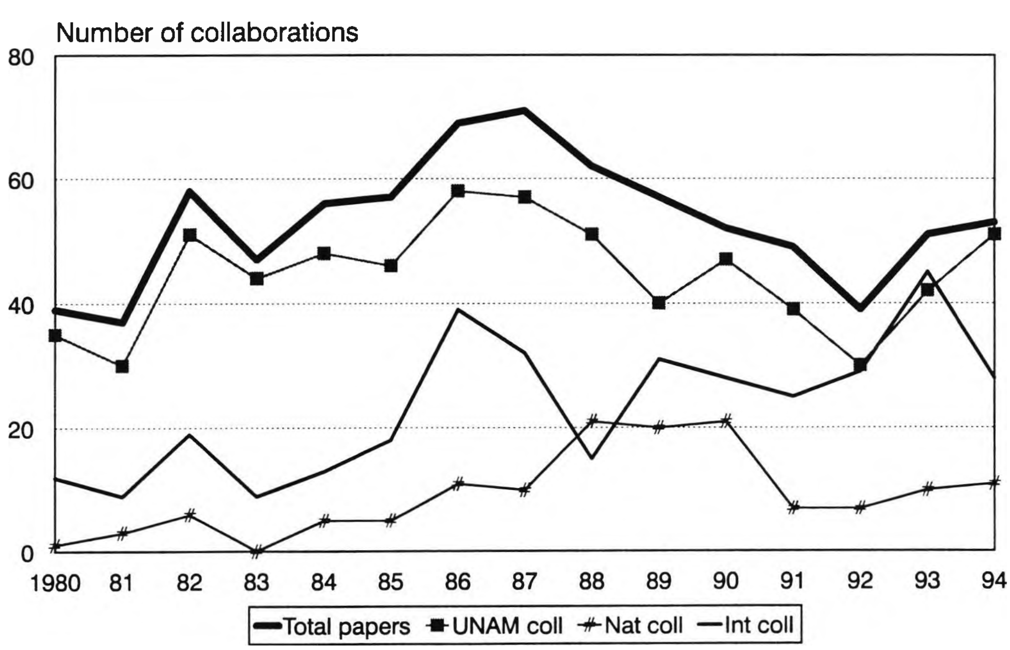
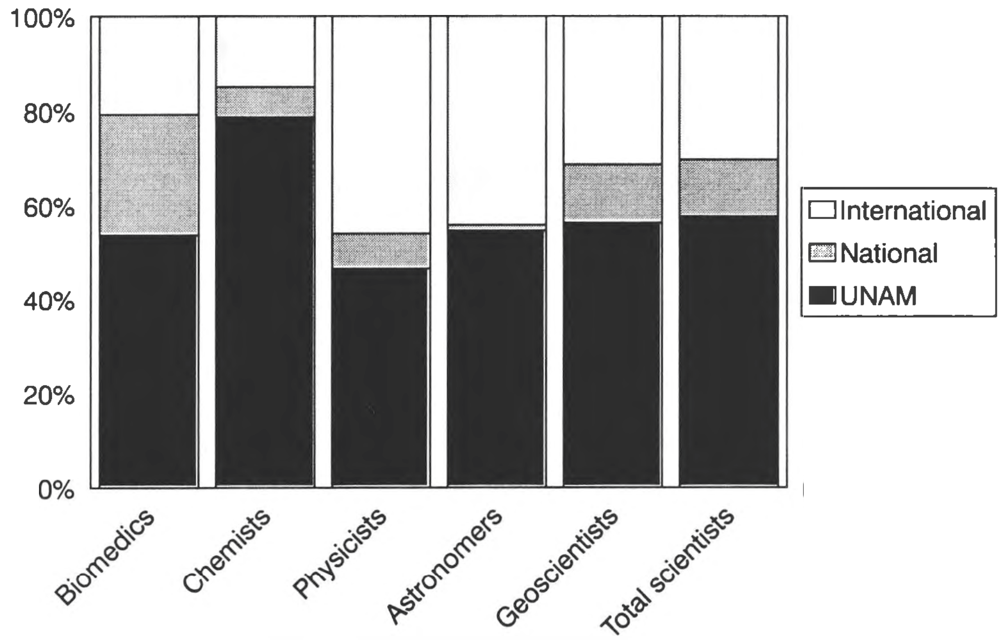


Figure 9-30. Different levels of institutional collaboration and annual production of papers of the 15 scientists

9.4.4 *Institutional Collaboration and Disciplines*

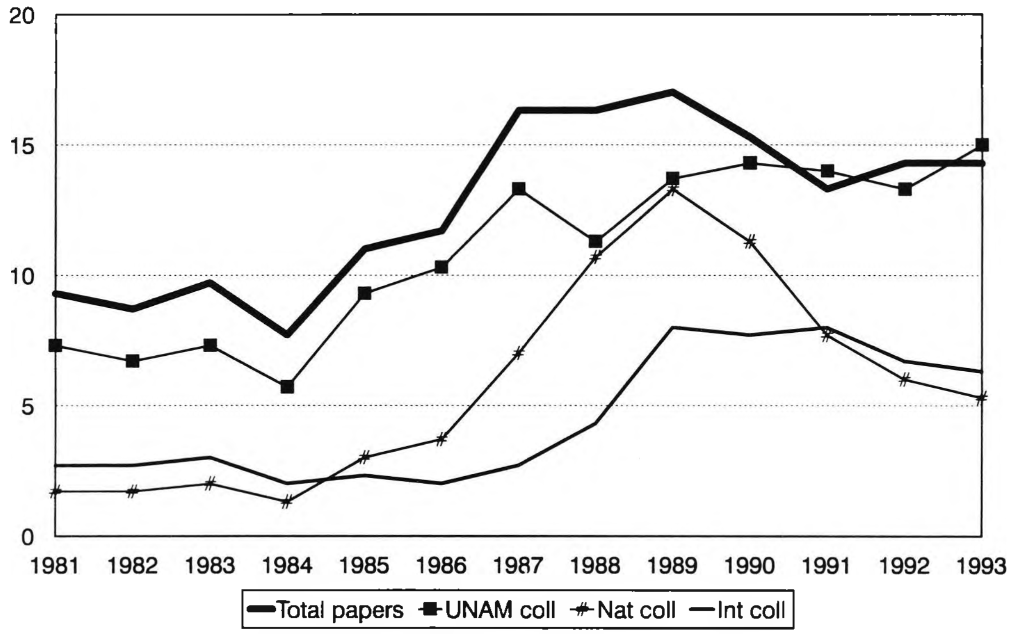
Collaboration with other institutes of the UNAM represented 57.7% of the total number of collaborations, with other national institutions, 11.9%, and 30.4% with institutions abroad (Figure 9-31). Approximately one quarter of the institutional collaborations of the biomedical researchers was with other national institutions, a figure noticeably higher than in other disciplinary groups. Almost 80% of the chemists' institutional collaborations were with colleagues from their own institution while the physicists and the astronomers showed high collaboration rates with institutions abroad (approximately 45% in both cases).



NB Figures refer to institutional coauthorships. In the case of the UNAM collaborations with both the author's own institute and with other UNAM institutes are included.

Figure 9-31. Institutional collaborations of the 15 scientists in different disciplines

Taking the biomedical researchers as an example of a group of researchers with a high collaboration profile at national level, Figure 9-32 shows the annual tendency of all levels of their institutional collaborations from 1980 to 1994. Co-authorship with other national institutions showed a sharp rise from 1980 to 1989, after which period it showed a definite decline. Collaboration with colleagues from the UNAM and that with other national counterparts followed fairly closely the production of papers from 1981-1987. International collaborations also showed a notable increase up to 1989 after when levels remained stable.

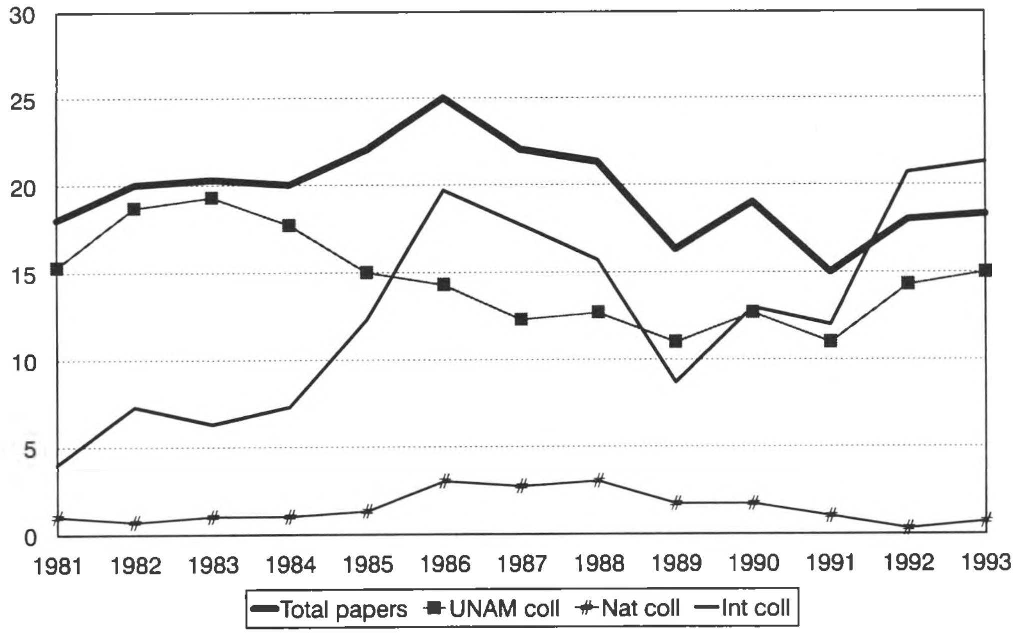


Total papers = 189 Total collaborations = 311

Figure 9-32. Different levels of institutional collaboration and annual production of papers (3yr moving averages) of the biomedics

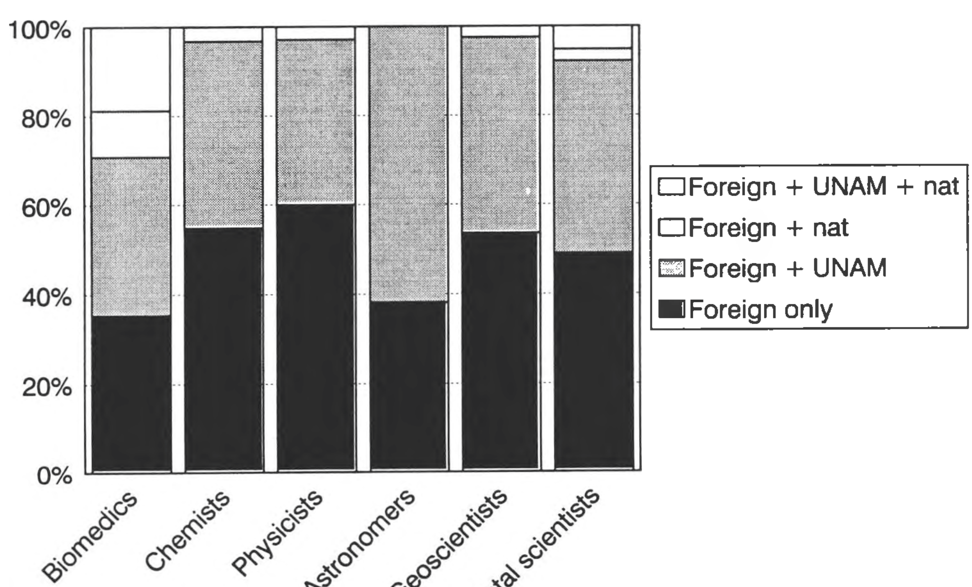
In the case of the institutional co-authorships of the physicists and astronomers which show an important international component, collaboration with colleagues from the UNAM showed a decline from 1983 through to 1991, while international collaboration was on the increase (Figure 9-33). From 1986 onwards the number of international institutional co-authorships followed closely the levels of production of papers, suggesting a direct relationship between these two variables. The peaks in the production of papers found in 1986, 1988 and 1990 coincided with peaks in the number of co-authorships at international level.

Figure 9-34 illustrates the relationship between international and national co-authorships at different levels in the different groups of scientists. Approximately half of all international papers involved only the UNAM scientist with the foreign institution or institutions. However, the other 50% reported colleagues from the UNAM and/or other national institutions as co-authors, indicating an involvement of local colleagues in the international partnerships. Most of these (43.1% of total international papers) involved colleagues from the UNAM, with 13.5% of papers being co-signed with peers from other Mexican research institutes. The biomedical scientists showed a much higher level of involvement with their national colleagues in their international partnerships with 64.6% of their international papers co-authored with UNAM and other national colleagues and 29.6% with scientists from other national institutions. The physicists on the other hand published 60% of their international papers with foreign colleagues only while the astronomers involved their UNAM colleagues in 61.9% of papers co-authored internationally.



Total papers = 292 Total collaborations = 440

Figure 9-33. Different levels of institutional collaboration and annual production of papers (3yr moving averages) of the physicists and the astronomers



Total international papers: Biomedics=48 Chemists=31 Physicists=70 Astronomers=42 Geoscientists=41

Figure 9-34. Papers in international institutional collaboration in co-authorship with UNAM and other national institutions

9.4.5 *Institutional Affiliations in Papers in International Collaboration*

The addresses reported by the different groups of UNAM scientists in papers co-authored with foreign institutions are analysed in Figure 9-35. In 76.3% of the total of 232 international papers, the Mexican scientists gave a UNAM affiliation. While the biomedical researchers, the astronomers and the geoscientists showed low frequencies of reporting foreign institutional affiliations (<17% of international papers), the chemists and the physicists were much more likely to do so (in 54.8% and 35.7% of cases, respectively).

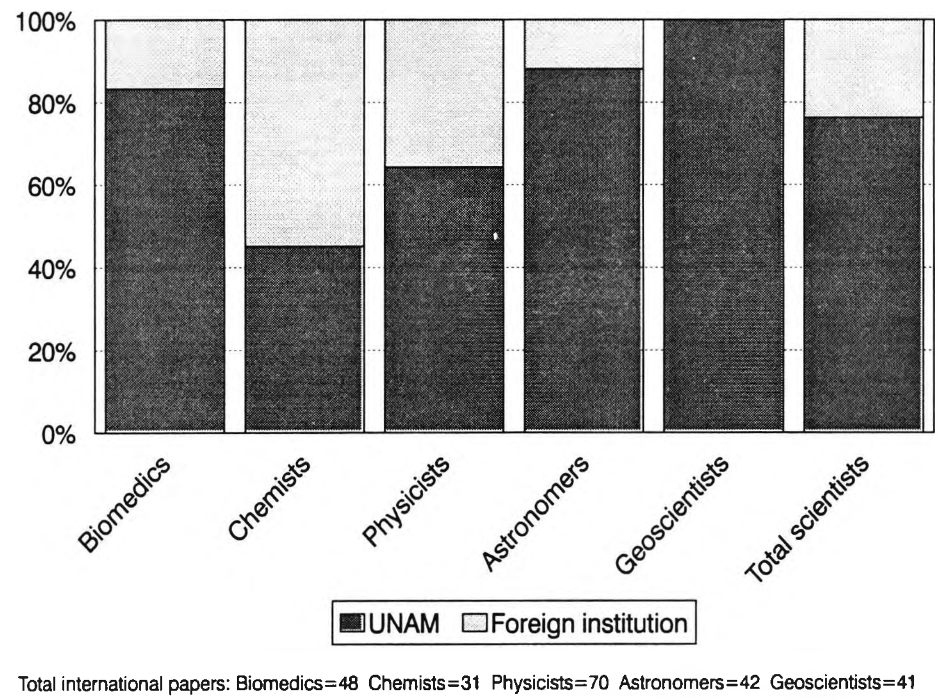
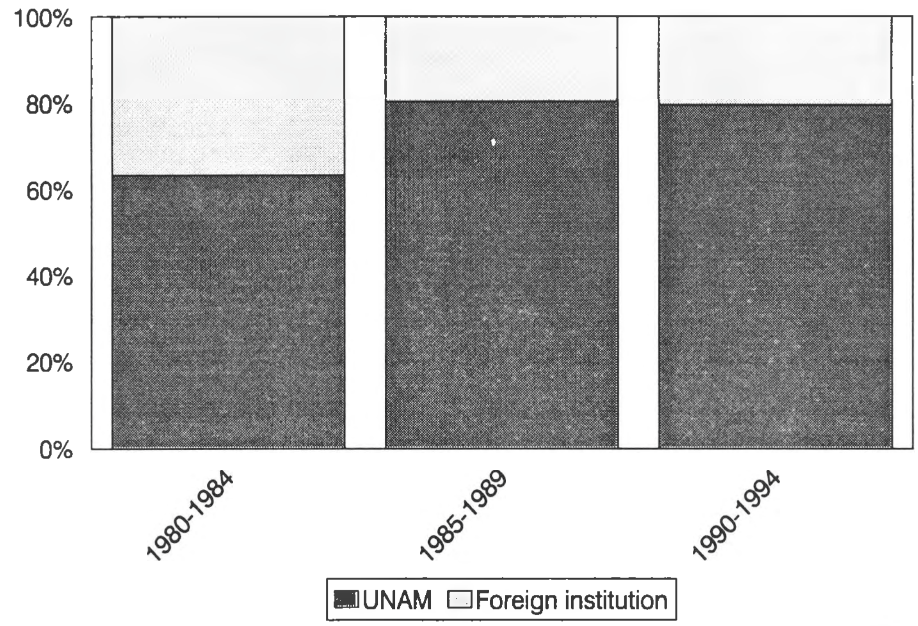


Figure 9-35. Institutional affiliations of the 15 scientists in papers published in international collaboration

The scientists showed a greater tendency to report a foreign address during the first five year period of the 15 years studied (36.7% of papers) than during the later two when the percentage of papers reporting an address abroad was constant at around 20% (Figure 9-36). However, the absolute number of papers reporting a foreign address for the Mexican scientists did not show any significant change over the three five-year periods from 1980 to 1994 (18, 17, and 20, respectively).



Total international papers 1980-84=49, 1985-89=86, 1990-94=97

Figure 9-36. Changes in the institutional affiliations of the 15 scientists in papers in international collaboration

9.4.6 *Co-authorships in National and International Collaboration*

Figure 9-37 shows the percentages of co-authorships and individual co-authors at different levels of collaboration of the five groups of scientists from 1980-1989. As found earlier with respect to institutional collaborations, the biomedics show higher levels of national collaboration than the other groups. In all cases co-authorships at institutional level (within the UNAM) represented a greater percentage of total co-authorships than did the percentage of institutional co-authors with respect to the total number of individual co-authors, suggesting an important number of UNAM colleagues who collaborated in various papers. On the other hand, the percentage of international co-authorships was smaller in relation to that of foreign authors, suggesting a larger number of co-authors at international level collaborating in fewer papers.

With the exception of the physicists and the astronomers where there was little difference between the numbers of national (UNAM and non-UNAM) and foreign scientists with whom they had published, the other groups had co-authored with a larger number of national than international colleagues. This was most evident in the case of the biomedics and the chemists (Figure 9-38).

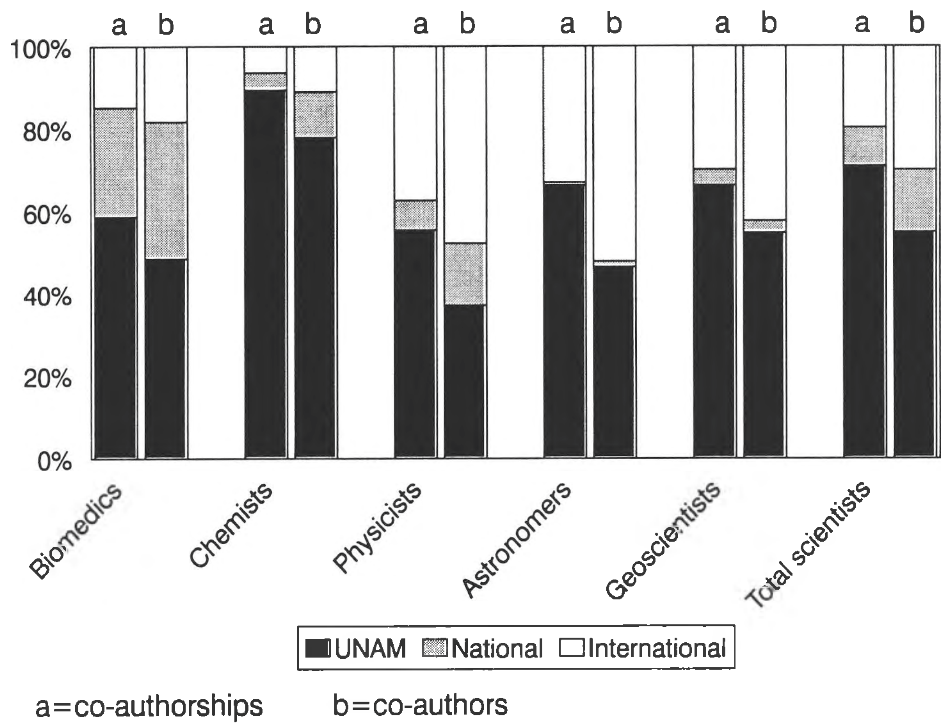


Figure 9-37. Institutional, national and international co-authorships and co-authors 1980-89

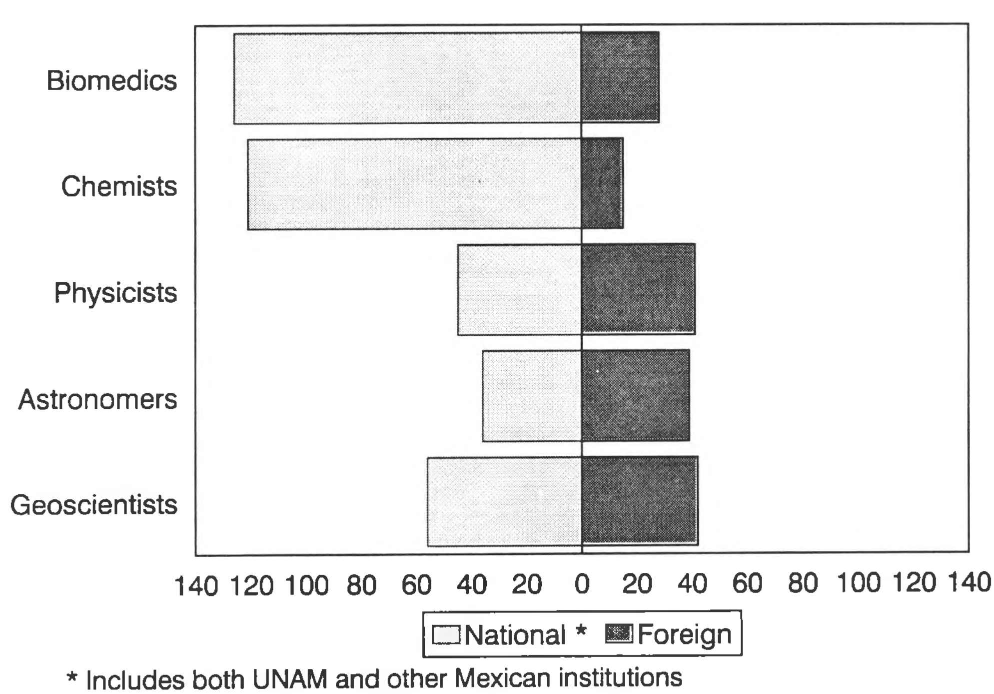
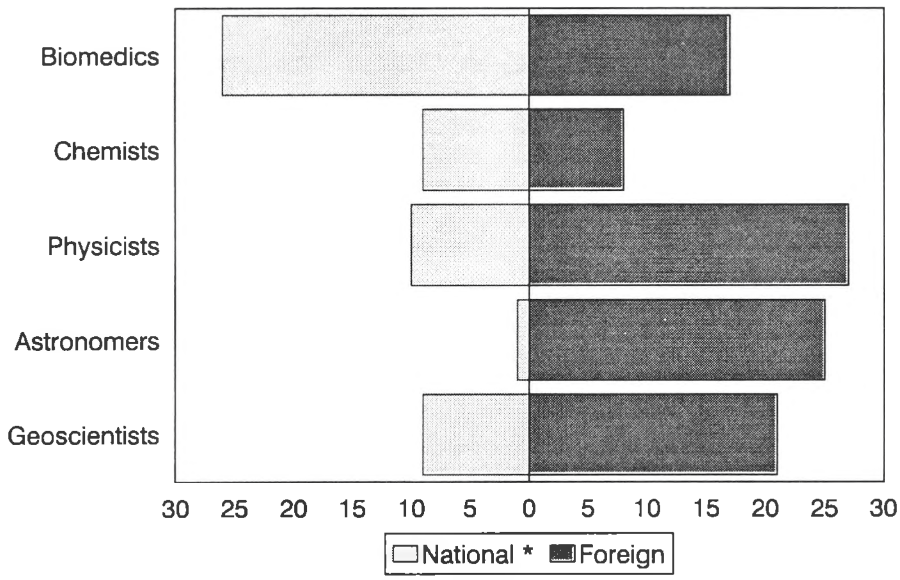


Figure 9-38. Number of individual national and foreign co-authors 1980-89

When looking at the relationship between the number of collaborating national and foreign institutions for the different groups of scientists, two distinct patterns are seen (Figure 9-39). The first pattern, seen with respect to the biomedics and the chemists, shows a relative balance between the number of national and foreign institutions. The second pattern shown by the physicists, astronomers, and the geoscientists, indicates collaboration with a much larger number of foreign institutions than national institutions, which is particularly marked in the case of the astronomers.



* Includes both UNAM and other Mexican institutions
Refers to total numbers for the individual scientists in each group

Figure 9-39. Number of national and foreign collaborating institutions 1980-89

9.4.7 *Discussion*

The frequency of international collaboration in the papers by the sample of highly visible Mexican scientists, is comparable with that reported for Mexican science as a whole (Russell 1995). In both cases, approximately 30% of all papers (articles, notes, reviews, and letters) had at least one co-author reporting foreign institutional affiliation. A marked upward trend from 1980 onwards in the number of papers in international co-authorship was seen both for the country as a whole and for the sample of 15 scientists. In the particular case of the three physicists analysed in the present study, a higher level of international papers was found than that reported for physics research in Mexico as a whole (41% for 1980-1994 as compared to 32% for Mexico from 1980-1990). These results suggest a particularly high international profile for this group of UNAM physicists.

The four scientists with the lowest production of internationally co-authored papers (Astronomer 2, Geoscientist 2, Chemist 2 and Chemist 3) were those scientists with the greatest length of time since they had received their PhD (Figure 8-1). No similar relationship was found with respect to the production of national papers. Two of these scientists, the non-chemists, also had median or below median values for the number of papers in international co-authorship found in groups of Mexican scientists working in similar fields (see section 9.1.7).

From these results it is interesting to speculate that, while overall production of papers does not necessarily decline with age, the desire, or perhaps the need to collaborate with foreign colleagues diminishes. This could possibly be related to the fact that these "senior" scientists will have become experts in their particular line of research with well established research interests and infrastructure. The development of innovative research topics which perhaps require the input or facilities of foreign specialists, are more likely to be undertaken by younger scientists. On the other, as alluded to by some of the scientists interviewed, it might be that the older scientists are less prepared to travel.

An increase in the number of papers co-authored with European institutions is also consistent with the trend for the country as a whole. The number of Mexican European papers increased 3.2 fold from 1980-1990 while the corresponding figure for papers co-authored with the USA/Canada was 1.9 (Russell 1995). Low levels of co-authorship were found with other countries in Latin America, corresponding to 8.7% of all internationally co-authored papers.

A UNESCO study, cited by Efana (Efana 1993), affirms that the problems of international mobility and formalised scientific cooperation tend to be reduced considerably when the affinities of language, culture, and history are relatively strong, such that higher levels of collaboration with other Latin American countries could have been expected both at national level and in the sample of 15 scientists. However, in the case of countries on the periphery, these affinities are normally outweighed by scientific considerations, particularly in the case of scientists, such as those in the present analysis, with a high profile in the mainstream scientific literature.

Results for the 15 scientists indicate that important collaborations are established with colleagues from the UNAM, confirming that these highly visible scientists form part of established groups of scientists within their own institution. The findings with respect to the number of scientists who have appeared as co-authors in the total number of papers of the 15 scientists, show that in spite of a supposedly small number of scientists in DCs such as Mexico, there was no lack of national colleagues with whom to co-publish. However, as all 15 scientists were involved with teaching activities, particularly at postgraduate level, some of the institutionally, and to a lesser extent, the nationally co-authored papers could correspond to thesis research. The important role played by institutional colleagues is supported by the finding that the trend in the annual production of papers follows closely that of UNAM co-authorships (Figure 9-30).

Field differences appear to influence the relative numbers of national and foreign colleagues with whom the scientists have co-published. Papers in exact fields of physics and astronomy had a more even balance between the numbers of individual national and international co-authors than those in the more applied fields of biomedicine and chemistry where local collaborators predominated. Herzog found that communication-related behaviour shows considerable variation across fields. Life scientists report a lower rate of foreign contact than do their counterparts in the physical and formal sciences. Although life scientists are less likely to form stable and enduring relationships with foreign colleagues, they constitute a much more cohesive community, complete with identifiable liaison roles ("gatekeepers") which serve to link the national community with their international scientific fraternity (Herzog 1983).

The increase in the number of institutional collaborations per paper of the 15 scientists from 1980 onwards is also consistent with global trends. Science is increasingly a collaborative activity, particularly with respect to collaboration between scientists from different countries (Katz and Hicks 1995).

Pao found that global collaborators (those who in addition to collaborating within their own group, also co-author with members of other groups) in schistosomiasis research are more productive than those scientists who restrict their collaboration to their own local groups (Pao 1992). In the present study all 15 scientists were found to co-author with both local and foreign researchers (Figure 9-31). Only in the case of the astronomers was little co-authorships found nationally outside their own groups that could be attributed to the absence of other established groups in this field. Few Mexican institutions, other than the Institute of Astronomy in the UNAM, carry out research in astronomy and astrophysics, as shown by the fact that the UNAM produces almost 75% of all Mexican mainstream research in Earth and Space Sciences (see Figure 7-2). In addition, only one non-UNAM researcher figured in a homogenous sample of 20 Mexican scientists working in the field of astronomy and astrophysics (see section 9.1.6).

Results for the exact scientists show a direct relationship from 1986 onwards between number of papers published and the levels of international institutional collaboration, implying that productivity is driven by international co-authorship (see Figure 9-33). Productivity of the biomedics, on the other hand, was more closely associated with levels of national co-authorship (see Figure 9-32). This could be at least partially explained by the long tradition in Mexico of the health sciences research (Martínez Palomo 1994), as well as the number and variety (research institutes, universities, hospitals, government departments, etc.) of Mexican institutes dedicated to medical research. Another consideration is the fact that many topics in the health sciences, particularly in developing countries, focus on local diseases and local public health problems.

An important finding of the present research is the involvement of local and national colleagues in the internationally co-authored papers of the 15 scientists, especially in the case of the biomedics and the astronomers (see Figure 9-34). Overall 50% of all internationally co-authored papers were cosigned with other colleagues from the UNAM or other Mexican institutions, indicating that foreign collaboration in these cases is not restricted to one Mexican scientist alone but rather extends to other national colleagues. This can be considered an important spinoff of promoting the foreign collaboration of individual scientists. Of course, it is quite possible that, in many cases, the collaboration was not instigated by the scientists studied in the present analysis, but rather that their co-authorship was the result of the involvement of a local collaborator in an international project.

Collaboration patterns and scientific mobility are known to vary between fields. Mobility is typically less frequent in applied research than in basic fields (Carlson and Martin-Rovet, 1995). Scientists in basic fields achieve recognition from the international research community suggesting higher levels of international collaboration in these areas (Luukonen, *et al.*, 1992) More applied fields can be expected to show higher levels of national collaboration, as is the case of biomedical research in the present study, although scientists in all five fields showed varying levels of international co-authorship.

The technique of tracing author mobility by analysing the occurrence of institutional affiliations in published papers requires further study. It is possible to speculate from the present results that research disciplines where laboratory work is the norm, such as chemistry and physics, show higher incidences of foreign addresses because of time physically spent in laboratories abroad. On the other hand, in disciplines where field studies are often carried out, such as in astronomy, and in the geosciences, the scientists tend to report the address of their home institution. Although there is an unwritten rule that scientists are expected to give as their institutional affiliation in the published report the address of the institute where the work was carried out, this is not always heeded (Day 1994). It could also be that the accredited institution is where the work was written up which could well be the home institution. In some cases two institutional affiliations are noted, suggesting that both institutions were involved in the experimental procedure.

The fact that international papers have a greater number of authors suggests a variety of scenarios. The first concerns the involvement of both national and international colleagues in the work. The second relates to the greater critical mass of scientists in industrialised countries in any one field, implying the availability of a greater number of collaborators for any one project. A third explanation could be the incorporation of the developing country scientists into big science projects, more characteristic of the scientifically advanced countries.

Chapter 10

Effect of Sabbaticals

10.1 CHARACTERISTICS OF THE SABBATICALS ANALYSED

A total of eleven full sabbaticals of one year, and two half sabbaticals of six months taken from 1975 onwards, were analysed (Table 10-1). This time period was chosen so that any influence of the sabbaticals would be likely to continue through to the early eighties. Data from two researchers were not included: Chemist 2 whose only sabbatical was taken from 1962 to 1963, and Physicist 3 who took two complete sabbaticals and one half sabbatical from 1981 to 1990, making it impossible to differentiate the influences of the individual visits. Geoscientist 1 had short foreign stays (>3 months) two and four years after the sabbatical analysed, and Geoscientist 3, a short stay two years after his sabbatical which could possibly have influenced results.

All sabbaticals included in the analysis were taken in institutions in either Western Europe (n=8) or in North America (n=7); two sabbaticals involved institutions in both regions. All were carried out in higher education or research institutions.

10.2 CONTRIBUTION OF THE SABBATICALS TO THE TOTAL OF INTERNATIONALLY CO-AUTHORED PAPERS

A total of 66 papers (range 0 to 21 per scientist) were co-authored with the sabbatical institutions included in the present analysis (Table 10-2). Overall these papers made up 32.5% of the total co-authored with foreign institutions during the 15 years from 1980-1994. There was a large variation in the individual percentages with five of the 13 sabbaticals contributing approximately one third of all papers published with foreign institutions, corresponding to two of the biomedics, the two physicists, and one of the astronomers. All Chemist 1's internationally co-authored papers were with the same US institution where he had made three visits of one year's duration (one postdoctoral stay and two sabbbaticals) between 1978 and 1989.

Table 10-1

Characteristics of the 13 sabbaticals analysed

SCIENTIST	SABBATICAL Full	SABBATICAL Half	YEAR	COUNTRY	TYPE OF INSTITUTION
BIOMEDIC 1	✓		*1980-81*	*USA*	*University*
BIOMEDIC 2	✓		*1983-84*	*USA*	*Research Inst*
BIOMEDIC 3	✓		*1987-88*	*UK*	*Univ/Res Inst*
CHEMIST 1	✓		*1982-83*	*USA*	*University*
CHEMIST 2	****	****	********	**********	***********
CHEMIST 3	✓		*1977-78*	*France*	*University*
PHYSICIST 1	✓		*1985-86*	*USA*	*Univ/Res Inst*
PHYSICIST 2	✓		*1985-86*	*France/USA UK/Pto Rico*[1]	*Universities*
PHYSICIST 3	****	****	********	**********	***********
ASTRONOMER 1	✓		*1975-76*	*USA/UK*	*Res Inst/Univ*
ASTRONOMER 2		✓	*1985*	*Spain*	*University*
ASTRONOMER 3		✓	*1980*	*W.Germany*	*University*
GEOSCIENTIST 1	✓		*1982-83*	*France/Italy*	*Universities*
GEOSCIENTIST 2	✓		*1979-80*	*UK*	*University*
GEOSCIENTIST 3	✓		*1980-81*	*USA*	*University*

[1] 1 month visits to both the UK and Puerto Rico during the sabbatical

Table 10-2

Contribution of the 13 sabbaticals to the total of internationally co-authored papers

SCIENTIST	Papers coauthored with the sabbatical institutions	Total no. of internationally co-authored papers 1980-1994	%
Biomedic 1	4	11	36.4
Biomedic 2	2	18	11.1
Biomedic 3	6	19	31.6
3 x BIOMEDICS	12	48	25.0
Chemist 1	21*	20	105.0
Chemist 3	1	6	16.7
2 x CHEMISTS	22	26	84.6
Physicist 1	12	35	34.3
Physicist 2	3**	11	27.3
2 x PHYSICISTS	15	46	32.6
Astronomer 1	5	18	27.8
Astronomer 2	4	5	80.0
Astronomer 3	2	19	10.5
3 x ASTRONOMERS	11	42	26.2
Geoscientist 1	3	13	23.1
Geoscientist 2	0	1	0
Geoscientist 3	3	27	11.1
3 x GEOSCIENTISTS	6	41	14.6
ALL 13 SCIENTISTS	**66**	**203**	**32.5**

* includes 1 paper prior to 1980
** includes 2 papers prior to 1980

10.3 PUBLICATION OF CO-AUTHORED PAPERS FOLLOWING SABBATICALS

Dividing the 66 papers into periods of two years before and after the two years corresponding to the sabbatical period (zero in the graph), co-authorship with the sabbatical institutions was shown to begin during the sabbatical years, reaching maximum values during the following two years (Figure 10-1). An effect is still apparent four years later, but returns to pre-sabbatical levels after six years. The presence of a small number of papers co-authored with sabbatical institutions both prior to the sabbaticals and more than 6 years later, is due to previous or posterior sabbaticals taken at the same institutions by Chemist 1, and by Physicist 2.

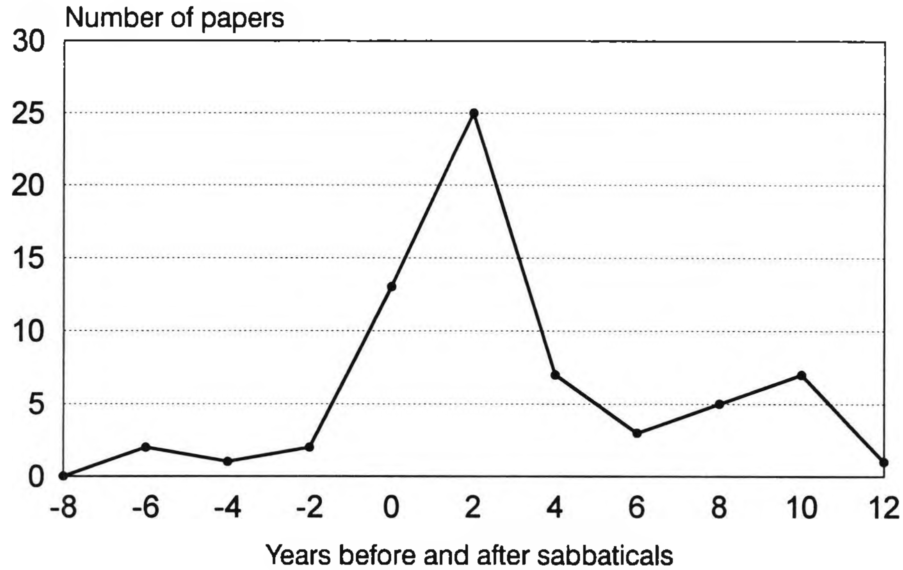


Figure 10-1. Two-yearly distribution of papers of the 13 scientists co-authored with sabbatical institutions

10.4 Effect of the Sabbaticals on Total Production of Papers; Production of Internationally Co-authored Papers; and Levels of International Institutional Co-authorship

In order to establish the effect of the sabbaticals on the total output of papers, and those published in international co-authorship, as well as on the number of international institutional co-authorships, individual totals for these three parameters for the two years prior to the sabbaticals (n_1) were taken as baseline. "Extra" papers or co-authorships (above these baseline values) seen during the two years of the sabbaticals (n_2), from 2-4 years later (n_3) and from 4-6 years later (n_4), were considered to be a consequence of the sabbaticals, independently of whether or not these were co-authored with the sabbatical institutions.

Eight of the 13 scientists showed a positive effect of sabbaticals on the production of papers with all three Astronomers (two with half sabbaticals), 1 Biomedic 2, and Physicist 1 showing negative effects but none of these differences were statistically significant (see below). In general, 21 "extra" papers could be attributed to the sabbatical period, giving a low average of 1.6 "extra" papers per scientist (Table 10.3).

On the other hand, much more marked effects were seen on the number of internationally co-authored papers, and levels of international institutional co-authorship, some of which were statistically significant (see below). In all but one of the 13 sabbaticals, there was a positive effect on the numbers of internationally co-authored papers, and on the levels of international co-authorships. The exception was Astronomer 1's sabbatical taken from 1975 to 1976, since when he reports only one visit abroad of four month's duration in 1986.

The significance of the effect of the sabbaticals on these three parameters using a chi-square test can be seen in Appendix 3 for the individual sabbaticals, as well as for the aggregate groups of 2 or 3 sabbaticals within the five disciplinary areas. Data are presented only where expected values (E) were >5 (Tables A3-1 to A3-4). Results for the aggregate data of the 13 sabbaticals can be seen in Table 10-4.

Table 10-3

Effect of the 13 sabbaticals on production of papers and institutional collaborations

GROUP OF SCIENTISTS	ADDITIONAL PAPERS/ SCIENTIST	ADDITIONAL INTERNATIONALLY COAUTHORED PAPERS/ SCIENTIST	ADDITIONAL INSTITUTIONAL COLLABORATIONS/ SCIENTIST
BIOMEDICS (n=3)	-0.6	7	10.6
CHEMISTS (n=2)	11	2.5	2.5
PHYSICISTS (n=2)	2.5	8	16.5
ASTRONOMERS (n=3)	-7.7	-0.6	1
GEOSCIENTISTS (n=3)	6.3	3	3.3
AVERAGE TOTAL	1.6	4.3	6.4
INDIVIDUAL RANGE	-15 to +17	-5 to +14	-4 to +30

No significance was found for any of the individual and aggregate data with respect to an increase in the production of papers following the sabbaticals. The increase in the production of internationally co-authored papers was significant at a confidence level of 5% for Physicist 1, at the 1% level for the group of two physicists, and at a confidence level of 0.5% for the group of 3 biomedics, and for the 13 scientists as a whole.

The increase in the level of international institutional co-authorships was significant at a confidence level of 0.5% for Biomedic 3, the group of three biomedics; Physicist 1; group of two physicists; and the group of 13 scientists.

As would be expected the individual figures for all three parameters were low with respect to the great majority of the 13 scientists, and in many cases figures corresponded to 0. Even at the aggregate level of the groups of two or three scientists many of the totals were <5. Only with respect to the aggregate data of the 13 are all figures for all three variables >15 except for two totals (10 and 12).

Table 10-4

Effect of the 13 sabbaticals on the production of papers and patterns of international co-authorship

		n_1[a]	n_2	n_3	n_4	E	x^2
TOTAL PRODUCTION OF PAPERS	0	84	98	98	77	89.25	
	0-E	-5.25	8.75	8.75	-12.25		
	$(0-E)^2$	27.56	76.56	76.56	150.06		
	$(0-E^2)/E$	0.31	0.86	0.86	1.68		**3.71**
PRODUCTION OF INTERNATIONALLY CO-AUTHORED PAPERS	0	10	27	34	18	22.25	
	0-E	-12.25	4.75	11.75	-4.25		
	$(0-E)^2$	150.06	22.56	138.06	18.06		
	$(0-E^2)/E$	6.74	1.01	6.21	0.80		**14.76**[b]
LEVELS OF INTERNATIONAL INSTITUTIONAL CO-AUTHORSHIP	0	12	39	52	28	32.75	
	0-E	-20.75	6.25	19.25	-4.75		
	$(0-E)^2$	430.56	39.06	37.01	22.56		
	$(0-E^2)/E$	13.15	1.19	11.31	0.69		**26.34**[b]

[a] n_1 = Total for the two years previous to the sabbatical
n_2 = Two year period which includes the sabbatical
n_3 = Two years following the sabbatical
n_4 = Third and fourth year after the sabbatical

[b] Significant at a confidence level of 0.5%

10.5 Contribution of Sabbaticals and other Prolonged Visits to the International Co-authorships of the 15 Scientists

The contribution of papers co-authored as a result of visits of more than three months reported in the CVs of the 15 scientists, to the total number of internationally co-authored papers is shown in Figure 10-2. The lines show a similar pattern of gradual increase from 1980 to 1984 with peaks occurring in certain years. The distance between the two lines varies considerably from year to year, with 113 papers co-authored with institutions visited making up just less than half (48.7%) of all internationally co-authored papers (n=232) during the 15 years studied, suggesting that international links other than those established during prolonged visits of the 15 scientists to foreign institutions, play an important role in integrating Mexican researchers into the mainstream of scientific activity.

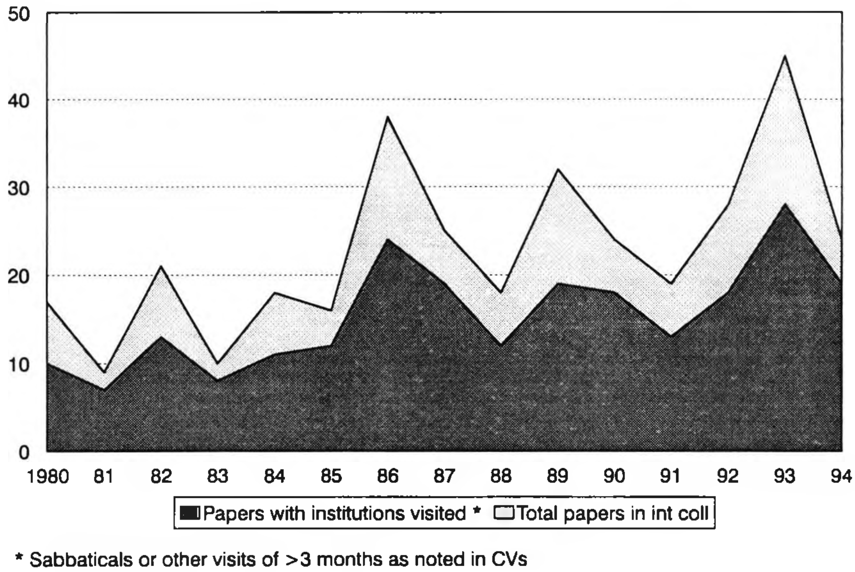


Figure 10-2. Annual production of papers in international collaboration of the 15 scientists resulting from prolonged visits to foreign institutions

10.6 INTERVIEW RESULTS

Biomedic 1

This scientist chose to spend his 1980-81 sabbatical at the University of California at Los Angeles (UCLA) mainly to learn a technique new to his laboratory and related to his work on sleep. He had already formed a friendship with D.J. McGinty during a previous stay at UC Irvine as a visiting scientist. Prior to the sabbatical they had agreed on a joint research project which involved the application of this particular technique. The fact that California has a pleasant climate also influenced his decision.

The year abroad was financed from various sources. As well as receiving his salary from the UNAM, he was the recipient of a Guggenheim award and UCLA paid him an additional salary. He experienced no special difficulties during the sabbatical.

He considered that there was no increase necessarily in the number of papers following the year at UCLA. Also he felt that the sabbatical had little impact on his sleep research other than what was intended. However, while in California he attended a talk on transplants which had a very significant long- term effect on the development of his research. On his return to Mexico, he started working in this new research area which brought him his two highly cited papers.

The fact that the collaboration with McGinty did not continue after the sabbatical had little effect on the research of Biomedic 1. Even though they do not see each other very often, they have continued their friendship and it is possible they might collaborate again through a doctoral student exchange.

Biomedic 2

Biomedic 2 received an invitation to spend a sabbatical from 1983-1984 at the Institute for Basic Research in Developmental Disabilities in New York from G.E. Gaull whom she knew from meetings in the field of taurine research. He was interested in a collaboration on the possible acceleratory effect of this substance on cell reproduction. They soon discovered that taurine affected cell death rather than reproduction and so their joint research continued along these lines. Biomedic 2 was the one to carry out the research, write up the experiments and Gaull intervened in the discussions when the important ideas were forthcoming.

The sabbatical was financed partially by her salary from the UNAM and by support from the host institution. She also mentioned that her husband was a commercial attaché in New York which helped her economic situation. She experienced no particular problems during her visit.

When asked if she thought the year in New York led to an increase in productivity, she answered that it stopped her feeling inhibited when speaking English, something she believed was very positive for the development of her career as a scientist. As far as the effect on her research, this continued very much as before although she did consider that a visit such as this one, does tend to increase the scientist's range of skills and tools which could possibly have a potentiating effect on their research. She mentioned certain conveniences in her host institution in contrast to working in Mexico, such as ready access to reagents, which not only allowed her to quickly achieve her objectives, but also made the work more pleasant. In this particular visit she had not learned a new technique but in other visits abroad, this has been the main purpose.

She is no longer in contact with Gaull as he went to work in food industry.

Biomedic 3

This scientist explained that she chose to spend her 1987-88 sabbatical in London with Diane McLaren at the National Institute for Medical Research (NIMR) at Mill Hill and with Don MacManus from Imperial College because she wanted to work at top level institutions. She had already approached these two scientists during the World Congress of Parasitology in Australia with proposals for her sabbatical.

Although McClaren worked with a different model in a different parasite, she was willing to collaborate with Biomedic 3 to test a previous hypothesis of the Mexican researcher on a possible synergism in the immune response in pigs, a study which would have been impossible to carry out in Mexico. With MacManus, she wanted to learn molecular biology to apply it to her study of cysticercosis. However, she needed additional financing as the research was expensive.

Spending the sabbatical in two different institutions was coincidental. A European Community grant to work with MacManus came through when she was already at NIMR giving her a chance to work at both institutions. Her only difficulty with the sabbatical related to organising her time and her family duties to travel between Mill Hill in North London and Imperial College in Central London. She thoroughly enjoyed the cultural life of London and her only unpleasant memory of that year was her divorce.

While with MacManus they submitted an application to the Rockefeller Foundation for a grant of half a million US dollars which was given when the British scientist had already decided to work in Australia. The work was then done with Phillip Craig at the University of Salford. Back in Mexico, this money enabled her not only to survive as a researcher but also to develop.

When asked if the sabbatical increased her productivity, she mentioned the eight or nine papers she wrote during that year. McClaren helped to revise a paper she had submitted while still in Mexico. She also received invitations to give talks at several universities and institutes around the country.

Overall the year abroad had a very significant impact on her research career. She had got her postgraduate qualifications from Mexico so it was her first experience of working in a foreign laboratory. She commented specifically on the ease of getting reagents from one day to the next, a process which in Mexico could take several months, and the wonderful library services.

With respect to continued collaboration following the sabbatical, she told me that Diane McClaren was no longer at NIMR but they met occasionally at meetings and had a warm personal relationship. She had visited MacManus and had written another grant application with him, this time unsuccessfully. Also one of her students had got their degree with him.

<u>Chemist 1</u>

The 1982-83 sabbatical at Louisiana State University of this chemist was the second of three spent at this institution, principally with Nicholas Fischer. At the time when Chemist 1 was about to take the first of his three sabbaticals, a invitation was received at the Institute of Chemistry for a postdoctoral appointment at Louisiana. He accepted the invitation although it did not occur in the years immediately following on from the doctorate which he had done in Mexico. His principal objectives during his first visit abroad were to learn, carry out research and generally broaden his horizons. This first sabbatical was financed by the postdoctoral appointment and by his UNAM salary. During the second he also received financing from the US university and from the UNAM. The main problem faced was his poor knowledge of English and he ranks his acquired knowledge of the language as one of the important benefits of his sabbaticals.

This second visit was the most productive of the three as far as he is concerned, producing eight or nine papers. He attributes this to the fact that he was already familiar with the workings of the department and that he had under his tutorage several Latin American doctoral students allowing him greater scope and more opportunity for collaborative work.

The increased productivity was the main impact of this sabbatical. When asked if the visit had any effect on the thrust and development of his research, he replied that the research was very similar to what he had been doing in Mexico. However, he emphasised that in Louisiana he came into contact with different problems, some of which he tackled during subsequent visits. The advantage of spending several sabbaticals at the same place is the possibility of continuing projects which had been left unfinished during earlier visits. Other reasons for choosing to continue his visits to Louisiana were the fact that the collaboration had been successful and that he had made important personal friendships there. He explained that although some of the work done during the sabbaticals was written up and published sometime later, all the research work in collaboration with this group was done while he was in the US.

The collaboration with Louisiana is ongoing although he is planning to take his next sabbatical at a university in Southern Mexico.

Chemist 3

This chemist spent her 1977-78 sabbatical at the Université Scientifique et Medicale in Grenoble, France with P.Crabbé and J.L.Luche. She had previously collaborated with Crabbé when he was director of Syntex in Mexico and was interested in spending the year with him at a new research complex "Organisation for Chemistry in Development" for the study of products for the treatment of diseases of little interest to the pharmaceutical companies. She experimented with a method that had been developed by the French group and which she later applied on her return to Mexico. However, she told me that the purpose of the visit was to see how they set about solving problems in synthesis and related topics, and that she had learnt a lot.

She received support from the French government, in addition to her UNAM salary. She considered the fact that her daughters were able to attend a local school as an added benefit and mentioned what a beautiful city Grenoble is. She was well received and encountered no special difficulties.

She does not believe that the sabbatical increased her productivity but mentioned that the paper she wrote with the French researchers is one of her most cited publications as it refers to a method which is still used.

She kept in contact with Crabbé until his death about seven or eight years ago, but not with Luche.

Physicist 1

Concerning his 1985-86 sabbatical in two US institutions, Yale University and Brookhaven National Laboratory, Physicist 1 explained that after completing his doctorate in Mexico and publishing his first papers on group theory, he felt the need to go abroad to immerse himself in the field of nuclear physics. A particular interest in a new model which was revolutionising the subject developed by a group at Yale, motivated him to write to

F.Iachello, the leader of this group. Iachello suggested he might also like to visit R.F.Costen and D.Warner at Brookhaven who were experimentalists, an area in which there is little experience in Mexico.

He mentioned that the atmosphere at Yale was very competitive and that he spent a lot of time working on his own or with one of the graduate students with whom he collaborated more than with the professors. Some of the added advantages of being at Yale were the wonderful library and the opportunity to attend colloquia.

While abroad he received his UNAM salary and a half salary from Yale which he considered insufficient as he took his family along with him. Apart from the financial restrictions, he encountered many difficulties on this first trip abroad related to the adaptation of the family to their new environment such as the children adapting to their new schools, the harsh winter, etc. He now tries to make only short visits to institutions abroad which have worked successfully for him.

The visit to Yale and Brookhaven coincided with a very productive time in this physicist's career. The fact that Yale was a prestigious institution made him feel that he had to prove himself to a certain extent. His interactions at Yale, particularly with Iachello who had made important contributions in four or five different areas of physics, motivated him to start research in molecular physics. He published four or five papers with Iachello and continued work in this area in Mexico establishing a small group.

Another long-term effect were the professional links he established during that stay which led to other interactions and exchanges. It was important for him to form part of the large group of researchers working in the field worldwide.

Physicist 2

Although my questions were focussed on his 1985-86 in College de France and at New York University with one month stays with J.Rowlinson at Oxford University and the University of Puerto Rico, in many instances Physicist 2 preferred to answer in general terms.

With respect to a lack of co-authored papers following his sabbaticals, he explained that he has always been in close contact with foreign scientists with whom he shares common research interests and that he has made visits to many different institutions during his sabbaticals. Nonetheless, in spite of the importance for his work of these interactions, they have not generally resulted in the publication of co-authored papers. He mentioned one particular case where he had already published one paper on the topic that he was researching during a sabbatical which was beginning to be cited. He feared that if he published a second paper on the same topic with his American host then it would be this second paper that would be cited rather than his first original one. He also feared that he would lose credit for this work which would then be assigned to the American scientist.

Many of the scientists whom he told me had been most influential for his research, are now approaching their 70s. For instance, he named John Rowlinson as one of these, but it was only after his second visit in to Rowlinson during the 1985-86 sabbatical that they wrote a paper together at the Englishman's suggestion. Physicist 2 pointed out that the style of work of Rowlinson was very different from the American approach where from the beginning a piece of collaborative work is planned specifically to produce results for the publication of a paper. In this case, Rowlinson left preprints on the Mexican scientist's desk and he invited him to meetings to put him in contact with others in the field. His initial contact with Rowlinson was at a conference in Mexico to which the Englishman had been invited by a former doctoral student, also Mexican.

He considers that all his stays abroad have had a profound impact on his research career beginning with the doctoral degree from the University of St. Andrews in Scotland. In general, the foreign scientists have acted as role models for the development of his research career. He has benefited from watching the way they work and how they function within their own scientific communities. They have also influenced his choice of research topics. He described his visits to foreign institutions as like breathing fresh air.

The 1985-86 sabbatical was partially financed by a Guggenheim scholarship and by a prize from the Organisation of American States. He considered that this sabbatical increased his productivity as he published an important number of papers in that period. However, as he explained, this was totally divorced from his objectives. He also mentioned that his family has always been keen to travel abroad, more specially to Europe as his wife is Scottish and the ideal situation had been to visit various places. It never occurred to him to think that these visits would bring him extraordinary benefits, such as ideas that he would otherwise never have thought of, for instance. Although in retrospective he finds that some of these things do actually occur but he neither expects it nor does he plan for it. He feels that just getting out of the normal routine and working in another place is very stimulating and that it is possible that this alone could lead to increased production of papers.

When asked if he was still in touch with the scientists he visited during the 1985-86 sabbatical, he told me that Rowlinson is now retired.

<u>Astronomer 1</u>

The 1975-76 sabbatical of this scientist and his astronomer wife, was equally divided between making observations at the Kitt Peak National Laboratory in Tucson, Arizona and working with M.J. Seaton of University College, London (UCL). Seaton is one of the foremost researchers in atomic physics, two thirds of his work is in this field and one third in astronomy. Astronomer 1 wrote to Seaton when he was a student at Berkeley and later met him personally during a visit to London in 1970. Because the Englishman's work is very abstract, Astronomer 1 was mainly interested in its application to astronomy.

The half sabbatical at UCL was organised by Seaton who secured the logistic and extra economic support from the Royal Society. The visit was also financed by Conacyt and the UNAM salaries. Seaton invited the Mexican couple to exclusive gatherings of astronomers and they got to know the stream of astronomers from different parts who were passed through UCL at that time. Astronomer 1 commented that the objectives of the visit to UCL were to bring the Mexican scientists up-to-date, to observe new ways of working, to learn new techniques and to establish a closer relationship with Seaton's group. There was the added cultural interest of living in London.

When I asked him why the articles published with Seaton and the group at UCL did not appear until few years after the visit, he replied that during the sabbatical in London they were working with data from Kitt Peak and from earlier observations in Chile. Astronomer 1 still periodically visits Seaton when in London and he considers that the sabbatical at UCL opened a door for him and his wife.

The purpose of the visit to Kitt Peak National Laboratory was to carry out observations using new technology and to renew relations with American colleagues. No co-authored articles resulted from this stay but they gathered useful data. Astonomer 1 also felt that the visit gave him and his wife international visibility. He mentioned that in a period of six months about 250 scientists pass through this laboratory.

Astronomer 1 considered that the visits to Kitt Peak and UCL increased the quality, rather than the quantity of their work.

Astronomer 2

This scientist spent a six month sabbatical at the University of Laguna in Tenerife in 1985 with A. Mampaso. On a previous visit to Mexico the Spanish astronomer had invited her to Tenerife to help them develop their research work at the newly formed astrophysics institute. She therefore went to pass on her knowledge to other scientists. A common language allowed her to give a one month series of lectures and the rest of the time was spent doing research and looking up the literature on active galactic nuclei.

She received a salary from the Spanish institute as well as her UNAM salary. She encountered no particular problems with the sabbatical. She considered that her productivity increased following the visit as she had embarked while in the Canaries on a review paper. She also remarked that there was no interferences as there would have been in Mexico.

With respect to the impact of the sabbatical on the development of her research, she mentioned the access to good instrumentation in Tenerife which merited a return visit after the sabbatical. She developed certain models as a result of these observations and considered it was important, as she put it, to live with the problem. The collaboration with the Spaniards is still active and they have another paper in the pipeline.

Astronomer 3

Astronomer 3 spent a six month sabbatical at the University of Heidelberg in 1980 for the purpose of working with a particular group of German scientists. He had some unusual observational data that he wanted to reduce and analyse using theoretical models that were being developed by this group at that time. He had got to know these scientists at international meetings.

The University of Heidelberg paid him a salary and travel expenses. He considered the visit successful from a scientific point of view but did not enjoy his stay there very much as he found German society too hermetic. He does not feel that the sabbatical increased his productivity but the visit was important in the sense that it gave him access to computers with graphic capabilities necessary for an adequate presentation of his data. He described the impact of the sabbatical on his research career as positive but not definitive. There are very few continuing effects of the visit on his research activities and he has had very little professional contact with the German group since returning to Mexico.

<u>Geoscientist 1</u>

Geoscientist 1 divided his 1982-83 sabbatical equally between the Pierre and Marie Curie University in Paris and Milan Polytechnic. At that time he was interested in sources of seismic activity and rupture mechanics so he went first to Paris to work with R. Madariaga who is the expert on the subject whom he knew through his publications. He attributes the lack of co-authored articles to the fact that at the beginning a true collaboration was impossible as he was new to the field and was still at the learning stage. Since then their sporadic collaboration has been hampered by the Mexican scientist's busy schedule and a lack of potential collaborators. Nonetheless, they are working on some joint papers.

In Italy he worked with E. Faccioli and R. Fregonese on what he described as certain applied topics which resulted in a co-authored paper. He was familiar with their research and had met Faccioli some years before when he was the UNESCO representative in Mexico. The financing for the sabbatical was obtained from different sources: salary and sabbatical grant from the UNAM and salaries from both foreign institutes.

During the sabbatical he found time to work on a single authored paper on the development of three dimensional models which has been one of his most successful. Other very positive effects of the sabbatical he described as the opportunity to improve his knowledge of French and to learn Italian. He worked like a madman and in Italy met his future wife.

<u>Geoscientist 2</u>

For his 1979-80 sabbatical at Imperial College, London, Geoscientist 2 took advantage of a joint programme between the Royal Academy and the Mexican Academy of Sciences at a time when he was looking for a place to go for private reasons. He was interested in spending time among engineers which had been his original field.

At Imperial his counterpart was Prof. Ambraseys, a distinguished earthquake engineer, whom he had already met and who, as Geoscientist 2 pointed out, left him very much to his own devices but was always available for consultation. When asked if his intentions were to work more closely with Ambraseys, he told me he did not really know what he expected. It was sort of a troubled time in his family life. His principal objective during the sabbatical was to spend some time at a first rate British institution. He knew of Imperial's reputation and their focus on the technological side which is what he was looking for.

He explained that the decision to spend a year in an engineering department had an important but delayed effect on the development of his research and on his productivity. In 1985 when the big earthquake struck Mexico he was ready to go back to the more applied area of engineering and these two events radically changed the course of his research.

He encountered no special problems and described his year in London as splendid, wonderful. He mentioned more than once that he thoroughly enjoyed walking around the City and getting to know it well. He still sees Prof. Ambraseys at meetings and they exchange reprints.

Geoscientist 3

This scientist's 1980-81 sabbatical was spent at University of California at San Diego with Jim Brune whom he described as a famous seismologist with innovative ideas. Brune had been carrying out experiments in Mexico with other members of the UNAM group since the 70s. Later he and Brune talked about the possiblity of joint research projects and that the best way for these to be carried out would be for the Mexican scientist to spend his sabbatical in California. There he met John Anderson with whom he collaborated on a second project. Geoscientist 3's intention during the sabbatical was also to bring himself up to date, see new things, to extend his international contacts and to get away from things in Mexico.

The visit was financed by his UNAM salary and by money from the Californian institution. This naturalised Mexican scientist had previously studied in the US so it was not his first encounter with the American culture although he did remark on differences with Mexico.

He was not sure if the year abroad increased his productivity. It has been his only sabbatical as later on, he said, it is more difficult to go abroad with growing children. Also as an experimental scientist his observational material is in Mexico. He considered that the shorter visits of three months he has made abroad in recent years are more beneficial to his research as they have involved specific goals, although it is sometimes difficult to finish the work in so short a time. He only goes abroad when he feels there is something he can learn there that can contribute to the understanding of his research problems in Mexico.

When I asked him if he thought that sabbaticals abroad were less necessary for Mexican scientists like himself who were well established than perhaps to those who are just starting a research career, he said he supposed so. However, the opportunity to get away from the frenetic rhythm of work in Mexico and to have time to think is always tempting given the right circumstances.

With regard to the overall impact of the sabbatical, Geoscientist 3 considers that this was significant mainly because it was the beginning of an important ongoing collaboraton with the group in California. He also mentioned the two articles that resulted from the visit. He felt that he probably would have been involved in these projects regardless of the sabbatical.

He mentioned that he continues to write papers with members of the original group in California when data are forthcoming from the seismic networks which require interpretation. However, these days the two sides work independently and in some ways are in competition with each other.

10.7 Discussion

The present bibliometric findings point to increased international co-authorship following sabbaticals spent abroad but suggest no significant effect on the total production of papers, at least not in this elite group of scientists. The fact that in all but one case (Geoscientist 2), at least two papers were published in co-authorship with the sabbatical institutions, suggests that positive interactions occured as a result of these visits. However, these collaborations did not lead to general higher productions of papers but rather publication rates appeared to follow their normal course.

During the interviews only two of the scientists mentioned an important number of papers published as a direct result of the sabbatical although several believed that their long term productivity was positively affected by what they had learnt or been exposed to during their visit abroad. In some cases it was having the right conditions, especially the time, to write up earlier work and to work out new ideas. Some mentioned changes in their research interests which radically affected the course of their research career which is one case was purely circumstantial.

Some had well defined objectives like learning a new technique, a new field, using specialised equipment not available at that time in Mexico, obtaining information or working with people who could help them with a specific problem like interpretation of data or carrying out a specific piece of research while others had more vague intentions, sometimes associated with getting away from existing professional or family situations.

For the three scientists who had done their postgraduate education entirely in Mexico, the sabbatical was their first experience of working in a foreign institution and was particularly significant. An analysis of Brazilian biochemists found that the most productive were those who had done a postdoctoral period in a foreign university following on from a Brazilian PhD (De Meis and Longo 1990).

Nearly all of the scientists interviewed commented on the important contacts made during the sabbaticals. In some cases these introductions then caused a ripple effect widening and strengthening their associations within the invisible colleges of their respective fields. Some of the host scientists, particularly the more established members of international scientific community, had acted as a kind of godfather to the Mexican scientists, introducing them to the leaders in the field.

In their study on international contact and research performance in all fields in leading Norwegian universities, Kyvik and Larsen found less effect on the number of articles published between those professors who had spent a long-term research stay (one term or more) abroad and those who had not , than with respect to whether or not they had attended conferences abroad (Kyvik and Larsen 1994). Assuming a causal effect between research stays abroad and productivity, the effect is very small on the total output of publications, but strong on international publishing (defined by these authors as publication in a non-Scandanavian language). They found this tendency to hold for the different age groups as well as for the various fields of learning. The importance for productivity of keeping in touch with foreign colleagues is evident from the fact that, in the absence of this activity, there were virtually no differences between those with stays abroad and those who have spent their careers exclusively at Norwegian universities.

In their study on Mexican scientists Carvajal and Lomnitz found that the period of high production is associated with the research carried out at foreign universities. With the passage of time it becomes more difficult for the researchers to keep up with the latest findings in their respective areas, equipment is difficult to acquire and maintain, and, in the face of these obstacles, many abandon the scientific career. Those who overcome these hurdles by securing minimal infrastructure, manage to reestablish their scientific production (Carvajal and Lomnitz 1981).

The highly productive UNAM scientists analysed in the present study are already established researchers with a solid production of international papers. It is therefore, perhaps, not suprising, in the light of these authors´ opinions that no significant increase in production of papers was seen following sabbaticals. It is possible that, in the case of less visible scientists, sabbatical and other leaves of absence will show an effect, not only on co-authorship patterns, but also on the total number of papers published. Contact with foreign groups could act as a catalyst and lead to an increase in the publication rates of papers. If this were the case, then it could be argued that less productive scientists would be more likely to benefit from sabbaticals and other visits abroad than the more established ones.

Although the total number of articles follow the sabbaticals analysed in the present study did not increase the nature of their publications underwent a change as is clear from Table 10-3. As could be expected there was a significant increase in the number of internationally co-authored papers of the scientists as a group and in the number of international institutional co-authorships indicating greater indices of international collaboration and visibility follow sabbaticals. This was particularly notable in the case of Physicist 1 who during the interview expressed the view that his sabbatical at Yale coincided with a very productive time in his career. He also mentioned a productive collaborative partnership with a scientist he worked with at this prestigious US institution.

However, a significant increase in the number of international institutional co-authorships following sabbaticals did not occur in all individual cases. Physicist 2, for instance, who visited four different institutions in four different countries during his sabbatical mentioned during the interview that in spite of the importance of his interactions with foreign scientists during sabbaticals and other visits, these have not always led to the publication of co-authored papers. It is possible to speculate in this particular case that the four visits might have been too short to carry out any productive collaboration at least in the short-term.

It is obviously unwise to base policy decisions solely on quantitative indicators, especially those emphasising only short-term gains. The benefit of a stay abroad could also be seen in terms of an increase in the number of papers in the long-term, or, more importantly in an improvement in the quality of work published, benefits which were mentioned by some of the Mexican scientists during the interviews. Collaboration in science has been associated with a number of motivations, of which increased knowledge and the exchange of skills and data (Beaver and Rosen 1979a) are among those most often put forward. In order to make science more productive, Gaillard maintains that scientists and scientific data should be constantly on the move from country to country (Gaillard 1991).

One of the ways of securing access to resources and funding is through collaboration (Pao 1992) which is particularly important for scientists from DCs whose research often suffers for lack of adequate financing and equipment. Several of the scientists, and particularly the astronomers, mentioned availability of certain facilities for carrying out their research available at the host institutions. Only Biomedic 3, however, specially mentioned obtaining important research financing as a result of activities realised during the foreign sabbatical.

All 13 scientists has secured additional financing to allow them to go on sabbatical, in most cases accompanied by their families. More often than not they received some support from the host institution and a few had secured international scholarships or awards. Geoscientist 2 was the only one whose visit was facilitated by an existing agreement between a Mexican institution and the foreign country.

Many of the scientists mentioned social and/or cultural influences as varying positive and negative factors in the choice and outcome of their sabbaticals. Getting to know a place, learning or perfecting a language, and cultural activities were seen as important aspects which were used as markers to indicate successful and enjoyable visits. Family situations such as the age of the children, the willingness of the wife to spend a year away from home or the situation of the husband were often mentioned as variables which had to be taken into consideration when planning a sabbatical abroad.

Visits abroad have already been shown to foment and cement relationships between scientists. Daily working contact with foreign scientists makes crucial allies (and often lasting friendships), invaluable in the highly stratified and, sometimes hostile, world of international science. Developing country scientists gain entry into the international scientific community through contact with foreign colleagues (Schott 1991; Schott 1993; Schott 1995). Spinoffs from visits abroad also include the exchange of graduate students and the invitation of other conationals to collaborate in bilateral or multilateral projects. Visits also allow intensive use of libraries and other information resources and, often, for developing country scientists, a general feeling of being at the centre of research activity in their particular fields. In the present study all 13 scientists mentioned at least one of these circumstances, particularly with respect to the wonderful library facilities and the exchange of graduate students.

The important number of international co-authorships in the present study apparently not related to visits abroad, indicate that these highly productive researchers have established a whole series of international contacts above and beyond those resulting from prolonged research stays abroad. These "other" links could have affected the findings with respect to the effect of sabbaticals on the different parameters measured in this study. Scientific links, like all social interactions, tend to multiply, especially in the present climate of increased collaboration and mobility of scientists on a worldwide scale. One of the difficulties of the present analysis was trying to separate out the influence of the sabbatical visits from other types of shorter visits, occurring just before or just after the sabbatical leaves of absence.

From some of the comments made during the interviews, it seems possible that in the case of older scientists sabbaticals are less of an option, partially due to the responsibilities associated with having older children and greater difficulty in taking a long break from a busy and ongoing research schedule. Shorter and more frequent visits abroad to maintain contact with foreign research scientists have proved a viable alternative for two of the scientists interviewed.

An interesting finding from the present analysis is the fact that the peak in the number of papers co-authored with the sabbatical institutions occurred during the two year period following the termination of the stay abroad (Figure 10-1). This could be due to the publication lag between the submission of a paper and its eventual publication. In spite of this, some papers did get published during the two years of the sabbaticals. The fact that most sabbaticals take place during the academic year which begins in the autumn of the first year and ends in the summer of the following year, means that a year's sabbatical will most likely straddle two calendar years, giving papers an extra six months to be published during the second calendar year of the sabbatical period.

The periods of two years taken prior, during and after the sabbaticals taken in the present study seem to be adequate for measuring the effect of sabbaticals on different research and publication parameters and could be used to extend this line of enquiry. Of particular interest would be a comparative study of the effects of sabbaticals or other prolonged visits to institutions abroad between different groups of scientists, particularly, as previously suggested, between productive and not so productive scientists.

In a larger study it would also be interesting to differentiate between the different types of visits made, ranging from postdoctoral training to sabbatical leaves. These systems have been tested in the industrialised countries for many years already, but very few DCs, for instance, have officially adopted the system of regular, paid sabbatical leave (Gaillard 1991). The results of a Dutch study suggest that postdocs are too early on in their careers, and their presence in a research group too short, to expect them to establish and maintain international contacts (Van Steijn, Postel et al. 1993). Visiting professors were reported to be a more effective way of introducing new ideas and consolidating international contact. However, this does not alter the idea that postdocs might be expected to establish international contacts more easily later on in their careers.

Researchers and professors at the UNAM may take a year's paid sabbatical after completing six years of service or a six month paid sabbatical after three. Conditions and requirements will vary in individual cases in accordance with the norms of the different collegiate bodies involved. Scientists are normally expected to spend their sabbaticals abroad in "centres of excellence" in their own particular fields, or, alternatively, encouraged to spend their time developing and fostering research in universities and institutes outside the main centres in and around Mexico City. Both the UNAM and CONACYT have limited funds available to compensate for the inadequacy of Mexican salaries in an international context.

From the bibliometric findings alone, it can be concluded that sabbatical leaves of absence had a positive effect on the career development of these 13 scientists, a conclusion supported by the opinion of the scientists themselves. However, in the case of these highly productive scientists, the effect could not be generally attributed to an increase in the number of papers published. While bibliometric analysis reflected increased levels of international co-authorship which are known to increase the visibility of developing country scientists within the international scientific community, the scientists themselves named many benefits among which were the important new contacts made while at foreign institutions.

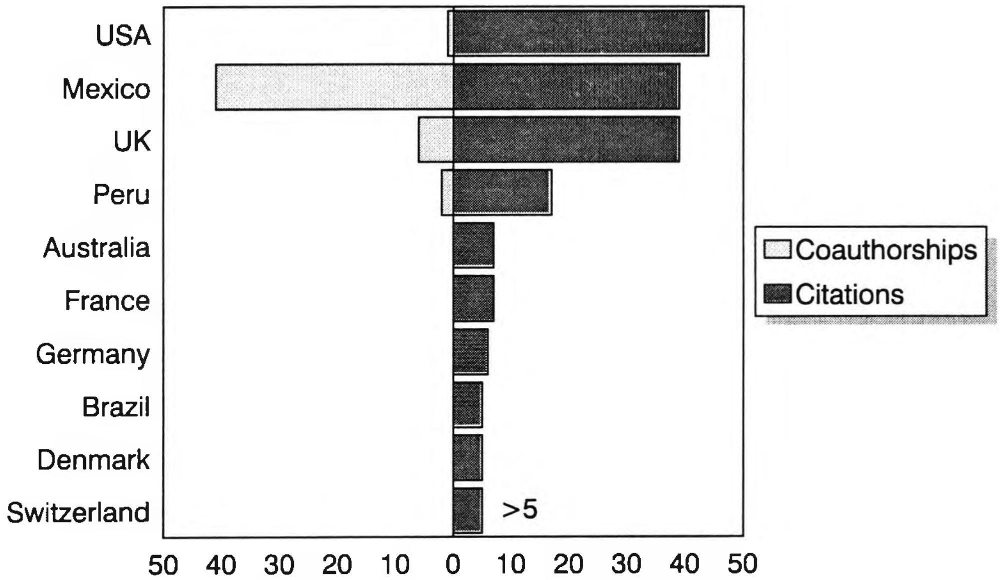
Chapter 11

Links between Co-authorship Patterns and Citation Patterns

11.1 Collaborating Countries and Citing Countries

Biomedic 3

Biomedic 3 showed co-authorship with only the four top countries that most cited her work, namely the USA, Mexico, the UK and Peru (Figure 11-1). No co-authorships were found with other countries during this period (1985-1989) except for one collaboration with Israel. Apart from Australia and Brazil all other citing countries with more than five citations to this scientist's work were European. The important national network established by this scientist is apparent from the large number of co-authorships identified with researchers from outside her own UNAM institution, as well as the volume of citations given to her work by national colleagues.



Coauthorships 1980-1989 (levels 2-5) , Citations 1985-1993 to 1985-1989 papers

Figure 11-1. Biomedic 3. Number of institutional collaborations and citations according to country.

Chemist 1

Chemist 1 received an important number of citations from Spain as well as the USA and the UK (Figure 11-2). As with Biomedic 3 national citations were among the most numerous. Co-authorships during this period were exclusively with national colleagues or with those from the USA. A certain balance can be seen with respect to the number of co-authorships with the USA and the number of citations (12 co-authorships and 21 citations with colleagues north of the border).

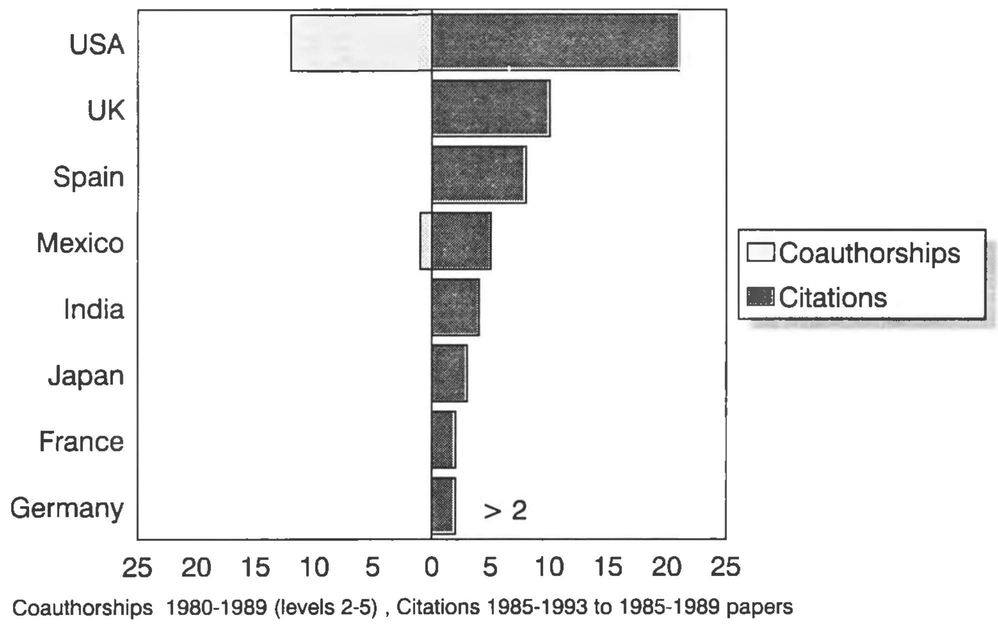


Figure 11-2. Chemist 1. Number of institutional collaborations and citations according to country.

Physicist 1

Physicist 1 also showed a certain equilibrium between the number of co-authorships with the USA and the number of citations, 26 co-authorships compared to 43 citations (Figure 11-3). With the exception of France, Physicist 1 showed co-authorships with the top five citing countries. Few co-authorships with national institutions were reflected in a small number of Mexican citations.

Physicist 2

Physicist 2´s 1985-1989 co-authorships were all with colleagues from his own institute or with other UNAM institutes (12 co-authorships) except for one co-authorship with the UK (Figure 11-4). Both the UK and Mexico were among the top citing countries. As in case of Physicist 1 (Figure 11-3) the USA, Germany and the UK were the most citing countries.

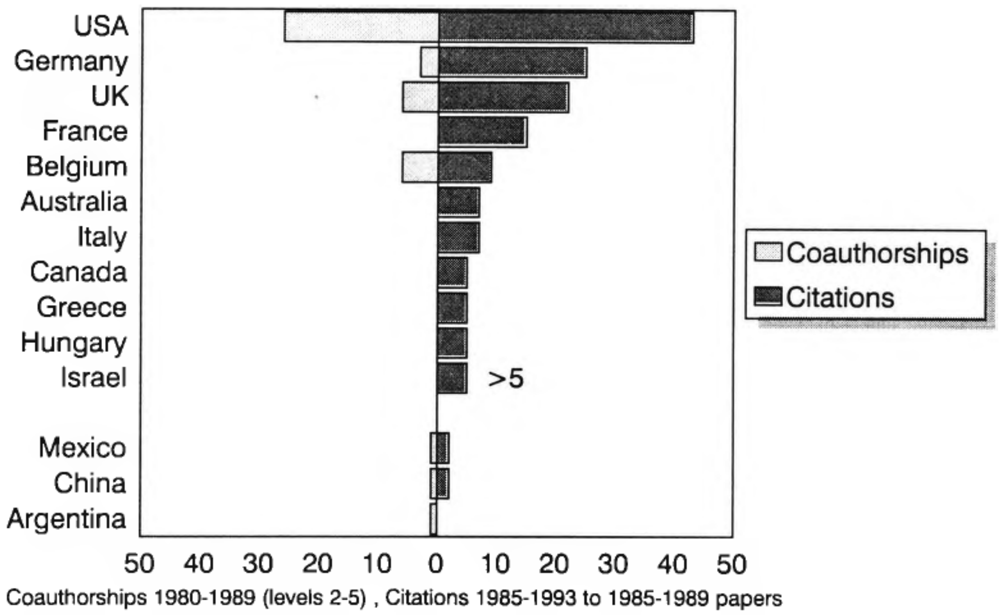


Figure 11-3. Physicist 1. Number of institutional collaborations and citations according to country.

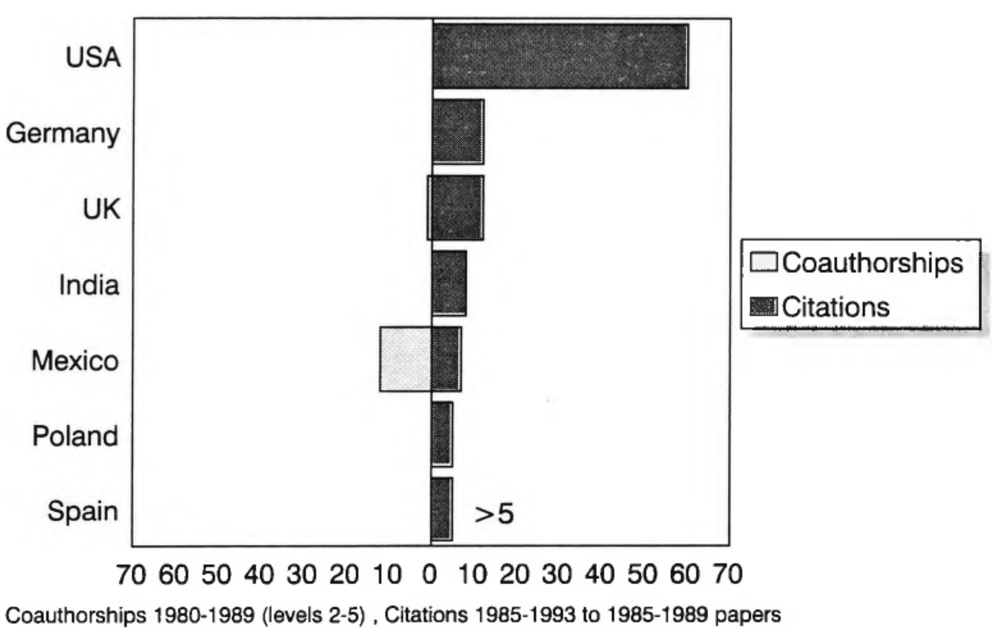


Figure 11-4. Physicist 2. Number of institutional collaborations and citations according to country.

Physicist 3

With respect to Physicist 3, citations from colleagues from other national institutions occupied second place after the USA (Figure 11-5). One co-authorship with France was offset by five citations. Five co-authorships with Colombia and three with Puerto Rico did not lead to citations other than self-citations to papers written with Physicist 3.

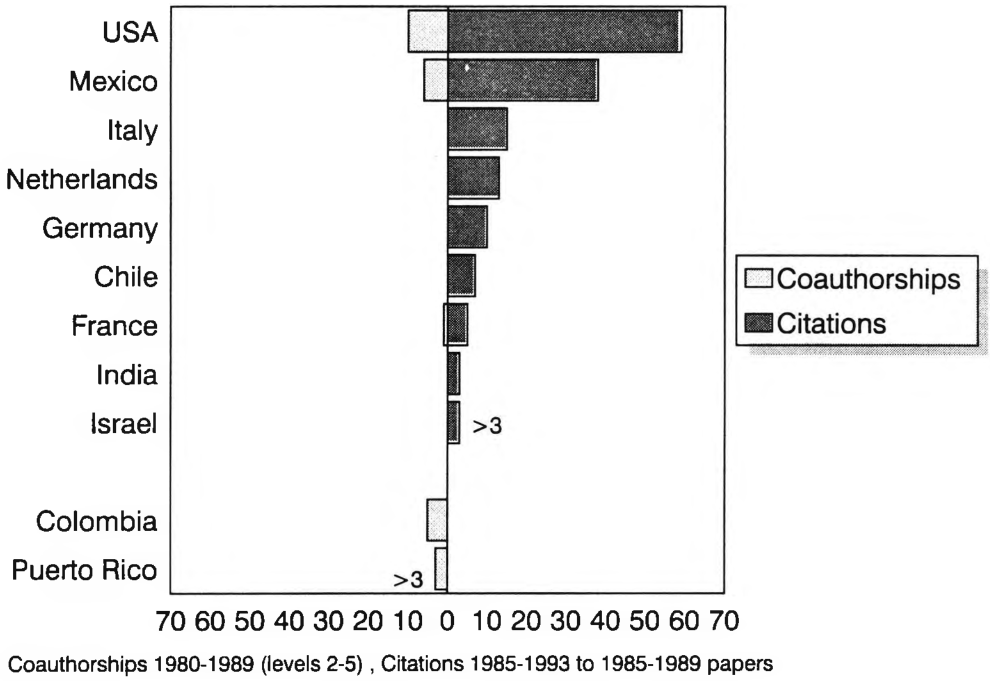


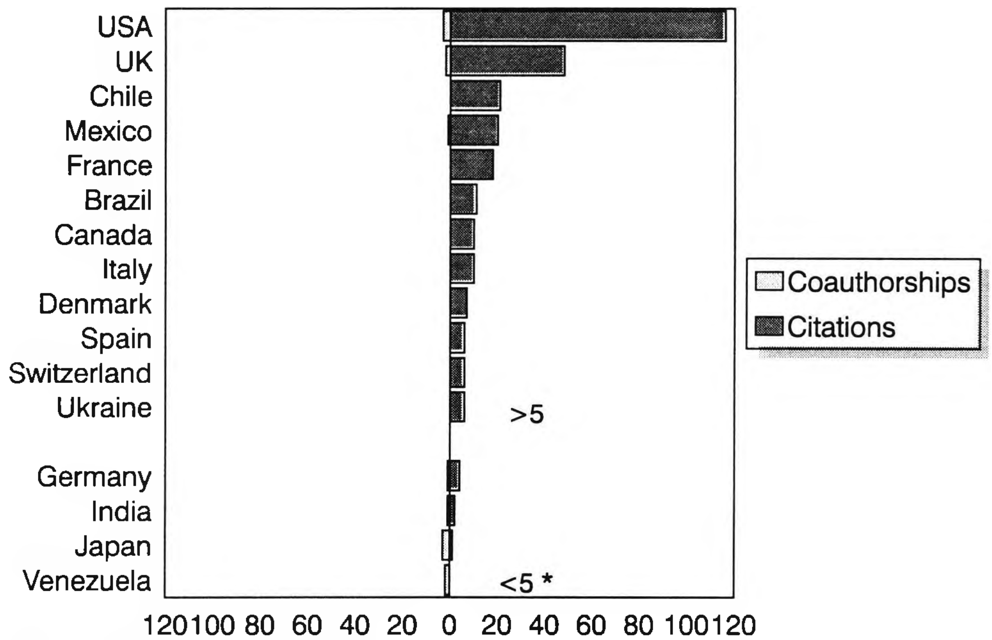
Figure 11-5. Physicist 3. Number of institutional collaborations and citations according to country.

Astronomer 1

Astronomer 1 had high levels of citations with the USA and the UK, with relatively little co-authorship in comparison; three co-authorships and 116 citations with the USA, and 2 co-authorships and 48 citations with the UK (Figure 11-6). Collaboration with Germany, India, and Japan led to a small number of citations from these countries.

Geoscientist 1

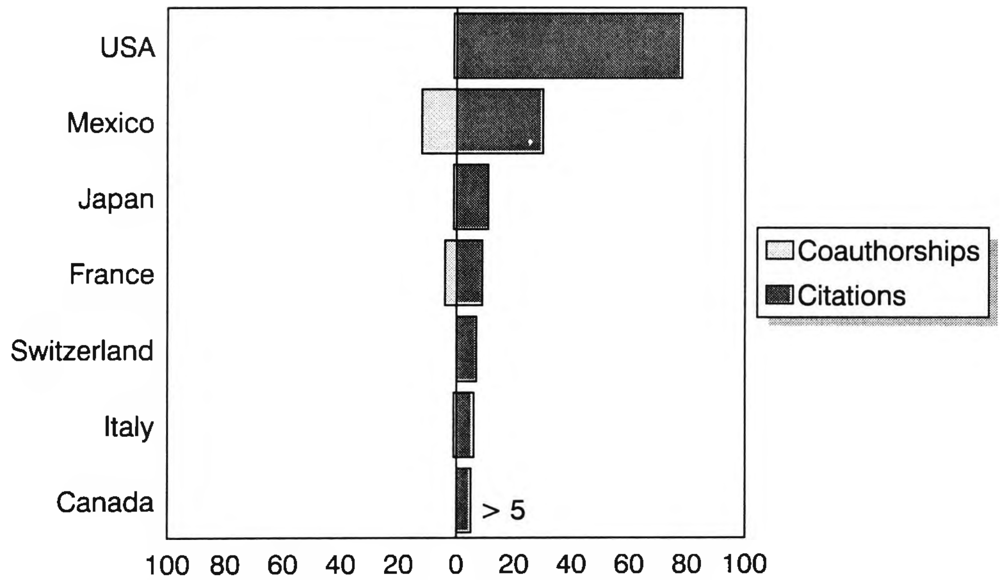
Co-authoring countries were also among the most citing in the case of Geoscientist 1 (Figure 11-7). All countries with which this scientist had co-authored from 1985-1989 were also citing countries, with the top places being occupied by the USA, Mexico, Japan and France.



*where coauthroships were also found

Coauthorships 1980-1989 (levels 2-5) , Citations 1985-1993 to 1985-1989 papers

Figure 11-6. Astronomer 1. Number of institutional collaborations and citations according to country.



Coauthorships 1980-1989 (levels 2-5) , Citations 1985-1993 to 1985-1989 papers

Figure 11-7. Geoscientiist 1. Number of institutional collaborations and citations according to country.

11.2 Collaborating Institutions and Citing Institutions

Biomedic 3

The two top citing institutes of Biomedic 3's work were both national institutions (Figure 11-8). Important levels of citations were received from the two UK institutes, National Institute for Medical Research at Mill Hill and Imperial College, London where this scientist had spent a postdoctoral period from 1987-1988, and the Center for Disease Control in Atlanta with which she had collaborated. Other co-authoring national institutions did not cite papers by this author, either co-authored with them or otherwise.

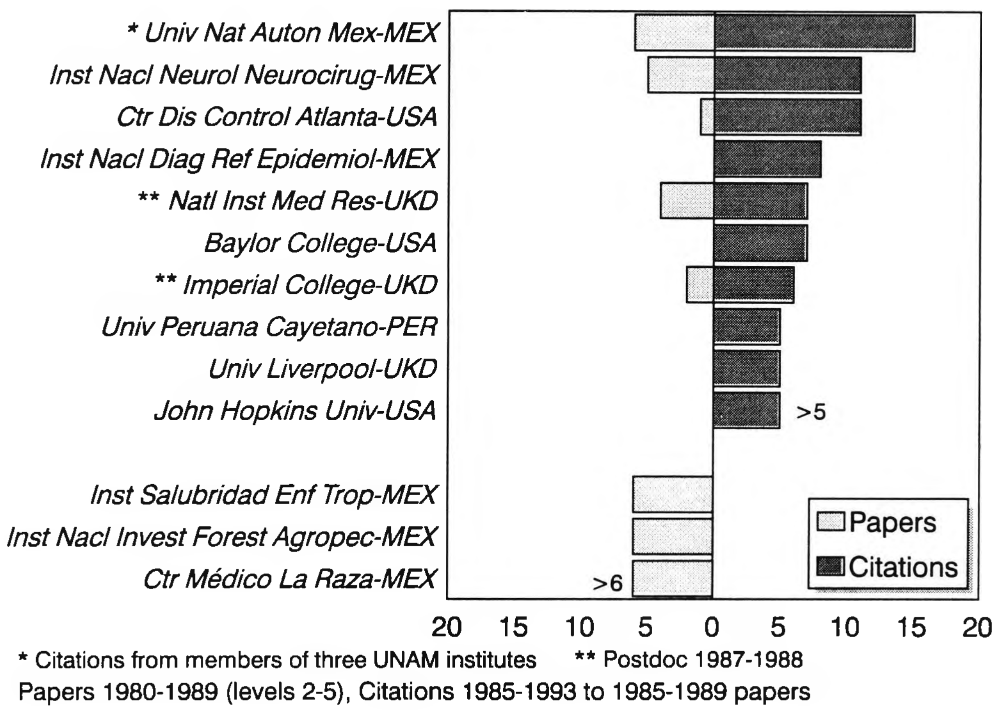


Figure 11-8. Biomedic 3. Number of institutional co-authorships and citations

Chemist 1

Chemist 1 received the greatest number of citations from the Spanish Institute of Natural Organic Products in Tenerife followed by the USDA Southern Region Research Center in New Orleans (Figure 11-9). Louisiana State University, where this scientist had spent three consecutive sabbaticals and which showed the highest level of co-authorship outside his own UNAM institute, also figured high in the list of citing institutions.

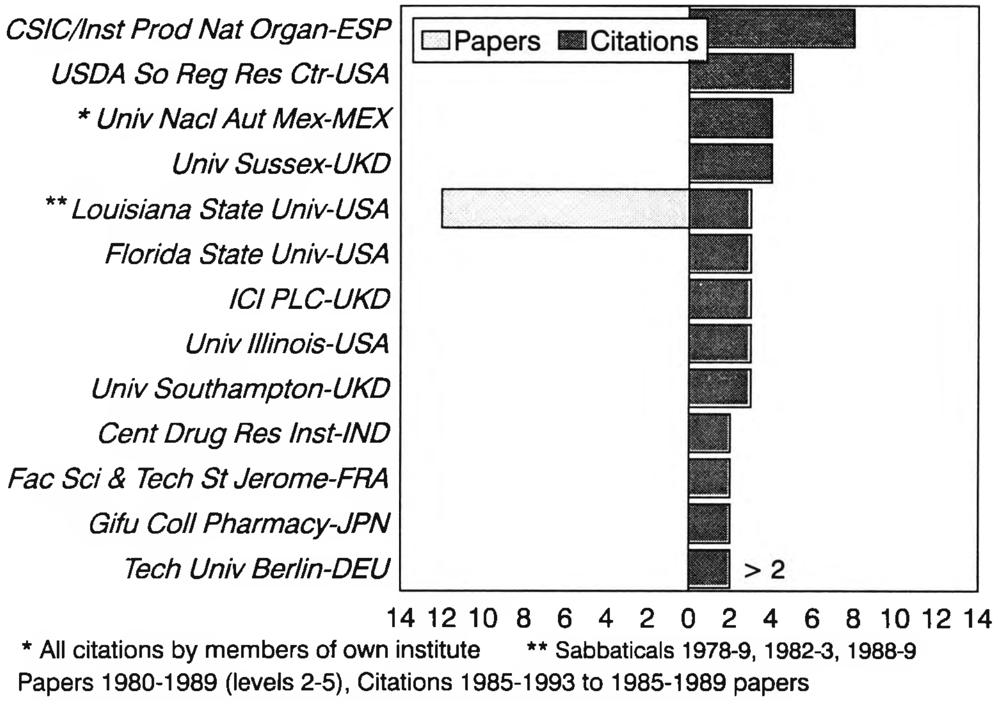


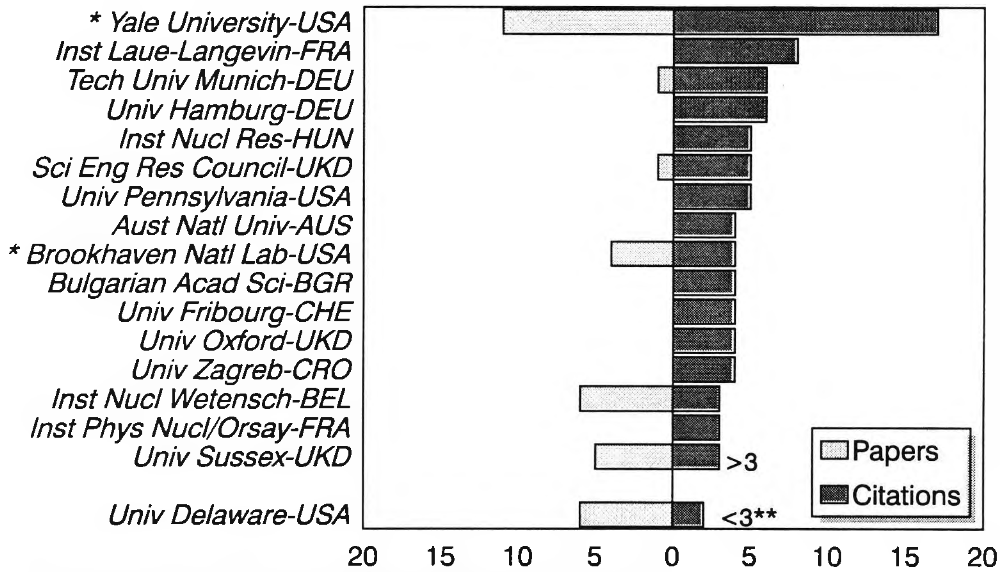
Figure 11-9. Chemist 1. Number of institutional co-authorships and citations

Physicist 1

When looking at the relationships between collaborating and citing institutions of Physicist 1, the dominant role played by one institution in particular, Yale University, is apparent (Figure 11-10) This scientist spent eight months as a visiting professor at this prestigious US institution in 1985-86. Previously he had spent 2 months at Brookhaven National Laboratory, a visit that produced several co-authored papers and could be related to the subsequent citations received from this institute. Co-authorships with the Technische Universität München in Germany, the Science and Engineering Research Council, and the University of Sussex in the UK, and the Instituut voor Nucleaire Wetenschappen in Belgium, also related to important citation rates by scientists at these institutions.

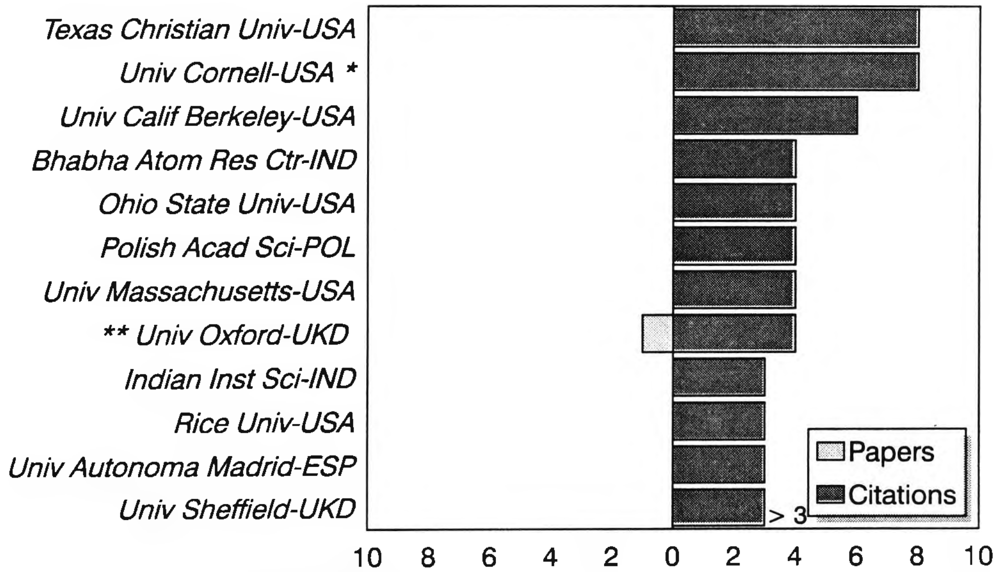
Physicist 2

Physicist 2´s lack of international co-authorship in this period, except for one paper with the University of Oxford, did not prevent his work from being cited by institutions in different parts of the world (Figure 11-11). A postdoctoral visit to Cornell University in 1979 produced no co-authored papers, but might have influenced the considerable citation rate given to his 1985-89 work by members of this university. Also this author travelled extensively during his 1978-79 and 1985-6 sabbaticals visiting a total of five institutions in four countries (UK, USA, France and Puerto Rico) during these two years.



* sabbatical 1985-6 **where coauthorship was also found
Papers 1980-1989 (levels 2-5), Citations 1985-1993 to 1985-1989 papers

Figure 11-10. Physicist 1. Number of institutional co-authorships and citations

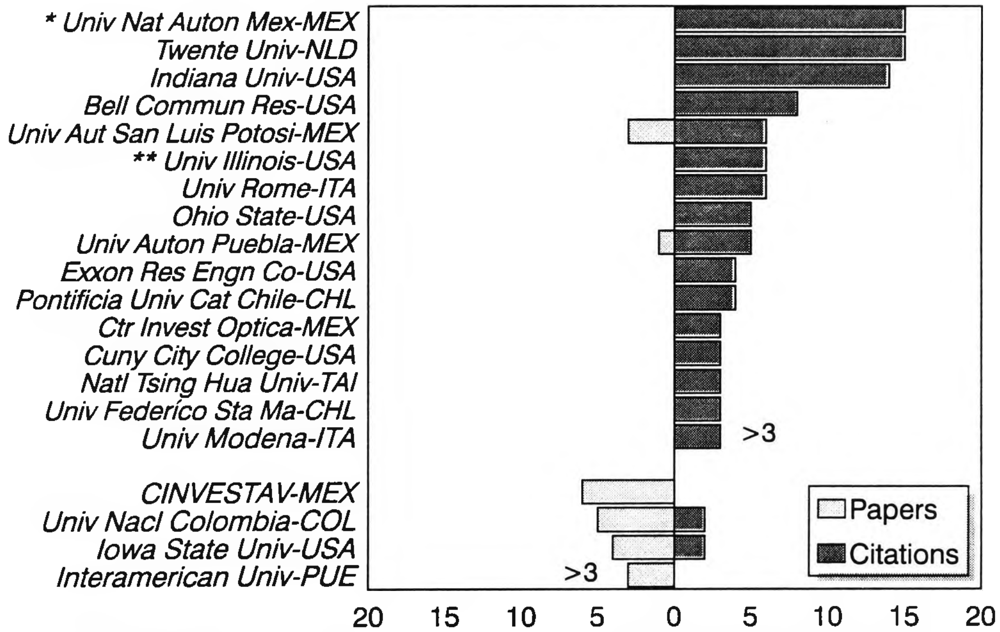


* Visit 1979 ** Visits 1979 and1985
Papers 1980-1989 (levels 2-5), Citations 1985-1993 to 1985-1989 papers

Figure 11-11. Physicist 2. Number of institutional co-authorships and citations

Physicist 3

Physicist 3, as with Biomedic 3 (Figure 11-8), received most citations from other institutes within the UNAM, with other Mexican institutions also appearing among the most citing (Figure 11-12). However, most of the UNAM citations were by Physicist 3´s co-authors to their co-authored papers. An equal number of citations was given by the Twente University in Holland to which this scientist has no apparent link. Although no co-authored papers were published in this period with the University of Illinois where Physicist 3 had completed his PhD in 1971, several citations were given by this institution. Co-authorships with the CINVESTAV of the Mexican Instituto Politécnico Nacional (IPN) can be related to the sabbatical that this scientist spent at this institution in 1986.



* 14 were citations by coauthor to coauthored papers ** PhD from this university 1971
Papers 1980-1989 (levels 2-5), Citations 1985-1993 to 1985-1989 papers

Figure 11-12. Physicist 3. Number of institutional co-authorships and citations

Astronomer 1

The greatest number of citations received by Astronomer 1 were from his own institute, followed by those given by the University of Chile and two UK institutions, the Royal Greenwich Observatory and University College, London (Figure 11-13). This scientist had previously been a visiting researcher to the latter institution. Two co-authored papers with the Centro de Investigaciones Astronómicas in Venezuela were not cited by other authors.

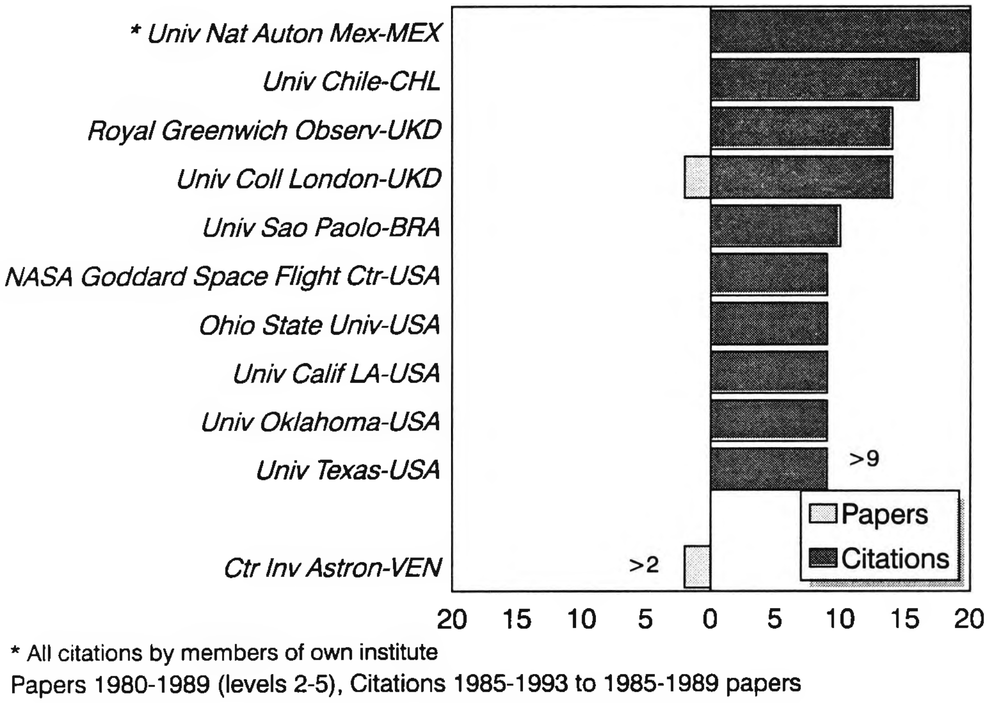


Figure 11-13. Astronomer 1. Number of institutional co-authorships and citations

Geoscientist 1

Geoscientist 1 also received the highest number of citations from colleagues at the UNAM, both from his own institute and from two others (Figure 11-14). The next largest number of citations was from the University of Southern California in Los Angeles, where this scientist had been a visiting professor both in 1985 and again in 1987, visits which led to one co-authored paper between 1985 and 1989. The Observatoire de Grenoble of the Université de Joseph Fourier published four co-authored papers with Geoscientist 1 and cited his papers five times. A second Mexican institution with which this scientist had co-authored, also figured among the most citing institutions. Two other national institutions producing co-authored papers with Geoscientist 1, did not appear among the citing institutions during this period.

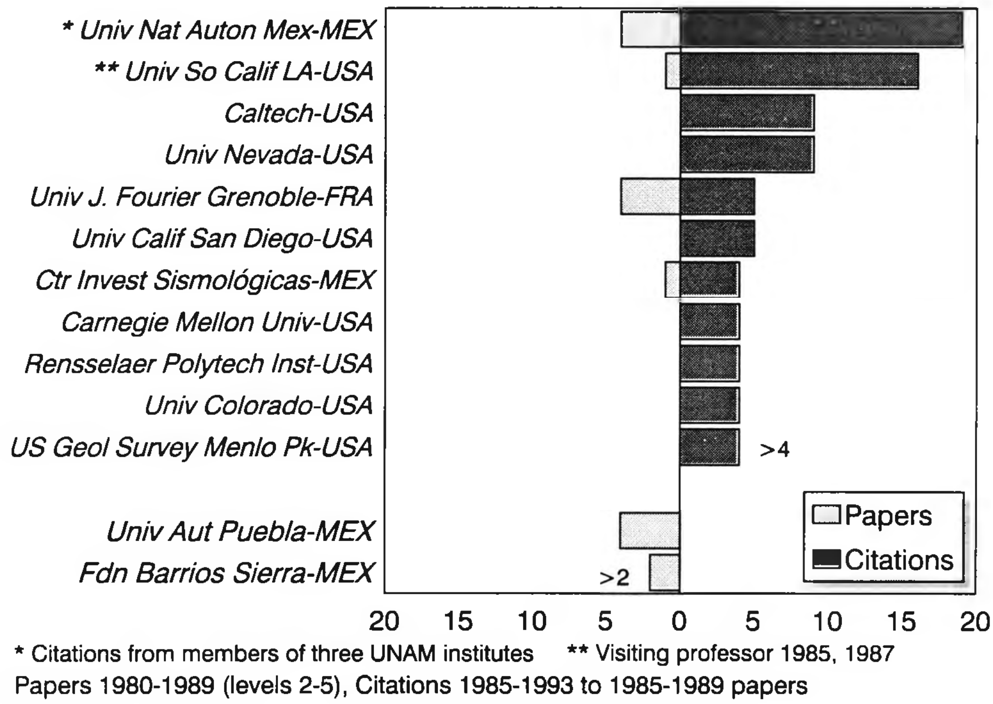


Figure 11-14. Geoscientist 1. Number of institutional co-authorships and citations

11.3 Co-authors and Citing Authors (Bibliometric and Interview Results)

Biomedic 3

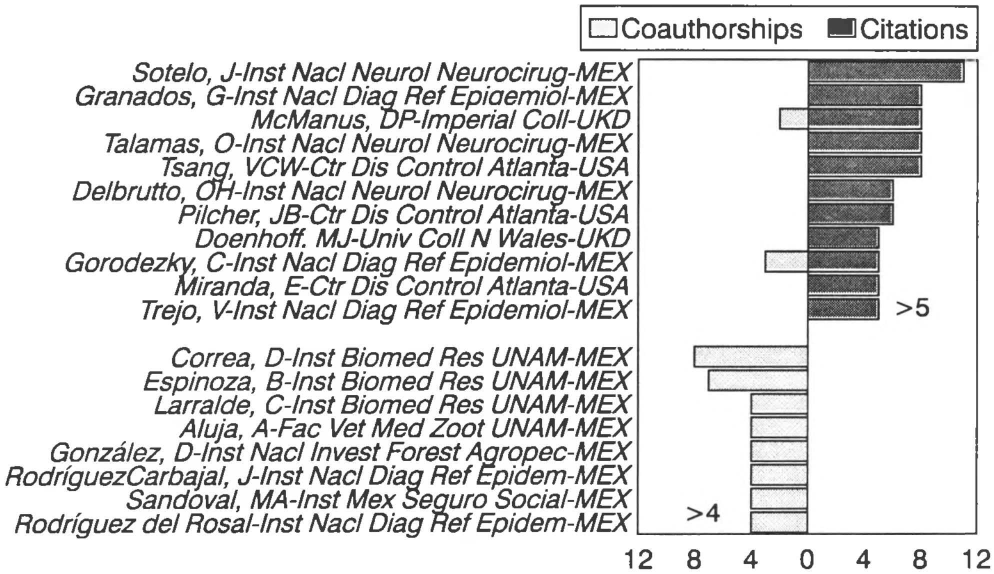
Six of the 11 authors who most cited Biomedic 3's work were from national institutions other than the UNAM (Figure 11-15). Only one national colleague, C. Gorodezky, cited this scientist´s work as well as co-authoring with her. A strong national component was apparent in Biomedic 3's network of collaborators and those citing her, seen also at country level (Figure 11-1). The only exceptions were D.P. McManus of Imperial College, London where she had spent part of a postdoctoral stay, and who had been the co-author of two of her papers, and a group from the Center for Disease Control (CDC) in Atlanta, one of whose members she had co-authored with during this period.

When questioned on the links shown in this graph, the scientist expressed obvious satisfaction that the author who most cited her work during this period was J. Sotelo, a Mexican scientist of high national standing, and with whom she had recently written a review paper. She knew the scientists who had cited her work with the exception of G.Granados and O. Talamas. She thought Granados must be part of the same institutional group of Mexican researchers as C.Gorodezky and of V. Trejo who had been her student [1]. Talamas,

[1] All eight papers of Gorodezky were with Granados and all five papers of Trejo were with both Gorodezky and Granados confirming that there are all members of the same group.

she believed to be a member of the same group as Sotelo and O.H. Delbrutto [2]. She was unaware that V.C.W. Tsang had cited her papers although she associated him with the group of P.M. Schantz, J.B.Pilcher and E.Miranda from the CDC [3]. She mentioned that Tsang had developed a test for the diagnosis of Cysticercosis. M.J. Doenhoff she had met during her sabbatical in the UK, and although he was not working on cysticercosis, he was developing techniques for the detection of antigens in a related disease area. She considered the work of all the groups she identified through the analysis of this graph as relevant to a greater or lesser extent to her own work and considered them to form part of the same invisible college.

The lack of citations by some of her Mexican co-authors to other papers written by her, she attributed to the fact that these co-authored papers had been written when many of them were her master's and doctoral students.



Coauthorships 1980-1989 (levels 1-5) , Citations 1985-1993 to 1985-1989 papers not coauthored with citing author

Figure 11-15. Biomedic 3. Number of collaborations and citations according to author

Chemist 1

In the case of Chemist 1 there was little relationship between those authors who most collaborated with him and those most citing his work (Figure 11-16). His institutional colleagues did not cite his work other than that written in co-authorship, except for one colleague, R.A. Toscano, who had not written papers with him during this particular period. At international level N. Fischer from Louisiana State University, who co-authored nine

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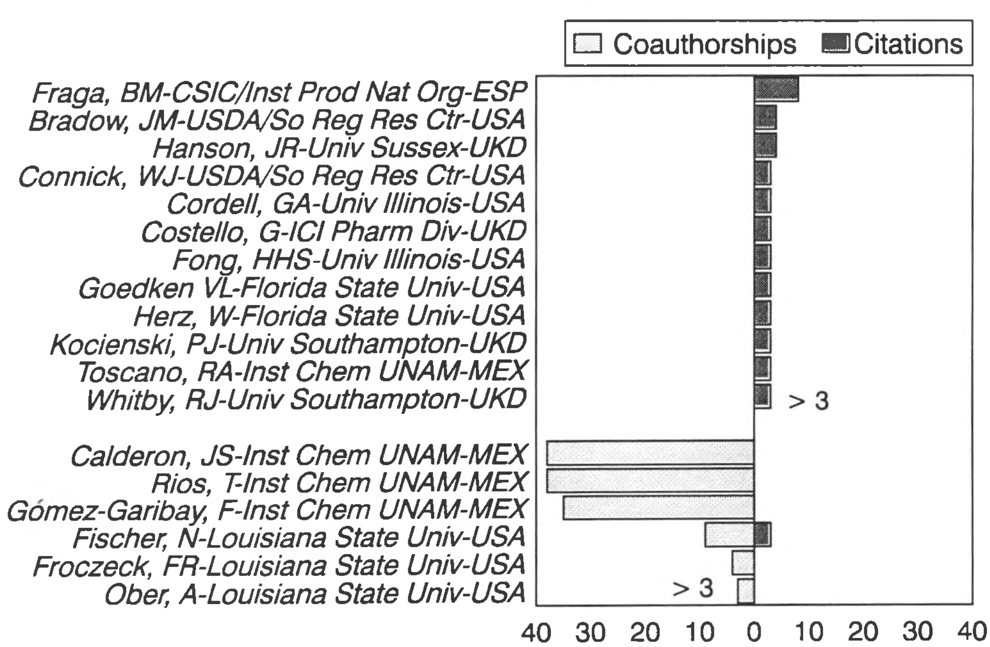
[2] All eight citing papers by Talamas were co-authored with Sotelo and three with Delbrutto.

[3] She later co-authored various papers with Peter Schantz and, during the first part of the interview, mentioned her collaboration with him as one of the most important for the development of her research work. Seven of the eight of the citing papers by Tsang were with at least one member of this group from CDC.

1985-1989 papers with Chemist 1, cited three of his other papers published during this period. The most citing author, B.M. Fraga from the Spanish Institute of Natural Organic Products, wrote a series of review articles from 1987 to 1992 citing eight of Chemist 1´s 1985-1989 papers. This European author also cited the work of Chemist 2 and to a lesser extent, Chemist 3 in this review series.

In the interview with Chemist 1, he commented that both B.M. Fraga and J.R. Hanson periodically write review articles on topics related directly to his work that explains their frequent citation of his papers. The group at the University of Illinois (H.H.S. Fong and G.A. Cordell) worked at one time on the same genus of plants that he has also studied. W. Herz from Florida State is known personally to Chemist 1 as he is actively involved in the same research area and has been to meetings in Mexico at the invitation of the Mexican scientist.

He knew most of the scientists quoting his work, if not personally then through their papers and considered them to be part of the same network of scientists as himself. He got to know Judith Bradow, for instance, while he was on sabbatical in Louisiana and had published papers with her. There were however, notable exceptions. He did not know of V.L Goedken, however, it is likely that this citing author is part of the same group as W. Herz whom he knows personally[4]. Nonetheless, he could think of no links with the three UK authors, G.Costello, P.J.Kocienski and R.J.Whitby, with whose work he was not acquainted.



* Citations to coauthored papers

Coauthorships 1980-1989 (levels 1-5) , Citations 1985-1993 to 1985-1989 papers not coauthored with citing author

Figure 11-16. Chemist 1.. Number of collaborations and citations according to author

[4] This indeed seemed to be the case. All three papers by Herz included Goedken

In spite of the fact that several of the citing authors were working on topics closely related to the special interests of Chemist 1, he had never considered collaboration with them. As he said, the opportunity had never arisen.

Physicist 1

At the level of individual researchers, Physicist 1's most frequent co-author was, P.Vanisacker, a UNAM colleague from the Institute of Physics rather than from Physicist 1's own Institute for Nuclear Sciences (Figure 11-17). He cited other papers by Physicist 1 five times during this period. High levels of co-authorship with other colleagues from the UNAM were seen in the absence of citations (other than those given to co-authored papers). Co-authors from Yale and Brookhaven, as well as scientists from institutes in several other countries, cited Physicist 1's papers indicating a widespread influence of his research work. A high level of mobility was found in this group of scientists with five of his co-authors and three of the citing scientists reporting changes in institutional affiliations during this time, all of which also involved moves between countries, and, in most cases, between regions.

When interviewed, Physicist 1 claimed knowledge of all citing authors with three exceptions. He claimed that there was a mistake in the graph and that U. Mayerhofer of the Technische Universitat of Munich, whom he did not know, was really Mauthofer from the University of Frankfurt with whom he wrote three papers at the end of the 80s[5]. Nonetheless he did not know Vonegidy either who was from the same institution in Munich.

Also he could not place C.Grosche although he thought that he might have cited work on the theory of algebraic dispersion that he did between 1984 and 1986 with a fellow Mexican researcher[6]. He did not continue this work but considered their contribution important for the development of this particular area. He recounted that this paper changed the way of thinking of a group at Yale who were already working on this problem and that it is now the American group who receive the citations rather than his original paper. He believes that this is often the case when the original work is done in a scientifically small country.

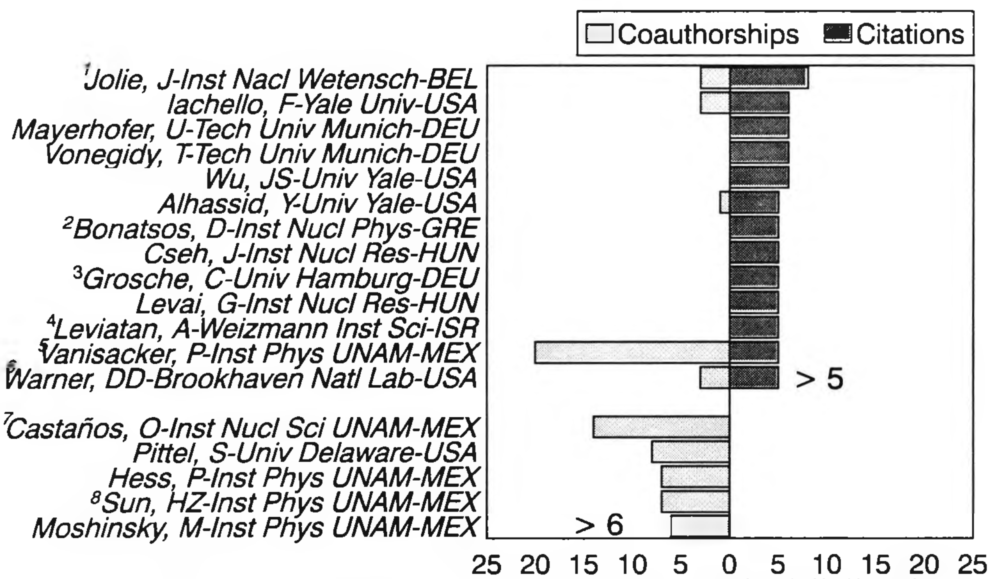
Physicist 1 attributed the fact that Pittel had not cited his papers except those co-authored with him, to the large differences between the work they had collaborated on and the work that Pittel normally carries out. H.Z. Sun, he mentioned, is a Chinese researcher who spent many years in Mexico but has published little since returning to his home country.

When I mentioned the high mobility of the researchers in the graph he attributed this to the fact that most of them are from Europe where he claimed it is difficult to find a permanent post.

5 There was no mistake in the graph indicating that Physicist 1 did not know the group from Munich.

6 This was indeed the case.

He considered that all the names he recognised from the graph form part of the same network, half of which he knew personally and half through the scientific literature. He went on to point out that they are all nuclear physicists and, due to the fact that he has now changed to the field of molecular physics, only the work of F.Iachello and P.Vanisacker continues to be relevant to his present interests. When asked if he had considered possible collaborations with those of this group with whom he had not previously worked, he replied that he does not plan collaborations, they happen naturally.



Coauthorships 1980-1989 (levels 1-5) , Citations 1985-1993 to 1985-1989 papers not coauthored with citing author

Afterwards:
[1] Inst Laue-Langevin-FRA [2] Univ Oxford-UKD [3] Imp Coll Sci Tech-UKD
[4] Yale Univ-USA [5] Univ Sussex-UKD/SERC-UKD/Univ Surrey-UKD
[6] SERC-UKD [7] Louisiana State-USA [8] Univ Drexel-USA/Univ Beijing-PRC

Figure 11-17. Physicist 1. Number of collaborations and citations according to author

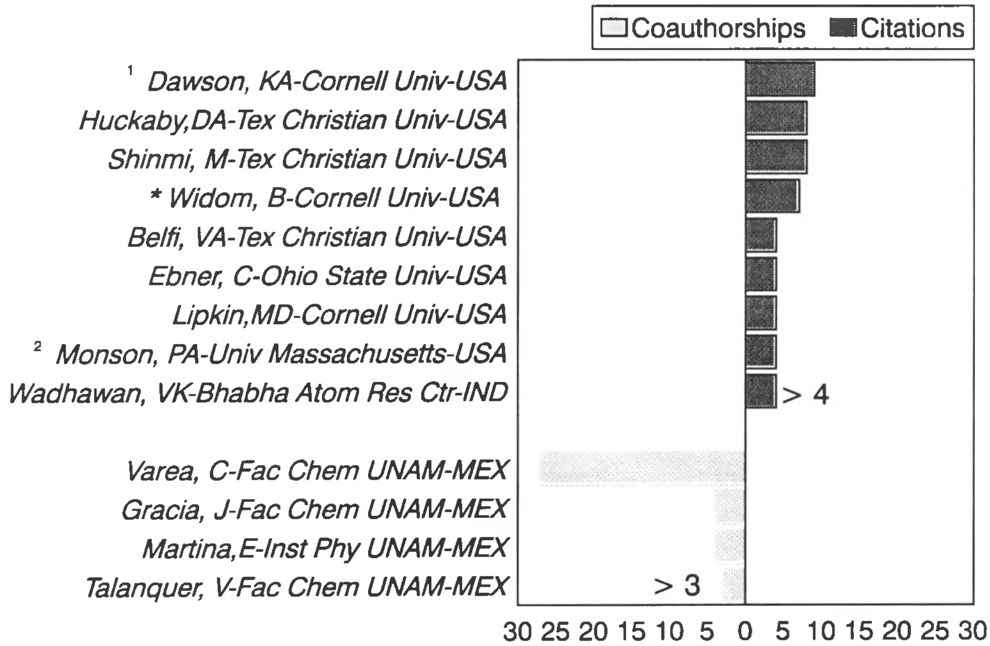
Physicist 2

Physicist 2 showed no important co-authorship activity with scientists other than his own UNAM colleagues from both the Faculty of Chemistry and the Institute of Physics (Figure 11-18). In 1988 Physicist 2 moved from a teaching position in the former institute to a research position in the latter. The possible influence of an earlier postdoctoral stay with B. Widom is reflected in the seven citations given by this researcher from Cornell University. The citations given to Physicist 2´s papers during this period were mainly from colleagues in the USA. Certain mobility was also seen in this group of scientists with two of the nine most citing authors changing institutions in this period.

When shown this graph, Physicist 2 claimed to know all the citing authors except for M.Shinmi, V.A.Belfi and V.K. Wadhawan. He thought that Shinmi might be a co-author of

Dave Huckaby which might also be the case of Belfi [1]. Apart from Wadhawan whom he thought might have cited some parallel work that he did on superconductivity [2], the rest of the citing authors all worked in his main field of numerical simulation, although there were other important scientists who did not figure on the graph. He knew that M.D. Lipkin and Ken Dawson were from Ben Widom's group at Cornell. Sam Ebner at Ohio he classified as Widom's main competitor. The main figures here, he identified as Dawson, Huckaby, Widom and Ebner, although he considered Huckaby more an "outsider". P.A. Monson's (a younger scientist) work was of little interest to him as he came from a different area.

When asked if he considered these scientists to form part of the same invisible college, he mentioned that sooner or later you get to know everybody in the "club". He went on to say that the group working in his field is very small when considering only the important figures. He pointed out that he had made no conscious attempt to belong to this "club", rather he let his reputation work for him which he believes had situated him as the best known internationally of the Mexican physicists working in the field of statistics.



Afterwards: 1 Univ Calif Berkeley-USA 2 Univ Oxford-UK * Postdoc with Widom 1979

Coauthorships 1980-1989 (levels 1-5) , Citations 1985-1993 to 1985-1989 papers not coauthored with citing author

Figure 11-18. Physicist 2. Number of collaborations and citations according to author

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1 This was confirmed by the fact that all eight citing papes by Shinmi were all with Huckaby and all four by Belfi with both Huckaby and Shinmi.

2 This assumption was correct. All four cites by Wadhawan were to the same paper by Physicist 2 on superconductivity.

In relation to the fact that there were no citations from his co-authors, he stated that Esteben Martínez is no longer a researcher and that Jesús Gracía, a doctoral graduate of his, works on experimental aspects and is closely associated with industry. Carmen Varea has always been his coworker and that Vicente Talanquer who was also his doctoral student, is now working independently and it is possible that he will cite his papers in the future.

Physicist 3

No apparent links were found with respect to the scientists co-authoring with Physicist 3 and those citing him (Figure 11-19). However, closer examination of the co-authorship and citation patterns of this scientist revealed the existence of links at both national and international level. For instance, all 1985-1993 papers written by G.H. Cocoletzi of the Autonomous University of Puebla which cited Physicist 3´s 1985-1989 papers, had been co-authored with W.L. Mochan who had been Physicist 3's most frequent co-author from 1980-1989. Also, according to Physicist 3´s CV, his research group collaborated intensively with R. Delsole of the University of Rome, among other scientists, between 1987 and 1991. The first co-authored paper with this Italian scientist appeared in 1991. R. Fuchs, of Iowa State University, J. Giraldo, of the National University of Colombia, and A. Lastras Martínez from the Autonomous University of San Luis Potosí, the latter appearing in Figure 11-19 only as a citing author, are also mentioned in Physicist 3's CV as important collaborators during the period from 1987 to 1991.

When shown the graph he found it interesting and asked to keep a copy. He mentioned that C.M.J. Wijers from the group in Holland has come periodically to events that he himself has organised in Mexico. He mentioned one in particular where he and Mochan were the editors of the proceedings published in the journal *Physica*. He did not have knowledge of the other two scientists from Twente but believed them to be young scientists working with Wijers [3]. He knew all the other citing authors and considers them part of the same circle of scientists although he was not aware of the term “invisible college”. There were no surprises for him in the graph as all the scientists form part of the same network.

He has never considered a formal collaboration with Wijers. There was no particular reason except that he believes scientific collaboration to be like marriage, it cannot be forced.

[3] All twelve papers by Poppe and all six by Vansilfhout were co-authored with Wijers confirming that they are members of the same group.

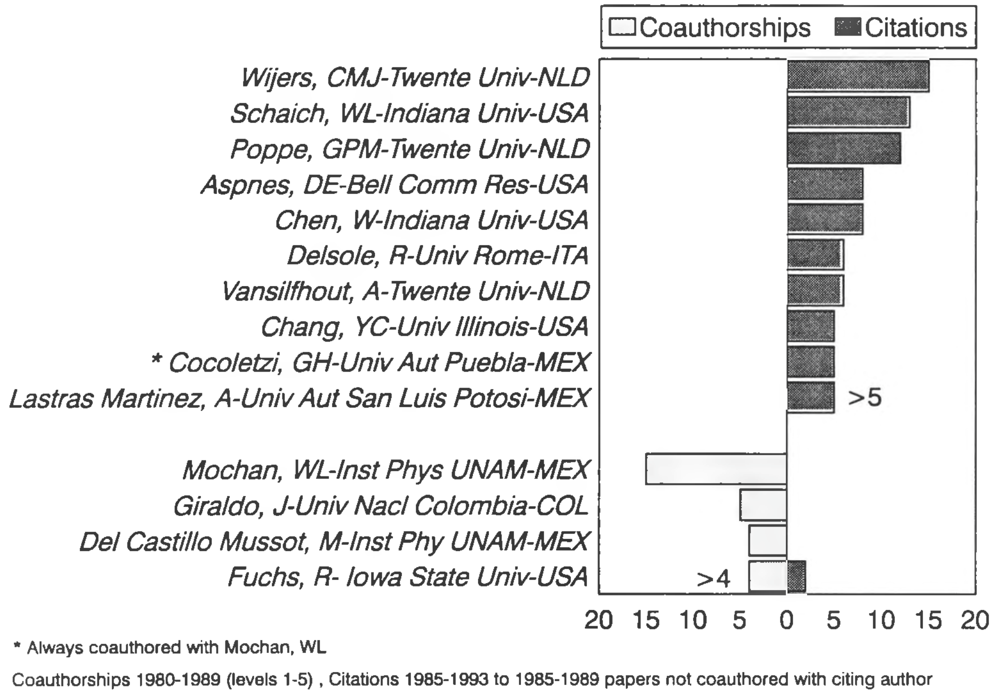


Figure 11-19. Physicist 3.. Number of collaborations and citations according to author

Astronomer 1

The scientist most frequently citing Astronomer 1's work was a fellow Latin American, M.T. Ruíz from the University of Chile (Figure 11-20). Astronomer 1 later collaborated with this author in the publication of two papers in 1992 and 1994. Citations were forthcoming during this period from other scientists from the region, including M. Peña from Astronomer 1's own institute and W.J. Maciel from the University of Sao Paolo in Brazil, as well as from UK and USA researchers. R.E.S. Clegg from University College, London, cited Astronomer 1's papers seven times, other than the two papers they had written together.

Astonomer 1 claimed to know all the researchers appearing in the graph and outlined numerous links between the different members of this group. In some cases he linked them to other people with whom he had worked. Some were important figures in the field like B.E.J. Pagel who is a leader in chemical evolution, and whom he knows both professionally and socially. L.H. Aller, a man of some 80 years, is the author of one of the two textbooks in the area of H II regions.

Some of the citing authors had attended regional meetings, such as the Mexico/Texas meetings of which there have been six, or the Latin American meetings on Astronomy and Astrophysics which are organised every three years. Astronomer 1 mentioned, for instance, that R.B.C. Henry had been to the Mexico/Texas meetings in

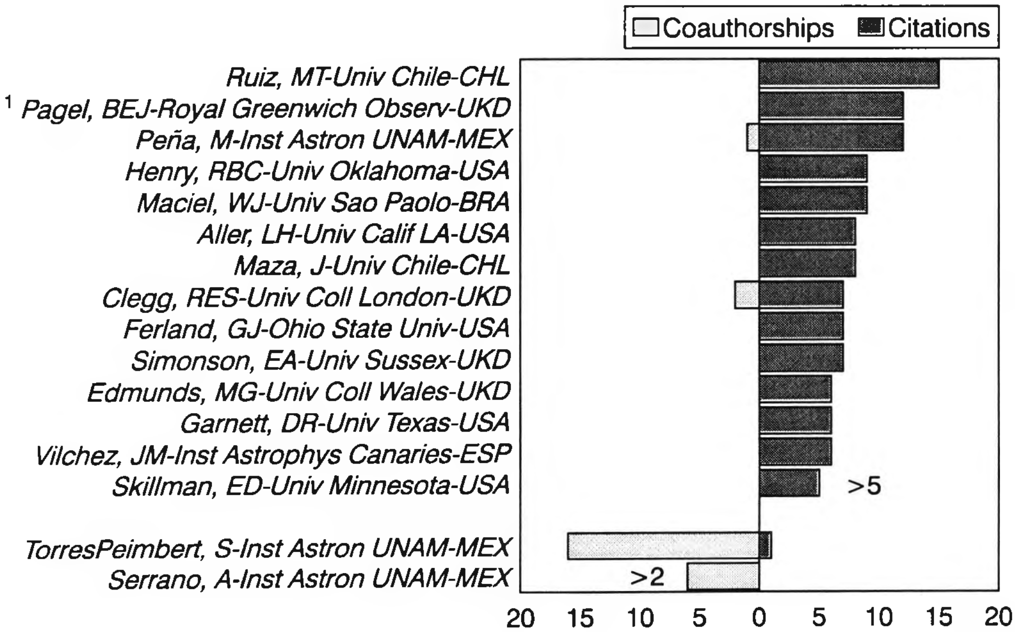
Mexico, had worked with Pagel, and, possibly, with some of Aller's students. E.A. Simonson and M.G. Edmunds did their PhDs with Pagel. D.R. Garnett studied at University of Texas and had been to all the Mexico/Texas meetings. E.D. Skillman also did his thesis at Texas. J.M.Vilchez, from the Canary Islands, was another who did his thesis with Pagel, and had direct links with Astronomer 1 through visits and exchange of postdoctoral students.

With respect to the Latin Americans, he mentioned that M.T. Ruíz had worked in Mexico and was now collaborating with him. J. Maza works with Ruiz, and W.J.Maciel, he knew through the Latin American meetings.

He had met G.J. Ferland, a theoretical scientist, at international conferences and commented that he had produced a method now used by many people and for which he was getting many citations.

With respect to the co-authorships on the graph, he told me that half of all his papers have been written with Sylvia Torres-Peimbert, his wife.

He considered that all the citing authors formed part of the same invisible college and the work of half of them highly relevant to his own work. He pointed out, however, that there are other scientists whose work is equally relevant for his research who do not appear on the graph.



Afterwards: 1 Nordita, Copenhagen-DEN

Coauthorships 1980-1989 (levels 1-5) , Citations 1985-1993 to 1985-1989 papers not coauthored with citing author

Figure 11-20. Astronomer 1. Number of collaborations and citations according to author

Geoscientist 1

Geoscientist 1 showed important co-authorship and citation links during this period with other UNAM scientists, one from his own Institute of Engineering, another from the Institute of Geophysics, as well as a group from the Institute of Physics (Figure 11-21). As was also the case with colleagues from the University of Southern California in Los Angeles, these scientists cited papers other than those that they might have co-authored with Geoscientist 1.

Geoscientist 1 knew all the citing authors on the graph without exception. He mentioned that he got to know J.G. Anderson many years ago when he was visiting another scientist at the University of Southern California and that he has visited Mexico many times. Anderson has cited Geoscientist 1 paper's because it contained an idea that he is applying in his research. M. Dravinski, he described as a colleague and scientific rival. He mentioned an ongoing scientific dispute that he has had with his colleagues from the Institute of Physics at the UNAM. At the time considered in the present analysis, this group was writing papers of a general, mainly methodological, nature and had referred to some of his previous work.

With regard to his most frequent co-authors during the period, he told me that J. Aviles and M.A. Bravo were his doctoral students and that he considered his collaboration with M. Campillo as one of the most important. Aviles is no longer a researcher and Bravo works independently. He did not consider the citing authors' work had influenced his work to any great extent, perhaps with the exception of S.K. Singh and M.Ordaz whose work had inspired him.

As to whether he considered his work is or has been relevant to the research of the citing authors, Geoscientist 1 mentioned that Aviles and Bravo had not continued his work but had found it useful. He told me that he had proposed a collaborative project with his colleagues from the Institute of Physics to try and resolve their differences with respect to the development and interpretation of a particular model but, as yet, it had not happened.

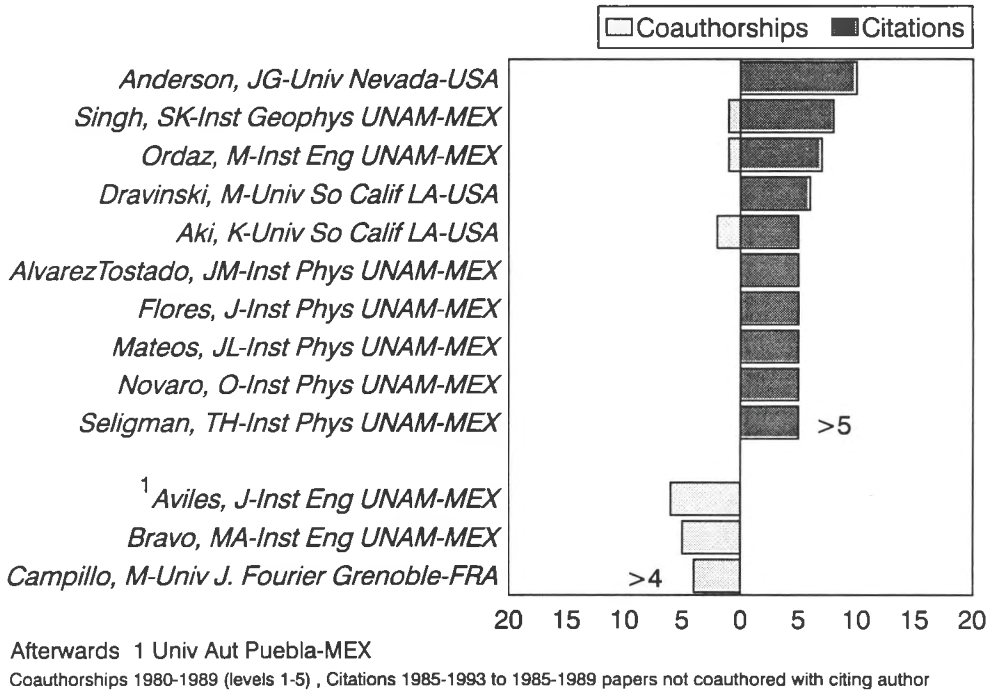


Figure 11-21. Geoscientist 1. Number of collaborations and citations according to author

11.4 Discussion

In all seven cases the USA was the country that most cited the Mexican scientists' work with the UK occupying the second or third position, expect in the cases of Physicist 3 and Geoscientist 1 where the UK did not figure among the most citing countries. These results are not surprising in the light of the fact that the USA is the most citing and most cited country in world science (Schubert, Glänzel et al. 1989). Also the USA has traditionally been Mexico's most frequent international scientific partner in spite of a recent increase in collaboration with Europe (Russell 1995).

Schott believes that the origins of influence upon the scientist follow the patterns of their deference (as measured by citations) more than their patterns of travel (Schott 1995). Although Brazilian and other Latin American scientists have travelled much more to Western Europe than to North America for meetings and institutional visits, they have deferred much more to North American science and have been much more influenced by science in North America than in Western Europe. General findings from the present study suggest that USA science is the most influenced by Mexican science, although an important number of citations were received from the principal Western European countries.

In all cases, but that of Physicist 2 who had only one co-authored paper with a foreign scientist, the countries of co-authorship occupied the top places in the list of citing countries suggesting a link between country of co-authorship and citing country. At institutional level there was also a tendency for co-authoring institutions to be among the most citing. However, both these effects could have been influenced by the co-authors citing the papers that they had written with the sample of seven UNAM scientists.

Eliminating citations to work co-authored with the UNAM scientists when looking at the co-authorship/citing relationship at individual co-author level, showed that at least some of the co-authors in all but the case of Physicist 2, found other papers by the UNAM scientists of sufficient relevance and quality to merit citation. Physicist 2, nonetheless, did have citations made to his work by a professor at Cornell University where he had previously spent his postdoctoral year.

In particular, the case of Physicist 1 suggests that international co-authorship can lead to increased international impact as measured by citations, as well as indicating the important role that sabbatical leaves of absence play in this process. The fact that this UNAM scientist forms part of a highly mobile group of scientists is most likely having a positive effect on his own visibility and opportunities for collaboration and mobility.

It seems quite likely that UNAM scientists will receive citations from his/her doctoral or postdoctoral institution when continuing a research interest initiated during this period of training, especially when this interest corresponds to that of the professor or group with which the UNAM scientist was associated. By the time sabbaticals are in the offering, the Mexican scientist will probably have established his/her own research interests and will be looking to spend the year, probably abroad, as part of a prestigious group working in the same area but offering increased expertise or resources. The important links established during prolonged visits abroad, either at the training stage or later as researchers in their own right, are evident from the present analysis. In all cases, increased visibility through citations could be related to at least one of these visits.

The fact that scientifically small countries have few research groups, even in the more established areas of research activity, makes it unlikely that Mexican scientists will receive many citations from national colleagues, particularly those in other institutions. The exception to this will be when scientists, such as Biomedic 3 or Physicist 3, have collaborated extensively with other national institutes, or when colleagues are working either individually or as research groups, in related areas within the same national institution. Examples of the latter case can be seen with respect to Physicist 1, Astronomer 1 and Geoscientist 1.

From the interviews it was apparent that many of the Mexican co-authors were postgraduate students, some of whom later abandoned their research careers. In other cases, co-authored papers were written on topics of secondary or onetime interest to the UNAM scientist, thus explaining a lack of citations to their other papers by these co-authors.

The interviews also revealed that all eight scientists were acquainted with the work of the great majority of authors citing their work. In many cases they were known to them personally and formed part of the same invisible colleges, meeting up at international meetings and visiting each other's institutions. I also found evidence of later collaborations with some of the citing authors with whom they had not previously collaborated. The graphs produced few surprises to the scientists interviewed although there were some notable exceptions. However, even when they could not place the scientist, they had some idea with which group they might be associated.

In many instances, the scientists explained to me the specific relevance of a citation and were obviously well aware, in general, of how and why they had been cited. Several of them told me that an idea of theirs had motivated or directed the development of other scientists' research indicating a significant influence of these UNAM scientists in their respective fields.

There were several mentions of citing authors from other countries having visited or even having worked in Mexico, suggesting a close liaison between citing and cited scientists. Physicist 3 had organised many international meetings in Mexico that gave him a central position in the field. Astronomer 1 was closely associated with two regional meetings that again gave him a pivotal position within this scientific community. It was obvious that this particular scientist's network of colleagues was highly interconnected and included some notable figures in the field, with apparent large mobility especially at doctoral and postdoctoral level. However, astronomy is known to be a truly international science. It should also be remembered that this scientist is the only one of the 15 to belong to the US Academy of Sciences, an achievement that reflects high prestige and recognition among the international scientific community.

It is also evident that different patterns of links will be found between scientists and institutions depending upon the universal scope and relevance of their mutual research interests. Topics of local interest will be relevant and therefore cited mainly by local colleagues or a handful of scientists in other countries with similar problems. On the other hand, basic topics will be of interest to a much wider group of scientists irrespective of their geographical or cultural context.

In this particular sample of seven scientists, Biomedic 3 working on applied aspects of a disease confined to developing countries, had collaborated with a large number of local scientists and institutions. However, the basic nature of her research on this disease determined that her studies were also of interest to scientists in the industrialised countries, even though these were basically confined to those with whom she had co-authored.

Chapter 12

The UNAM Scientists' Response on their Relationships with the National and International Scientific Communities

12.1 Role of the National and International Scientific Communities

12.1.1 *Response from the Questionnaires*

Seven of the 15 scientists considered that contact with the international scientific community was essential for the development of their research activity with five more considering it highly important by giving it a score of 5 on a scale of 1-5 (see summary of questionnaire results in Appendix 4). The only scientist who gave this consideration a low score of 2 was Biomedic 1.

On the other hand, only five considered contact with the international scientific community generally more important than that with the national scientific community with the other 10 giving equal importance to both. The five were Biomedic 2, Physicist 2, Physicist 3, Geoscientist 1 and Geoscientist 2.

The picture changed slightly with regard to the importance of recognition from the international scientific community, five considered it essential to the development of their research activity with six considering it highly important (score of 5). Biomedic I considered this recognition essential. However, three gave it a half way score of 3, these being Chemist 3 who had also given the same score to the importance of contact with the international scientific community, Astronomer 3, and Geoscientist 2 who had considered contact with the international scientific community more important than that with his national community.

Six scientists generally considered recognition from the international community of science as more important than national recognition with eight giving equal importance to both. Only Astronomer 3 gave a negative response.

The majority of the scientists (n=9) were of the opinion that the quality of research output is the same when collaborating with national or international colleague, with three (Biomedic 3, Chemist 2 and Geoscientist 1) assigning higher quality to research done with foreign scientists.

12.1.2 *Response from the Interviews*

When asked to name their most important collaborations between 1980 and 1994 with scientists outside their immediate research institute (i.e. with colleagues from other research institutes within the UNAM, other Mexican institutes or with institutes abroad), five of the Mexican researchers referred to joint work done nationally and eleven to joint work with colleagues abroad (see sections 12.2.1 and 12.3.2). Some chose to talk about more than one collaboration, sometimes describing collaborations from both national and international contexts.

The scientists were asked to mention collaborations with foreign institutions other than those resulting from sabbatical leaves of absence analysed in Chapter 10. In the case of Astronomer 2 no important joint work was discussed other than that carried out during her sabbatical (see section 10.6).

12.2 Collaboration with the National Scientific Community

12.2.1 *Response from the Interviews*

The five scientists who referred during the interviews to important collaborations with colleagues from other centres in the UNAM or other national institutes were Biomedic 1, the three chemists and Geoscientist 3. Biomedic 3 referred briefly to problems with collaborating with her national peers. Physicist 3 stressed the importance of internal collaborations.

Biomedic 1

In spite of the fact that Biomedic 1 did not recognise that he has had very extensive or intensive collaborations with either foreign or national colleagues, we discussed at length a joint research project with a Mexican clinician working in one of the government hospitals which brought him the two highly cited papers. The research, originally published in the prestigious *New England Journal of Medicine* in 1987, reported a controversial treatment for Parkinson's disease which involved adrenal medulla transplantation to the caudate nucleus. Biomedic 1 wanted to try out the treatment in humans which required the collaboration of a clinician with suitable patients and hospital facilities. The innovative treatment caused much impact both nationally and internationally and started a new line of research in the neurosciences which was quickly taken up by other groups.

Although initially only Biomedic 1 and the Mexican clinician were involved in the project, two groups were formed as a result of this collaboration, one in the basic aspects and the other in the clinical aspects. The training of students and the improvements experienced by the patients were described by Biomedic 1 as the principal benefits of this research. He considered that it represented a true collaboration as the input of each of the principal researchers was complementary to the other. The collaboration did not last long and Biomedic 1 attributes the rupture of the relationship to the fact that "other interests" began to surround this collaboration which he considered inappropriate. He preferred to go his own way from then on.

Biomedic 3

This scientist believes that working with national colleagues is equally as difficult as collaborating with foreign colleagues because Mexican scientists tend to be "territorial" making truly collaborative efforts impossible. A long research tradition in the biomedical sciences in Mexico makes finding national collaborators a possibility unlike other fields with few consolidated national research groups. Nonetheless, professional jealously makes it difficult for a true peer relationship to exist. She maintained that a common attitude among Mexican scientists is to believe intrinsically that they are right (and that the other person is wrong) making impossible a fruitful exchange of ideas and opinions.

Chemists 1, 2 and 3

All three chemists commented on projects developed in association with other Mexican scientists that, probably due to the similarity of their research interests, were collaborations of a similar kind. While the chemists were able to carry out the chemical isolation and analysis of natural products, they required the help of experts in other areas, such as pharmacology or taxonomy, to test the active principal or to classify the material. While Chemist 1 and Chemist 2 mentioned the collaboration with the same group at one of the government laboratories, Chemist 3 referred to the help given by a researcher at the Institute of Biology of the UNAM. All collaborations led to the publication of co-authored papers.

All three chemists considered the input of these scientists or groups of scientists to be complementary to their work and could be considered true collaborations as the lack of expertise in each other's area made it impossible for either party to have carried out the research without the help of the other. Two events marked the end of the joint work, the scattering of the collaborating group following the destruction of the government laboratory by the 1985 earthquake, according to Chemist 1, and the departure of the taxonomist from the Biology Institute in the case of Chemist 3. Chemist 2 mentioned that the leader of the group from the government laboratory still does some work with other colleagues at the Institute of Chemistry.

Chemist 1 considered that the benefits of the collaboration were to give a more complete answer to the problem. He alluded to certain difficulties related to professional jealousy which were not referred to by Chemist 2. However, although both Chemist 1 and Chemist 2 were talking about collaboration with the same group, they were involved in different joint projects.

Physicist 3

When Physicist 3 was asked at the end of the interview if he would like to add anything on any aspect of the questionnaire or interview or in general about his experiences or opinions on the subject of collaboration in science, particularly that with foreign scientists, he wanted to know why so much emphasis on international collaboration. He stressed the importance of his joint work with his colleagues within the Institute of Physics which he believes is equally worthy of analysis.

Geoscientist 3

Geoscientist 3 told me how important for the development of his research work was an ongoing collaboration with colleagues from the UNAM's Institute of Engineering. The invitation to participate in joint work was originally put forward by a prominent member of this institute when Geoscientist 3 was visiting professor at the Institute of Geophysics at the beginning of the 80s. He mentioned certain resentment in his own institute that he was spending so much time at the sister institute. Because of this he feels that sometimes these internal collaborations are not always looked kindly upon and that international collaborations are usually considered more meritorious.

As in the case of the chemists, he and his collaborators provide data complementary to each other. He named about eight or nine collaborators from the Institute of Engineering, including Geoscientist 1 although he was not one of the principal ones. While Geoscientist 3 concentrates on the basic aspects of the earth's structure and tremors, the engineers are concerned with the applied aspects of designing structures to withstand earthquakes. He mentioned that the 1985 earthquake caused an increase in the interest and spending in his field and that access to better instrumentation led not only to the availability of more accurate data but also to the production of data needed by both groups using the same instrumentation. Co-authored papers have been published as a result of this joint effort that has also attracted new blood into the field, particularly with respect to graduate students in certain engineering disciplines.

12.3 Collaboration with the International Scientific Community

12.3.1 *Response from the Questionnaires*

The main attributes that the Mexican scientists looked for in foreign research collaborator were principally shared research interests mentioned by 11 of them (see summary of questionnaire results in Appendix 4). Know how was also considered important by eight of the group but access to foreign research facilities was mentioned by only three.

The most frequent way of meeting their foreign collaborators was either at international meetings (n=14) or through reading their papers (n=12). In five cases the scientists mentioned introductions occurring during doctoral or postdoctoral visits and in six, during other visits to foreign institutions. Getting to know the foreign scientists when they visited Mexican institutions was noted only by Geoscientist 2.

When asked to select their principal motivations for collaborating with foreign researchers, the most common (n=8) was to gain their special competence. Other options, which six of the scientists considered important, were to learn a new technique and/or to diminish their isolation from the international scientific community. In five cases the lack of local specialists was considered a motivation and/or to gain the intellectual input of their foreign colleagues. To obtain financing was mentioned only in one case.

Twelve considered that their careers as research scientists had benefited from collaboration with foreign scientists, with two more maintaining that it was impossible to say. Only Biomedic 1 gave a negative answer.

Principal benefits were seen as increased international visibility of their research in 10 cases and increased productivity in nine cases. Increased prestige of the research was considered important by six of the scientists. Four considered that an increase in citations to their work was a benefit they associated with foreign collaboration while only three thought that the quality of the work increased. Permanence of funding was a benefit specified by Biomedic 3 who had secured important financing from the Rockefeller Foundation for a joint project with a British scientist.

Indirect benefits to their research work as a result of foreign collaborations were in 11 cases, the visits of foreign scientists to Mexico, and in 8 cases, the widening of their contacts within the international scientific community. Other important benefits were the exchange of graduate students and invitations to participate in international events, committees, etc.

Eight of the 15 scientists stated that their local colleagues were usually involved in their collaborations with foreign scientists with one other mentioning that it occurred in half of the projects. Astronomer 1 answered “no” in the past and “yes” in the present. Nine indicated that they made a conscious effort to involve their local colleagues in these international projects with one, “maybe”.

When asked if certain non scientific considerations had ever influenced their choice of foreign collaborator, 11 replied that the foreigner needs to be a likeable person, nine that they must have a compatible working style, and eight that personal friendship is a consideration. Other considerations were deemed of lesser importance, with Geoscientist 2 adding "a respect for Mexican culture and institutions". When asked to rate the importance of these non scientific considerations, six allocated a score of 5 which is highly important with three givng a score of 4 and five a score of 3. Only Biomedic 2 considered these of little importance.

Only four had experienced negative consequences of these joint research projects which were attributed in all cases to unfair allocation of credit or recognition for the work. Difficulties in interpersonal relationships were mentioned in three cases which were related mainly to cultural or personality differences.

With regard to science policy considerations, only three of the scientists replied that lack of financial support had ever prevented them from travelling abroad. Only Chemist 3 considered the support given by Mexican science policy initiatives to formal collaboration with foreign scientists to be limited. About one third of the scientists rated this as 3, another third as 4 and the other third as 5 or abundant.

12.3.2 *Response from the Interviews*

During the interviews the 10 UNAM scientists who referred to specific collaborations or contact with foreign scientists as being among the most significant for the development of their research were Biomedic 2, Biomedic 3, Chemist 3, the three physicists, Astronomer 1, Astronomer 3, Geoscientist 1 and Geoscientist 2. Biomedic 2, Chemist 2 and Geoscientist 2 responded to specific questions on co-authorships with different foreign institutions which did not appear to be associated with visits abroad mentioned in their CVs and which they had not previously referred to during the interviews. Biomedic 1 expressed some opinions on collaborations in general.

Biomedic 1

Biomedic 1 is of the opinion that collaborations although excellent in theory, are very complicated in practice. He believes that the parties concerned usually end up on bad terms mainly because each side wants the credit for the joint work. For this reason he does not much like to collaborate outside his own institution. He quoted the example of two scientists who share a common research problem but each uses a different approach or technique. This, he maintained, leads to a true collaboration between equal partners. However, when the research questions of mutual interest are exhausted then each scientist wants to continue working in their own particular line of research and probably ends up having to mount the technique of the other in their own laboratory. Continuing joint work would imply that one of the two parties has to give up their particular research interest.

Biomedic 2

This scientist commented that her main reason for seeking the collaboration of national or international colleagues has been to get help with techniques and data handling with which she was unfamiliar. She considers that none of her joint research ventures have had important impact on her research, rather they were concerned with "mutual help on some specific aspect". But she did speak of several short visits totalling seven months that she made from 1987 to 1988 to the Panum Institute in Copenhagen which she believed had important long term repercussions for her research work. The specific purpose of these visits was to learn the technique of nervous cell tissue culture that she is still using in her research work.

Biomedic 2 had got in touch with the Danish counterpart whom she had met in international congresses, to propose a joint project which he accepted. The collaboration continued for two or three years with the work being carried out in Mexico from which about ten publications ensued. Both scientists received financial support from their respective countries. The joint research stopped by mutual agreement when Biomedic 2 felt that her Danish counterpart was receiving the main credit for the work. She considered that his participation was minimal as it was outside his main research interest. For the same reason she thought that the foreign scientist would not have carried out this particular piece of research without her collaboration, although he could have done, and that he received greater benefit from the collaboration than she did. However, she went on to comment that the joint project brought benefits not only as a result of acquiring an important new technique but that collaboration with an "intelligent person" always produces interesting ideas and suggestions. The collaboration also brought about the exchange visits of one Mexican and two Danish students.

Three co-authorships with different US universities, which were not associated with visits abroad mentioned in Biomedic 2's CV, had differing explanations. One was the result of a doctoral student of Biomedic 2's visiting a US laboratory to learn a new technique while the other two related to visits by US scientists to the Mexican institution. In one case Biomedic 2 was interested in acquiring a new technique and had invited the American scientist to Mexico. However, the technique did not prove as useful to the Mexican group as they had thought and so the collaboration did not prosper. The other case involved the use of a substance which was difficult to synthesis and which US collaborator was able to supply. His input was important also with regard to the design of appropriate experiments.

Biomedic 2 emphasised the fact that her research depends very much on the use of reagents and the application of techniques. She agreed that where scientists limit their participation in a joint project to the supply of a substance then this is not a true collaboration. However, when these scientists also participate with suggestions or opinions about the research itself, then it can be considered collaboration. Modern research, she believes, demands collaboration otherwise time is lost, especially in Mexico, in acquiring the necessary equipment and resources. Technological progress makes it difficult for one laboratory to have all the necessary equipment.

Biomedic 3

Two significant international collaborations mentioned by this scientist were with researchers from the Centre for Disease Control (CDC) in Atlanta and from the University of Salford in the UK.

She had first got to know the US scientist at an international meeting when they identified a mutual research interest. He was later sent to Mexico by the CDC to give a course in epidemiology which is when the collaboration began with Biomedic 3 and one of the Mexican students taking the course. Financing was obtained from an American foundation and later from the International Development Research Centre (IDRC) in Canada. Several joint papers were published as a result of this collaboration which is still active. The fact that cysticercosis does not exist in the US, meant that the research could not have been carried out without the participation and experience of the Mexican group.

With the English group, Biomedic 3 applied an easy, quick and cheap method for the diagnosis of T.solium under Mexican field conditions which also involved the partial collaboration of the two researchers mentioned above. An important advance was made to the field when the presence of the tapeworm carrier was identified as the main risk factor for cysticercosis. Several joint papers were published. Biomedic 3's input was vital for the success of the project as she provided the infected faecal samples for diagnosis.

Biomedic 3 could think of no special problems associated with these two collaborations and emphasised the importance of what she described as "positive biochemistry" between the scientists. She considered that the benefits obtained were the same for the foreign and Mexican scientists. She believes that the man from CDC was given tenure on the strength of this work and she mentioned the large grant from the Rockefeller Foundation that she shared with the UK scientist.

As far as spinoffs from these collaborations are concerned, she mentioned invitations to international meetings, increased international recognition, and the training of undergraduate and graduate students through their involvement with these joint programmes.

Chemist 2

When asked specifically about collaborations with three foreign scientists, Chemist 2 explained to me that the joint research in each case was to gain access to X ray techniques to produce a "more complete picture" of the structures of certain natural substances. All collaborations, the first with the University of Missouri, the second with a researcher at Louisiana State University and a third with a Mexican-American scientist from UC-Irvine did not continue once his own institute developed this facility, although contact is still maintained with the Mexican-American. Co-authored papers followed in all cases. Contact had been made with the first two scientists as a result of the sabbaticals of Chemist 3 and Chemist 1 and with the third at a meeting in northern Mexico.

Chemist 3

This scientist selected an important collaboration with a Canadian scientist who is an expert in magnetic nuclear resonance. As in the joint research of the group of UNAM chemists previously mentioned in both the national and international contexts, the collaboration was to gain access to this expertise which was not available at the time within her own institute. The Canadian scientist provided the complementary data required for a complete analysis of the substances and also helped with the interpretation of the spectra. He made periodic visits to the UNAM and took home the natural products for analysis. There was no need for the Mexican scientist to make trips to Canada. She is still in contact with the foreign scientist and sometimes they "comment on things". The person now in charge of this technique in Mexico went to train at the Canadian laboratory.

Physicist 1

Physicist 1 mentioned two significant foreign collaborations not related to his sabbaticals. The first started when Pete Vanisacker, a Belgian scientist, was doing his postdoctoral stay at Physicist 1's institute. They have written many papers together and in 1994 published a book on their joint research work. After leaving Mexico, the Belgian scientist worked in many different countries but now works in France where Physicist 1 visits him frequently to continue their collaboration.

The other collaboration is with Stuart Pittel of the University of Delaware with whom the UNAM scientist has published fewer papers, but nonetheless his influence on Physicist 1's work has been significant. In the beginning the American scientist acted as a kind of mentor but they have now become personal friends and continue to publish together. The initial contact was made when Pittel visited an Argentine scientist working in the UNAM who had been his PhD supervisor. The exchange visits between Physicist 1 and Pittel were financed by a joint Conacyt-National Science Foundation agreement. The UNAM scientist described this collaboration as unusual in some ways as their respective fields are different for which reason their individual contributions have been complementary.

The main benefit of this collaboration apart from what the two scientists have learned from each other, has been the opportunity for Physicist 1 to transcend national boundaries and to work and collaborate with foreign groups. In this sense, Pittel has also been a kind of godfather figure to Physicist 1 as well as to other Mexicans. Recently Pittel was elected as a foreign member of the Mexican Academy of Sciences. Physicist 1 believes that he has possibly benefited more from the liaison than Pittel as when the relationship began, he was the less well-established scientist. Other benefits relate to the opportunity he was given to perfect his English, to discover that Mexican physics is well respected abroad and to make long lasting friendships. There has been little student participation in their joint research due to the fact that their specialities are not entirely compatible.

He believes that their joint participation was vital to some, but not to all of the papers they have written together. He told me that he has continued to work in the field of nuclear physics, mainly as a result of his contact with Pittel and with Vanisacker and that without the input of these two scientists, he would not have done this research. He considers that Pittel as a result of the joint collaboration, began to move towards a branch of nuclear physics where group theory (the specialist field of study of the Mexican school) has important implications.

When I asked him about a third collaboration with Jolie from a nuclear research institute in Ghent, he informed me that the contact was first established through Vanisacker and that the co-authored papers, of which there are about ten or twelve have usually involved both these Belgian scientists.

He agreed that he has probably made a large number of short visits in the last 15 years to institutions abroad which do not appear in his CV. He referred to the advent of email as a "great revolution" in the sense that discussions started during these short visits can be continued on his return home. He now finds it hard to believe how he ever managed to write so many papers with Vanisacker for instance, before the arrival of email. Nonetheless, he feels that person to person contact is essential during the "genesis" of a joint research project. After the initial details have been worked out, it is possible to continue and complete the project, even the writing up of the work, by email.

Physicist 2

This physicist has had few collaborations which have led to the publication of co-authored papers with the particular foreign scientists he named as the most influential in the development of his research work. However, he considers his integration into the international research community of his field is by reason of his associations with these and other foreign scientists, as well as through invitations to edit special issues of journals or to speak at special events. He also now occupies important editorial and reviewing positions that he attributes to his international contacts. He pointed out to me that his presence within this international network, has not been achieved by seeking strategic collaborations but rather through gradual contact with the different interconnected players.

He mentioned specifically that until he had some contribution to make to events abroad in the way of presentations or participation in discussions, he preferred not to go, leaving this activity to later years when he was more knowledgeable and experienced.

He explained that the foreign scientists have taught him different skills and habits. For example, his doctoral supervisor in Scotland, by his example taught him the application of scientific rigour and of the importance of questioning in scientific work, habits he recognises that would not have been so easily assimilated from the Mexican environment. Creativity in scientific research which is the basis for much of his work, he learned from other researchers, such as Rowlinson of Oxford University, and Widom and Fisher in Cornell. He first learned of Widom's work through Rowlinson during his first sabbatical.

Physicist 3

Physicist 3 named a relatively long list of foreign scientists with whom he had collaborated, all of which he considered important. Three of these collaborations were with Latin American scientists, one who had worked at the Institute of Physics, another from the National University in La Plata, Argentina and the other from the Brazilian Institute for Theoretical Physics. He specifically mentioned two ongoing collaborations with R. Fuchs, originally at Iowa State and now at Cambridge University, and with Y.Borensztein from the University of Paris.

When asked to refer to one of these important collaborations which had not continued, for example, that with Del Sole of the University of Rome, he seemed to remember that he got to know the Italian scientist in a workshop he had organised in Mexico many years ago. They shared a research interest in semiconductors. The collaboration came about because Del Sole had the necessary theoretical elements to improve a model which Physicist 1 and Mochan, his most frequent local co-author, had developed.

Although there is no research collaboration between the Italian and the Mexican scientists at present, the opportunity is always there. At the moment they are co-editing a book and writing a couple of book chapters together. Physicist considers it important to have kept in touch with Del Sole.

Contact had been via short visits that were not mentioned in Physicist 3's CV during the time one of his Mexican postdoctoral students was spending a year at the Italian institution. Physicist 1 explained that the best Mexican students usually want to study abroad and that arranging for them to spend six months or a year abroad with one of his foreign collaborators, often encourages them to stay in the country to do their postgraduate degree. The foreign stay gives them a chance to compare the situation abroad with that of Mexico and, very often, makes them appreciate the benefits of their home country. He felt that this arrangement is very beneficial both for the students themselves as well as for the development of his own research in Mexico.

With regard to difficulties with financing these visits, he told me he had never had problems to get resources for his collaborations. He considered that the benefits were the same for both parties and that several co-authored papers were forthcoming. With regard to the role played by the student he believes that Del Sole's group benefited from the her computing skills as well as her knowledge of physics. Physicist 3 was interested in the student learning a particular field with a view to starting research in this area in Mexico.

Referring to the model developed with the help of Del Sole, he considered that it would have been difficult, while not impossible, to have improved it without the help of the foreign researcher because it would have involved entering a new field. Equally it would have been possible but difficult for Del Sole to develop the model without the Mexican input. Specifically, Del Sole had not realised the important of a "local field effect" until the Mexicans pointed it out to him.

Physicist 3 considers that this was a true collaboration and that in his experience, collaborations with foreign scientists have usually been collaborations between equal partners, except in the cases of certain, while not all, Latin American scientists, who have come to Mexico to learn.

He believes that short visits of one month are sufficiently long for successful collaboration. Longer visits are difficult to arrange as he has a young family and a working wife who have sometimes been able to join him for part of this time. He went on to mention that electronic mail has facilitated enormously certain aspects of collaborative work, such as the exchange and revision of figures, for instance. However, a certain part of the work is impossible without physically getting together, the discussion, for instance and the final refinements to the paper. Visits are especially important to see how students are progressing.

Astronomer 1

Astronomer 1 pointed to the fact that collaborations outside his immediate group have been mainly with foreign scientists due to a lack of Mexican groups working in other national institutions. He mentioned in chronological order a large numbers of collaborations with institutions abroad that he considered important for his research. Much of his joint research involves observations using special equipment. For instance, during a visit to Japan to edit the proceedings of a symposium, he had collected data with local experts using a powerful radiotelescope which resulted in the publication of joint papers. The purpose of his trips abroad have been to observe, give conferences or to write the final versions of articles with his foreign collaborators.

He put special emphasis on his collaborations with two US groups working on interstellar media. These are with Shields's group from the University of Texas in Austin and Dufour's group from Rice University in Houston. Astronomer 1 considers his Mexican group to be on equal standing with the two US groups and believes that all three parties benefit equally from their joint research.

For the past several years he and his astronomer wife along with these two scientists, have organised a series of Mexico/Texas meetings on astronomy, each institution taking turns to host the event. He believes that one of the most important benefits of these meetings is that young researchers and graduate students with little financial resources from both sides of the border can attend.

He told me that the Texan and Mexican groups interact at different international meetings. While they share common research interests, each has distinct expertise and knowledge to contribute to the joint research. Some members of the groups are very theoretical, others good at carrying out observations and reducing data, and others with profound knowledge of the field are good at suggesting problems to be worked out. He considers that collaboration with the two First World universities has increased his visibility and that all parties concerned are happy for the collaboration to continue.

Dufour spent a half sabbatical in Mexico with Astronomer 1 during which time they finished one of their co-authored articles. Astronomer 1 also mentioned important contacts made and collaborations carried out as a result of foreign scientists visiting his UNAM institution. He mentioned specific cases of a prominent US scientist, an Armenian astronomer and a scientist from Chile.

He believes that the Institute of Astronomy is perhaps unique within the UNAM with respect to the number of foreign astronomer it receives. Astronomy is the most international science that exists as all astronomers study the same phenomena. This is not the case with other fields, such as geophysics, geology, or geography, which focus on local interests or conditions. Also the international scientific community of astronomers is small and mobile compared to other fields and that, coupled with the fact that the instruments used for observation are often one of a kind, means that each astronomer is an expert in a particular area, and therefore established scientists of different nationalities seek each other out for their special knowledge or expertise. Astronomer 1 mentioned certain patterns in international collaborations. The Brazilians, for instance, tend to collaborate more with the Europeans and the Mexicans with the Americans.

He mentioned an important Latin American network of astronomers who meet in regional meetings on astronomy and astrophysics held every three years. Through these events he keeps alive contacts with people made 10 or 15 years ago, particularly with the strong Latin American groups in Chile, Venezuela, Argentina and Brazil.

Astronomer 1 considers that his former collaborations remain latent and that at any moment he could rekindle their joint work when he has new data, for instance, or when he wants to visit to make some new observations. It is impossible to be actively involved with more than two or three projects at the same time while his potential international partners could be 12 or 15. He told me he has never experienced problems with financing and has always managed to travel wherever he has wanted to, even though some of his colleagues do complain of lack of funds for this purpose.

Astronomer 3

Astronomer 3's most significant foreign collaborations from 1980-1994 were mainly with research groups in Italy at astronomical observatories in Trieste and Milan and with a US group at the University of Massachusetts (UMASS).

Asked whether he encountered any logistic problems, he mentioned that these are always present. However, he did not ask for Mexican funding for these projects but let his foreign counterparts seek resources.

The most important benefit obtained from the liaison with the groups from Milan and UMASS was the equipping of the 2m telescope at the National Astronomical Observatory in Baja California, Mexico where he is based. He went on to comment that most, if not all, the observational equipment presently available at this observatory, belonging to the UNAM's Institute of Astronomy, are by products of these joint programmes. Furthermore, this equipment has been made available to anyone who has required it for research purposes. This has also benefited the Italian and US groups as they have been given access to telescope time that otherwise would have been restricted or granted in smaller proportion.

Astronomer 3 considers that the indirect benefits and spinoffs were predictable. However, the collaboration with researchers at UMASS, particularly with S. E. Strom, was the original contact for a major joint project between the US and Mexico which is known as the GTM/LMT (Gran Telescopio Milimetrico). He is presently the project scientist on the Mexican side.

He replied that it is hard to say whether the Italian and US groups could have carried out the joint work without his input. However, since these kind of collaborations start from personal contacts, he considered himself an important link in the chain. He referred to the fact that the Mexican astronomers are well known in the field and therefore "one must keep one's eyes open for opportunities". Often collaboration starts from direct contact during scientific meetings.

He thinks he could probably have not carried out the work himself, because of lack of equipment. The extremely poor conditions in which his observatory had to operate in the 80s was due both to the Mexican economic crisis and poor interest in the Baja California observatory shown by the authorities of the Institute of Astronomy at the UNAM before 1987.

At least a dozen co-authored papers were published as a result of the joint work. He expects the collaboration to continue for a few more years, at least until he retires, in about three or four more years. Continuing collaboration with these groups is important to cultivate a intellectually rewarding activity which, he believes, is achieved by maintaining contact with intelligent people.

Geoscientist 1

Geoscientist 1 indicated two collaborations as his most important, one with K. Aki from the University of Southern California in Los Angeles and the other with a French researcher, M. Campillo at the observatory in Grenoble.

He knew of Aki through his published work and went to visit him at his office when he worked in Boston. He met Campillo at a summer school in Italy, a scientist with "great organisational and numerical capacity" and they have been friends ever since. Neither collaboration has suffered from logistic problems as both foreign scientists are great facilitators.

Apart from providing the necessary environment for him to think and express his opinions, he feels that the discussions he has had with these two foreign scientists had been beneficial for all sides. Unexpected benefits relate to contact established with other scientists in the network through his association with Aki and Campillo.

He feels that the parts of the joint work could not have been done without his input as many of his observations were important for the outcome of the study. He also mentioned the application of certain types of techniques where he is the expert. Equally he believes that he could have done some of the joint work without the help of the foreign scientists. He had been working on alternative methods and different ways of looking at things which interested his counterparts and which were applied in a doctoral thesis at Grenoble. Furthermore, one of Campillo's students visited Mexico several times and together with Geoscientist 1 developed a new method which has been the basis of her continuing research interest.

The collaboration continues to a certain extent with Campillo and much less with Aki. The main reasons are the present institutional responsibilites of the Mexican scientist and the fact that he is now working with other Japanese scientists whom he met through Aki. His main limitation at the moment is a lack of Mexican colleagues to participate in these international ventures. He mentioned several times the problems associated with the absence of a group in Mexico, particularly with regard to having to do everything himself. However, his idea is to get together a group of good students who are capable of working independently.

If time allowed, the ideal way of collaborating with his foreign colleagues would be to spend short visits of two to three months in different places, such as Japan or Paris.

Geoscientist 2

This scientist referred to a special one off collaboration with the US Geological Survey (USGS) and the University of Washington where his role was mainly that of a facilitator although he did offer certain solutions to problems and was present during the experimental procedure. He had been approached by a geologist working for the Mexican Federal Electricity Commission to set up a shooting programme with the Americans to take cross profile measurements in Mexico which is still the longest profile available. The work was expensive as it involved the use of platforms and ships as one end of the profile was in a little inland lake and the other offshore. The US team provided all the equipment.

A joint paper resulted from the collaboration which Geoscientist 2 had a hand in writing and revising. As to other benefits resulting from the joint project, Geoscientist 2 believes that the Mexicans came off better than the Americans as without the collaboration of their northern neighbours, they would not have had the resources to carry out this important research. Also at that time the UNAM group was not as strong as it is now. Close contact was established with one USGS scientist who is still in touch with one of Geoscientist 2's colleagues at the UNAM, specifically Geoscientist 3. Geoscientist 2 experienced no particular logistic problems with this collaboration.

In reply to my questions about specific visits abroad that apparently had not resulted in the publication of joint work, the UNAM scientist remarked that a visit to the Indian Central Water Power Institute sponsored by the UNDP was solely to give classes. However, an in house publication was forthcoming. The main purpose of his trip to the Federal University of Bahia in Brazil was also to teach but this time, a joint discussion paper with a Brazilian student was published in one of the international journals [1]. A research visit to the University of Kyoto produced a paper in Japanese that was not included in Geoscientist 2's CV. The main thing that came out of this visit was getting a Japanese professor to come to work in Mexico on his retirement. A combined research/teaching visit to the University of Kiel in Germany did not have the expected results as far as the research aspect was concerned.

12.4 Publication Strategies

12.4.1 *Response from the Questionnaires*

Publication in international journals was a first option for all 15 scientists. The main reasons for publishing in Mexican journals were to give support to these journals in nine cases or that they had been requested to do so by colleagues in six cases (see summary of questionnaire results in Appendix 4). The fact that the Mexican journal is of international standing was a consideration in five instances. The fact that the subject matter of the paper was only or mainly of local interest or that the publication was destined for a specific audience were separate considerations in four other cases. A desire to publish in Spanish was present only in two instances, as was the fact that the scientist thought it unlikely that the paper would be accepted by a journal of international standing.

[1] This paper is included in Geoscientist 2's CV. However, the fact that it is a discussion paper meant that it was not considered in the present analysis.

Twelve of the scientists replied that all significant collaborations abroad had resulted in the publication of co-authored papers. Geoscientist 1 answered "yes and no" as he is behind with the writing up of results. Of the remaining two, Physicist 2 who elaborated on this point during the interview, wrote that he preferred to carry on his own research line within his group of local collaborators. Astronomer 3 mentioned a case(s) where his group lost interest in the topic or where the results turned out to be irrelevant or of little importance.

Likewise all but two of the scientists had not published co-authored papers with colleagues abroad that were not the result of a true collaborative research effort. In reference to these two cases, Physicist 1 wrote on the questionnaire that "collaborations are complex in the sense that an idea can originate during a visit and subsequently be developed with other collaborators or even with colleagues of these. The relative merit is difficult to gauge". Geoscientist 3 wrote of a situation where the Mexican group only provided the data for a research project in which they had little interest and minimal participation.

12.4.2 *Response from the Interviews*

In reference to the scientist's answers on publication strategies of results coming out of joint projects, many times the choice of journal was described as a "natural selection" or as "an obvious choice". As with the publication of the controversial treatment of Parkinson's disease described by Biomedic 1, the choice is "usually the best journal in the field". Physicist 1 also mentioned the existence of a core group of prestigious journals in the field in which the joint work was being carried out.

When the collaboration brings together experts from different fields, the decision is often focussed on publication in a journal in which of the two fields. The problem is sometimes resolved when as in the case of the joint work of Chemists 1 and 2 with the Mexican government laboratory, a paper had already been published by the UNAM scientists in their own speciality journal so that the joint work could be written up in a publication in the collaborating scientist's field. Geoscientist 3's work with the engineering group was published in seismology journals as his engineer colleagues were not much interested in the publishing aspect of the work. In other cases mentioned by Biomedic 2, Chemist 2 and Chemist 3, it was agreed to publish in the specialist journal of the scientist contributing more to the study or where the main focus of the study was in that particular field. Astronomer 3 mentioned that the decision of where to publish papers with his Italian and US co-authors was a "joint" decision while Geoscientist 1 told me sometimes he decided and other times, his foreign counterparts.

With regard to how the order of author names on the joint papers was decided, in the case of the adrenal transplantation in patients with Parkinson's disease, the Mexican clinician was the first author as he provided the patients and Biomedic 1 appeared as the author to whom reprint requests should be addressed. However, this UNAM researcher felt that the decision of who should appear first is "always a problem" but that "one should not fight about it too much". Chemist 3 had also experienced certain difficulties when deciding with national colleagues the name order on the joint paper, specifically with the leader of the collaborating group.

Geoscientist 1 and Geoscientist 3 agree that the first author should be the one who came up with the original idea or the person who did the most work, while Chemist 3 would assign this position to the scientist doing the fundamental work. Geoscientist 1 referring to his joint papers with Aki and Campillo, mentioned that it was possible to discuss with them this point but that agreement was usually easily reached. His doctoral students producing important pieces of work appear as first authors.

Biomedic 2 told me that in the case of her joint paper with her Danish counterpart, the first author was decided according to what type of cells were being studied and hence which of the two scientists was the specialist in that particular type of cell. In the case of Physicist 1's joint research with one of his American collaborators, he usually let the American decide as the topic did not correspond to his principal research interest.

When Physicist 3's contribution to a joint paper has been by giving opinions on criteria rather than carrying out the calculations, he usually appears as the last author. He considers that giving general rules for the order in which the author names should be noted is very difficult, rather the order will depend on the circumstances of each case. He has never had any problems when deciding on the name order in papers co-authored with foreign scientists. In his papers with Del Sole, the Italian as the more experienced scientist, was assigned the first author position.

Astronomer 3 noted that the name on his papers with the Italian and US scientists were sometimes in alphabetical order and sometimes the order was assigned according to the weight of the individual contributions to the study.

12.5 Integration into the International Scientific Community

12.5.1 *Response from the Questionnaires*

Only six scientists thought they were more aware or possibly so, of the work going on in their respective research areas in the United States than in other parts of the world, none of whom were astronomers (see summary of questionnaire results in Appendix 4). Thirteen answered that there was important work being carried out in their field in the USA or Canada, and 14 indicated Europe. The chemists were the only group where all three members did not indicate both of these options. The astronomers and the geoscientists were the most aware of significant work in progress outside these two main geographic regions. Eight scientists also acknowledged important Japanese research, two of which are astronomers. Astronomer 1 noted that the Japanese are strong on instrumentation and have the world's largest telescope.

12.5.2 *Response from the Interviews*

Some of the UNAM scientists mentioned that their institutes receive many visitors from abroad and emphasised the importance of international contacts made this way. Biomedic 1, for instance, told me of his collaboration with an American scientist whose sabbatical spent at the UNAM initiated a new line of research for the Mexican scientist. He also mentioned two East German scientists who were at the UNAM for almost a year. The intention to continue the collaboration was thwarted by the fall of the Berlin wall. Nonetheless, later on in the interview Biomedic 1 commented that it is unusual for an established First World scientist to come to Mexico to work on a joint project.

Physicist 1 and Astronomer 1 mentioned that their own institutes receive a large number of foreign visitors. Physicist 1 also told me that due to the saturation of the job markets in the US and Europe, Mexico has become a sought after place not only due to its proximity to the US but because of acceptable salaries and the possibility of additional research support from Conacyt. This situation has attracted researchers and postdoctoral students, especially from Eastern European countries and from China. He considered that some other UNAM institutes do not perhaps have sufficient international prestige to attract foreign scientists or, in other instances, institutional policy has been more restricted with regard to the employment of foreigners. However, he believes that market pressure is changing this situation. Apart from his own institute, he mentioned the Institute of Chemistry as having several foreign researchers.

During the interview, Astronomer 1 spoke about the evaluation of research performance in the light of the globalisation of science. The successful scientists of today in his view foster relations and carry out joint work with many groups, while sticking to a particular research area to maintain a certain identity. Before he was publishing about four articles a year but now produces more due to the way that research performance is evaluated. He has noted a change in his field from single author articles when he was a student to the multi-authored papers of today. He is not happy with the neoliberal role of present day science, especially the idea of the scientist as an impresario which is obliging researchers to compete with each other. The Matthew principle applies with rewards being bestowed on those who most frequently collaborate. Work rhythm is greater than before and, perhaps, scientists do not think too much about what they are publishing. The tendency in Mexico to count numbers of publications rather than carrying out qualitative judgements he believes has encouraged scientists to publish their work in small bits rather than in more meaningful divisions. He thinks that different evaluation methodologies and criteria should be combined to take into account not only the number of papers published but also citation rates, formation of research groups, creation of infrastructure and implementation of new research topics.

All three physicists mentioned meetings of international standing held in Mexico as important occasions for getting to know key people in the field. Some of these, as in the case of Physicist 3, had been organised by the UNAM scientists themselves. Reference has already been made to the significance of international relationships established and maintained through the Mexico/Texas and Latin American meetings described by Astronomer 1 (see section 12.3.2). Others, specifically Physicist 2, Physicist 3, and Astronomer 1 referred to writing book chapters, editing proceedings or special issues of journals with foreign scientists, activities that they considered as collaborative and indicative of an established position within international networks.

Several of the scientists referred to different kinds of discrimination towards Mexican research in the global scientific marketplace, limiting its acceptance and the significance of its international role. Biomedic 1 talked of prejudice on the part of reviewers and editors of international journals against papers submitted by scientists from developing countries. He described a generally negative attitude towards manuscripts from countries such as Mexico, Brazil or India which, he believes, are examined with a "magnifying glass" resulting in a whole series of objections which are not necessarily based on academic criteria. He believes that it is very difficult for Mexican scientists to enter into the "club". This was specifically his experience after the publication of the first paper on the transplant procedure in Parkinson's patients. The competitive nature of this whole research area made it especially difficult for researchers from other countries to accept a group from the Third World as contenders.

This same view was expressed by others. Biomedic 2 mentioned that she had written twice to a German group suggesting a joint project and that they did not even deign to reply. Astronomer 3 observed that international collaboration has not always been easy as foreign scientists have been reluctant to embrace cost saving proposals of the Mexicans for the design of equipment. Fortunately, these had usually worked out, an outcome that he attributed to local experience at having to make do with scant resources.

Biomedic 1 considers that it is difficult to achieve a true collaboration between equals with scientists from the industrialised countries as many of them see Third World scientists as just "an extra pair of hands". Going to a foreign laboratory to learn a new technique which can then be applied on returning home does not constitute, in his opinion, a true collaboration. In such cases, the visiting scientists are doing no more than "inserting themselves" into a system that is already in place.

Biomedic 3 referred to two types of foreign scientists who collaborate with scientists from the developing world, those she called "colonisers" and those who have a genuine desire to work together with the developing country scientist, in some instances for altruistic motives. The "colonisers", she explained, come "to impose and to gain advantage". Biomedic 1 alluded to his American colleague where he spent his sabbatical as being one of those foreign scientists who are "nice guys", not one of the prepotent ones. Geoscientist 3 also thought that perhaps, altruistic motives as well as scientific reasons had influenced an American scientist's decision to collaborate with the Mexican group.

Chemist 2 suggested that publication with foreign specialists leads to greater visibility of the work and an increase in citation rates. Help is also obtained with the writing up of the work and sometimes, it is the foreign scientist who submits the paper for publication thus increasing its chances of acceptance. He is convinced that a paper written by a US scientist has a much better chance of being cited than one of similar quality written by a Mexican.

Physicist 2 talked about how other scientists from developing countries, specifically from Latin America, go about getting themselves accepted into the international scientific networks. According to this researcher, remaining on the edge is real "torment" as it implies spending a lot of time working towards recognition, time which could otherwise be spent on research. Consequently, many scientists use sabbaticals or postdoctoral periods to work directly with notable scientists in the field, many he feels, before they have reached a suitable stage in their own careers. Sometimes the Mexican scientists instead of competing with foreign researchers will decide to continue their work. This will please the foreign scientists as their work is being cited and continued without having to employ a postdoctoral scientist. He even mentioned that the policy of some Mexican research institutes has been to boost the falling production of their researchers by sending them abroad. However, he feels it is not necessarily fair to criticise such strategies. What he believes is important is that these same scientists at some point in their careers must produce good independent work so that they can be judged on their own merit and not always be identified with the research of foreign scientists.

12.6 Discussion

The UNAM scientists expressed various motives for carrying out joint research with scientists outside their own institutions. Sometimes their counterparts offered complementary skills, data, equipment or techniques, filling a specific need of the Mexican scientists at a certain point in time. In other instances, the collaboration was sustained by a continuing need for the other scientist's particular expertise and shared research interests. Nonetheless in all cases the collaborating scientists provided more than just complementary information or facilities. Their contribution was described as intellectual input in the form of ideas, opinions, interpretation of results or help with the writing up or revision of papers.

In his study based on questionnaires and interviews with Swedish and American research scientists, Goran Melin found similar reasons for joint research outside their own institutions. These were usually described as having to do with gaining knowledge or skills, or gaining access to methods or equipment. The complementary nature of the input provided by the two parties is implicit in Melin´s findings when he mentions that the benefits also related to gained knowledge and quality with the counterparts contributing to "different" aspects of the research problem (Melin 1997).

In the present study both sides derived benefits from the joint projects, although not always to the same degree. In most cases it would not have been possible for each of the partners to carry out the research without the help of the other. In other instances, it would have proven too complicated, difficult or perhaps, too time consuming.

Scientific collaboration has been reported to be largely organised by the scientists themselves. Although there are a number of science policy initiatives that foster research collaboration (Melin and Persson 1996), in advanced scientific research, it is the personal element that counts more then the institutional (Salam 1966). Kriener and Schultz too suggest that the actors involved in informal collaboration in biotech R & D between universities and industry are loosely coupled with free interaction, driven more by accidental opportunities than by precise intentions and organisational strategies (Kreiner and Schultz 1993). In their study on Norwegian faculty members, Kyvik and Larsen found that while half collaborate with colleagues abroad on an informal basis, only one in five do so under the aegis of international collaborative agreements (Kyvik and Larsen 1996).

Although the UNAM scientists were not asked specifically if their international collaborations or stays abroad came under the umbrella of government or institutional programmes, a few of them did mention this type of support, particularly when referring to financial backing. Institutional strategies were not mentioned, rather contacts had been established by the Mexican scientists themselves. It is interesting to note that the general opinion of the !5 scientists was that getting financial support for travelling abroad and for joint ventures with foreign colleagues was not a problem. However, this could be do to the fact that these researchers are well known in their respective fields and might not be the case of less established Mexican scientists.

Melin concludes a series of studies on the coproduction of scientific knowledge by pointing out that the science is a functional, self organising system in which researchers like to collaborate with other scientists in order to advance knowledge. Although he does not make a distinction between national and foreign collaboration with regard to his Swedish scientists, he does mention a significant growth in the number of internationally co-authored Swedish mainstream papers in the natural and medical sciences from 1960 onwards (Melin 1997).

In the present study, the Mexican scientists described various ways of getting to know foreign scientists. Some contacts were planned with the researchers actively seeking out experts from other national or foreign institutions with a specific research objective in mind. Other times the collaborations were the result of chance encounters, these invariably occurring under predisposing circumstances and surroundings, such as those prevailing at international meetings or during visits to foreign laboratories.

The importance of contacts made at international meetings has been stressed by various authors. Liberman and Wolf, two Mexican researchers, describe scientific meetings as marketplaces of specialised knowledge where new links are established by exchange of information (Liberman and Wolf 1997). One of the ways that collaborative work between Norwegian and foreign researchers is brought about is described as accidental meetings at conferences (Kyvik and Larsen 1996).

An important finding from the interviews carried out in the present study, specifically with the physicists and the astronomers, is the significant role that national or regional meetings of international standing play in the development of joint projects with foreign colleagues and in the incorporation of these Mexican scientists into the international networks. During the interviews reported in section 8.5.2 the majority of the scientists specified that they were the members of their groups or were among the members of their groups, who were most likely to go to international scientific meetings. One of the main reasons given was that they, as acknowledged experts in their field, were most likely to get funding which was often forthcoming from the organisers of the meetings. Biomedic 2, for instance, mentioned that nowadays she goes to meetings only when she get s her expenses paid in this way. Mention was also made of trips to scientific events coming out of project funds. The principal restraint on participation in meetings, particularly at international level, was funding but this was mentioned principally with regard to student participation.

UNAM policy with regard to the provision of funding to attend meetings, particularly those taking place abroad, normally requires that the applicant have a paper accepted for oral presentation, at least in the case of the more junior scientists. However, as the funding is authorised by the director of the applicant's institute or research centre, then decisions can be based on the overall importance to the work or prestige of the institution of the applicant's participation in the event. Sometimes more subjective criteria are taken into consideration. Scientists whose projects are financed by earmarked UNAM funds or by Conacyt are normally expected to pay for trips to meetings out of the project budget. This is also likely to happen when the scientists receive international research funding.

Also mentioned by these same groups of researchers is the flow of international visitors to their UNAM institutes and the employment of an important number of foreign scientists. The majority of the UNAM scientists also saw the visits of foreign scientists to Mexico as the major indirect benefit derived from their international collaborations. Hagstrom believes that the most important function of exchange visits is the exchange of ideas and not technical details. When a noted scientist visits, the entire home group can benefit, not only mature scientists but students too (Hagstrom 1965).

Outcomes of the international collaborations were varying described during the interviews as increased international recognition, visibility and citation rates, greater numbers of international contacts, provision of equipment, more complete answers to problems, and the training and exchange of students. Analysis of the questionnaire showed that increased international visibility of research was indicated by 10 of the 15 Mexican scientists as a principal benefit of collaborating with foreign researchers with increased productivity being noted by nine. Only four selected the option of increase in the number of citations.

Increased productivity due to an extensive division of labour was also mentioned by the scientists in Melin's paper as being one of the main benefits of collaborative work. Other benefits mentioned by the Swedish researchers were increased quality of work as a result of the interactions and discussions of ideas, methods or results, as well as the generation of new ideas, new ways of thinking and new perspectives (Melin 1997).

Exchange of students is of particular importance to boost the dwindling number of young Mexicans opting for research careers, particularly in the basic sciences, and for the consolidation of groups in emerging areas of research. A conscious effort on the part of the UNAM scientists to involve their local colleagues and students in international projects manifested by at least nine of the 15 UNAM scientists will also help achieve this objective which is of paramount importance in Mexican science policy. Furthermore there is evidence that students make an important contribution to research productivity especially in the case of the more productive scientists (Fonseca, Velloso et al. 1997).

Collaborations in the present analysis terminated sometimes because the specific reason for the joint work ceased to exist, at other times because of the collaborating scientist moving to another institution or due to changing research interests, or in one case due to estrangement of the participating scientists. There was little evidence of sustained collaborations except in a few cases where personal friendships had been formed. Nonetheless, several of the UNAM scientists referred to the fact that many former collaborators can be called upon to embark on new joint research when suitable opportunities arise. Hence the importance of remaining in communication with former research partners.

A feeling expressed by most of the scientists interviewed is that collaborations are complicated and complex both with fellow Mexicans and with foreign colleagues. The importance of the human and social elements in collaborations came out very strongly in their replies both on the questionnaire and during the interviews. Although personal difficulties were rarely encountered once the joint ventures were under way, positive chemistry or mutual liking were mentioned as preconditions for joint ventures. It seems that a right mix of scientific and social considerations must be present for a successful collaboration to take place. In Melin's study all respondents also mentioned personal chemistry as a prerequisite for research collaboration (Melin 1997). The occasions when problems arose as reported in the present study were mainly associated with the allocation of credit for the joint work, in some cases when it was time to decide who should be assigned the first author position.

The main finding of a recent study on the role of human relations in the scientific productivity of Brazilian biochemists is that the most productive scientists attributed more importance to this aspect of their research than do their less productive colleagues. This latter group on the other hand, explained their low productivity in terms of material and other external factors (Fonseca, Velloso et al. 1997). Although the Brazilian study did not look specifically at the human element in research collaborations their findings also stress the important influence that social factors exert on scientific work and productivity.

Some of the UNAM scientists referred to family situations affecting the way they carry out their international collaborations and specifically to the difficulty involved in spending long periods away from home. The alternative of shorter and more frequent visits abroad has already been referred to when discussing sabbatical leaves of absence (see section 10.7).

The important role of email in reducing the number and length of visits required to foreign institutions as part of joint research ventures was emphasised by two of the UNAM physicists. Physicists and astronomers are known to make extensive use of new information technologies (Report 1993; Crawford 1996; Hurd 1996) suggesting that at least in these fields, electronic communication could and is opening up new ways of working for scientists from DCs.

Research interests and approaches are likely to change with time, as are institutional and family responsibilities. Martin-Rovet in her study on French researchers in the USA mentions two periods in the research career of French scientists when they undertake scientific stays abroad. This phenomenon is linked not only to professional motivation, but also to marital status and family situation. During the first stay they are likely to be single or recently married without children and around the age of 25; a second stay period is when the children are independent which usually happens after the age of 40 (Martin-Rovet 1995).

An interesting finding of the present analysis is the substantial involvement of the 15 UNAM scientists with their national scientific community. Only about a third considered that contact and/or recognition were more important with their international peers than with their national colleagues. The importance of national collaborations is demonstrated by the fact that five chose local joint ventures as among the most significant in the development of their research work. Furthermore, only three of the UNAM scientists considered their joint international work to be of higher quality than that with national colleagues.

The peripheral position of Mexican science is demonstrated by the experiences of varying forms of discrimination mentioned by some of the 15 scientists. The attitude taken by certain foreign scientists and journal editors is that Mexican science (and scientists) is inferior except perhaps in cases where knowledge of local conditions is required. Nonetheless, results from the interviews suggest that the majority of foreign colleagues with whom the UNAM scientists have worked do not share this perception. There are numerous mentions in the literature of prejudice against science from developing countries which can best be illustrated by Arunachalam´s statement that an address in the Third World, in the opinion of many Third World scientists, virtually repels citations (Arunachalam and Manorama 1989).

The UNAM scientists in the present study were unanimous in their preference for publishing in international journals. The fact that all of them were aware of work in their respective fields in areas of the world other than the US and Canada, suggests a proximity to international science and, in consequence, to the global scientific community.

In his study on almost 500 ex IFS grantees from 67 DCs in all parts of the world, Gaillard found that only about 20% published exclusively in national journals and that these were mainly younger scientists. Reasons for publishing at least part of their work in national publications ranged from the application of these publications in teaching to the desire to promote good quality scientific publications edited nationally (Gaillard 1991). The desire to support national journals was the main reason for publishing locally in the present study.

The UNAM scientists mentioned only a few specific and rather insignificant cases of collaborations that had not led to the publication of cosigned papers. This, coupled with the fact that few co-authored papers had been written in the absence of true collaborations, suggests that, at least in the present study, analysis of co-authorship patterns mirrors collaborative activity. Melin agrees that single authoring is a rare occurrence following collaborative work (Melin 1997).

Chapter 13

Conclusions

13.1 Relationship with the International Scientific Community

The different types of analyses carried out in the present study revealed varying characteristics, activities and relationships that point to a group of highly productive scientists who are well integrated into and recognised by both their own and the international scientific communities. High visibility in the international research literature appeared to be associated with other national indicators of scientific recognition, such as prizes, membership of elite scientific bodies, as well as with frequent contact with peers abroad.

They were among the members of their local groups with most contact with the national and international scientific communities and were found to play important roles at the interface of internal and external group actions. They were the group members most likely to present papers at international meetings and those responsible for the final versions of manuscripts to be sent for international publication. All were able communicators in English at least within their own scientific fields. The fact that some of the 15 scientists arranged for their doctoral students to spend time at foreign laboratories either while doing the research for their degree or later on as postdocs reinforced bonds already established by the scientists with foreign laboratories and facilitated joint work.

The importance of contact with the international scientific community for the development of the Mexican scientists' research activities and especially as a way of positioning themselves within the invisible colleges and international networks in their respective fields is evident from the present findings. Both the frequent occurrences of sabbaticals and other visits made abroad by the majority of the scientists indicate an important role for these activities in achieving integration, a suggestion which was corroborated by the scientists themselves.

The important role played by joint research ventures with colleagues abroad is shown by the fact that all but one of the 15 scientists mentioned that their careers as research scientists had benefited from collaboration with foreign colleagues. Collaboration leading to co-authorship is an indicator of a specific type of international contact representing the closest form of international interaction where the two parties join forces in the definition, analysis and solution of problems to achieve the common goal of producing new scientific knowledge.

Contact with foreign scientists, especially through prolonged visits to laboratories abroad, had an important influence on the Mexican scientists without the two parties necessarily embarking on a joint project. Examples were seen of doctoral, postdoctoral and sabbaticals visits that had lasting impacts on the careers of the Mexican scientists, sometimes by providing them with skills, approaches or ways of working that they might not have developed in their home environment. However, these influences could and did occur in the absence of joint research and co-authorship. Furthermore the 15 scientists in the present study were among the most productive of national researchers in their respective fields but not necessarily those showing the highest levels of international co-authored papers.

The snowballing effect of contacts leading to their gradual but progressive integration into the international scientific community and increasing levels of international co-authorship was frequently mentioned, often times by the formation of specific alliances described by the scientists as "lasting friendships". These social alliances in some cases seemed to override scientific considerations. As mentioned earlier in the thesis, it appears that the right mix of scientific and social elements have to be in place before collaboration takes place.

Collaborations were beneficial too in the sense that there appeared to be direct links between co-authors and citing authors. Citation analysis revealed that some of the co-authors made an important number of citations to the UNAM scientists' work other than those to the work they published together. Furthermore, the UNAM researchers knew most of the scientists who were citing their work and could identify them as members of their own invisible colleges or networks. Citations revealed the extent to which these Mexican scientists are integrated into global networks and are evidence of one of the few instances where information flow is from periphery to centre. In all cases the fact that increased visibility through citations could be linked to at least one stay abroad, lends support to the view that visits abroad lead to increased citation rates.

As was to be expected, contact, communication and collaboration were predominantly with scientists and institutions from the scientific centre. There was perhaps less reliance on those in the US and Canada than would have been anticipated considering the traditional influence that particularly the United States has on Mexican science. Increasingly frequent links were found with European colleagues which could be characteristic of the increasing globalisation of Mexican science. There was indication of South-South information flow with respect to a number of co-authorships found with Latin American colleagues, some publication in Latin American journals and a few visits reported to other countries in the region.

Results from the present study suggest that an increase in the production of papers does not necessarily follow sabbaticals spent abroad, at least in the short term. Nonetheless, the scientists mentioned techniques and other skills learned during sabbaticals and alliances made that had positive effects on the development of their research careers and on their long-term productivity. Increased productivity, however, was not something that was sought after, rather most of the scientists gave their motivations for collaborating with other scientists or making visits abroad as pursuing other objectives, such as access to specialised equipment or techniques, or carrying out specific pieces of work. Sabbaticals, however, did enlarge visibility in terms of an increase in the number of internationally co-authored papers.

All scientists had made a number of visits abroad during the 15 years studied and all but one sabbatical had been spent in foreign institutions invariably in the scientifically advanced countries. The purposes of visits abroad were varied but, particularly in the laboratory based sciences, were often to learn new techniques which would provide the researchers with additional skills necessary to keep them competitive in their respective research fields. When the techniques were available locally or nationally there was no need to look abroad. There was considerable evidence from the present analysis of daily contact or working on joint projects with foreign scientists providing intellectual stimulation and exchange of ideas leading to greater productivity, creativity or scope in subsequent research.

Going on sabbatical is perhaps more important at the beginning of the Mexican scientists careers in order to get experience in scientifically more advanced environments and particularly to initiate contact with scientists abroad. This is especially relevant for the scientists who do their PhDs in Mexico. Nevertheless, many of the scientists interviewed saw sabbaticals as giving them the advantage of time spent away from the routine and commitments of their home institutions, of finding themselves in new and stimulating environments with first rate facilities giving them both the intellectual and physical environment to rethink certain ideas and develop new ones. Also mentioned was time to catch up on writing papers, and perhaps, to learn new skills. In this sense sabbaticals were seen as productive times regardless of the career stage of the scientists concerned. However, the alternative of making frequent short visits in later years when family and professional responsibilities limit the time that can be spent out of the country had already been implemented by some of the UNAM scientists. Email was mentioned as an important, new facilitator for communication and collaboration between scientists reducing the need for face to face interactions.

The negative attitudes of certain foreign scientists towards Third World scientists and science were mentioned in some of the interviews. Notwithstanding definite examples were seen in the present study where the Mexican scientists were the principal partners in the joint work as suggested by their first author position. Also it was clear that the UNAM scientists made important theoretical contributions in many of the international collaborations as well as providing innovative ideas or approaches. There was also mention of collaborations that changed the way of thinking of foreign colleagues. Furthermore, the mutual benefits gained by both parties from the joint work suggest collaborations between equals.

Although certain general conclusions can be arrived at with regard to the importance of collaboration and contact of Mexican scientists in general and its relationship with productivity, visibility and impact, certain field differences were found. Production in the exact sciences, for instance, of which physics and astronomy are used as examples in the present study, appeared to be driven by international co-authorships, suggesting a direct relationship between performance and international collaboration. The findings of these so called international sciences contribute to the understanding of universal phenomena whose significance and relevance are not subject to geographic, political or cultural boundaries but are of interest to specialists anywhere in the world. In other fields of study, such as research into local diseases or earthquake phenomena seen in the present thesis, it is necessary to combine local and universal knowledge in order to solve problems that may require the involvement of both national and international colleagues.

13.2 Relationship with the National Scientific Community

Regardless of their fields of study, the 15 scientists in the present analysis were well integrated into their national communities as demonstrated by the recognition given to them at institutional and national levels. Their integration into established local groups and the importance of these in the development of their research is demonstrated by the frequency of collaborations with institutional colleagues, and especially by the identification in many cases of a main local partner or partners. Furthermore, in fields such as biomedicine with an important local component, the total production of papers followed closely the same pattern as that of papers written in UNAM co-authorship.

The experience, prestige and professional contacts of the 15 scientists made them leaders in their local research environments. Activities associated with this role were setting the research agenda of the groups, securing funding, and co-ordinating, promoting and facilitating the projects. There were obvious individual differences in the way the scientists collaborated with their national and international colleagues even between scientists in the same research areas. Some indicated stable internal groups showing consistent co-authorship patterns while others revealed networks of collaborators spanning both the national and international research environments

The smallness of the Mexican scientific community results in reduced scientific mobility between national groups as compared to the industrialised countries. This often means that postdocs can remain for extended periods within the same groups. The relative abundance of research institutes in certain fields such as the biological and medical sicences, compared to other fields such as astronomy with a small national scientific community, produces marked differences in the number of local, national and international co-authorships found.

Productivity was associated by some of the scientists with the presence of other senior scientists in the groups and/or the presence of important numbers of students, particularly at doctoral level. In the laboratory sciences important contributions to group productivity are made by technical staff and students who carry out the experimental work. In these cases the group leaders may contribute little in the way of experimental results. Productivity was also linked to the degree of student participation in the groups as each thesis project was expected to produce at least one published paper.

The importance of local and national colleagues for the development of the Mexican scientists' research is also shown by their involvement in international projects. The fact that one of the scientists attributed the lack of intermediary level local colleagues to his inability to take on joint projects with researchers abroad suggests that international collaborations require the input of local collaborators. In some cases these local collaborators were postgraduate students.

Contact and collaborations with scientists and institutions abroad benefited not only the work and career of the scientists directly involved but also helped the development of Mexican science. Multiplying effects were seen with respect to the provision of new techniques and the acquisition of equipment that could be used by other local scientists. Contacts made by individual scientists were often shared with other colleagues. The training and exchange of students as an important element in the joint projects with institutions abroad was frequently mentioned during the interviews with the 15 scientists.

In spite of the relevance of local collaborators and their integration into the higher spheres of their national scientific community, the UNAM scientists published few of their papers in national journals, with the exception of the astronomers whose national journal is included in the *Science Citation Index*. This indicates that the main projection of their research is towards the international scientific community and is consistent with the importance that they assigned to recognition by international peers.

13.3 Methodological Considerations

Co-authorships as bibliometric indicators of collaboration, provide totals, frequencies and distributions of collaborative activities that lead to the publication of joint papers. These data, although useful in themselves particularly when presented at aggregate levels, provide no insight into the motives, mechanisms, dynamics and results of the collaborations that require other methodological approaches involving the participation of the actors concerned.

In the present study co-authorship patterns were found to be appropriate indicators of collaboration, representing linkages on both intellectual and social levels. Furthermore these could be linked to other variables equally representative of the integration of scientists into the wider scientific community, such as visits made to foreign institutions and citation patterns. The combination of methodologies used in the present study led in many instances to the corroboration of the bibliometric findings but, perhaps more importantly, it was also possible to find explanations for these data as a result of putting the appropriate questions to the scientists involved. Certain specific questions posed by the analysis of the scientometric findings such as the suggested presence of citing authors in the same invisible colleges and networks as the 15 scientists under study, could only be satisfactorily answered by the scientists themselves. Similarly, the explanation for the absence of any obvious links between the UNAM scientists and certain of their foreign co-authors could be ascertained only at the time of the interviews. Although the basic structure of the internal research groups could be sketched using co-author analysis, to obtain information on the particular roles of the scientists within these groups it was necessary to contact appropriate group members.

The 15 CVs analysed in the present study were structured in a similar way providing quite detailed and accurate information with regard to many aspects of the scientists' research, such as the publication of papers, courses taught, and presentations in congresses. Other activities such as visits to foreign institutions, however, were included only when these referred to periods generally longer than a week or two making it necessary to acquire complementary information on aspects such as these during the interviews. Additional information included by some of the scientists in their CVs was indicative of the special importance that they gave to certain activities, such as the creation of research groups or the development of infrastructure.

One of the main constraints in carrying out interviews for retrospective studies is that this technique depends on how accurately the scientists are able to remember past events. The principal danger is that their replies may be influenced by current perspectives and interests. On very few occasions during the interviews did the scientists have difficulty remembering events and my overall impression was that they had fairly accurate levels of recall. Furthermore, the information given to me during the interviews usually tied in with the findings from the bio-bibliometric analysis. However, it cannot be denied that each scientists is an individual and, although there was certain agreement on many of the variables studied, there were other issues, particularly social and cultural aspects, where opinions were undoubtedly influenced by the particular way of thinking or beliefs of the individual scientist. This individuality can be uncovered only by talking to the scientists themselves.

13.4 Policy Implications

It is clear that joint research ventures and visits to foreign institutions have favoured the research careers of the 15 scientists in the present study. The fact that none of them originally reported difficulty in obtaining funding for these activities and in general considered national science policy initiatives adequate in this respect, suggests an awareness on the part of national policy makers of the importance of these international activities for the development of Mexican science. Nonetheless, during the second round of interviews a year later, concern was expressed by some of the scientists that funding was becoming more difficult to obtain. All scientists mentioned that this is particularly difficult to obtain for student participation especially in international meetings.

The fact that some of the scientists mentioned a successful series of short visits to carry out joint research projects with scientists abroad indicates a need for special funding for this type of international activity, over and above that provided for longer leaves of absence such as sabbaticals. While it is possible that the scientists might be able to find funding for these visits out of their soft research money, it is important that the local science administrators be aware of the benefits forthcoming from the support of these shorter stays abroad. Of particular relevance is the fact that, this way, the Mexican scientists spend less time away from research and teaching obligations within their home institutions.

The organisation in Mexico of meetings of international standing and the visits of foreign scientists to Mexican institutions were often mentioned as important ways of establishing and maintaining contact with foreign scientists. There was even some indication that Mexico might be an important node in international scientific networks in certain specialist fields in astronomy and physics. The benefits that these interactions represent not only for the scientists responsible for organising the events or visits, but also for other Mexican colleagues, particularly students, should be taken into consideration by those responsible for science policy. The provision of state or institutional funds to support the organisation of international events in Mexico and to facilitate the visits of international experts to national institutions should be readily available.

The importance of international alliances in the training of Mexican students, particularly with regard to their early incorporation into bilateral and multilateral research projects, was mentioned by several of the scientists in the present analysis. Providing the opportunity and resources for Mexican students to spend time at foreign laboratories while reading for a PhD in Mexico implies less money spent from government and international funds than that required to send them abroad to do their doctorates. Additional advantages for Mexican science are that the Mexican students become involved in projects related to the research interests of local groups, and their participation strengthens the relationship between the collaborating scientists.

13.5 Further Research

The scope of present findings suggests different topics where further research could be carried out.

The importance of internal collaborations for the development of the UNAM scientists' work came out strongly in the present study. The contribution that important group members such as other senior scientists and doctoral students, make to productivity was touched upon by some of the scientists during the interviews. The involvement of institutional peers in international projects suggests too an important role for local colleagues in joint ventures with foreign scientists. A research project should be designed specifically to shed more light on the dynamics of the relationship between internal group structures, productivity and involvement in joint projects at international level in a DC environment such as Mexico.

This could best be done by taking random samples of groups in the same general research areas to avoid having to allow for differences in the objectives and the way science is done in the different knowledge fields (as was apparent from the present study).

Another interesting aspect of collaborative work that was touched on by scientists in the present study, is the role of new communication technologies in joint research, particularly at international level. Future research directed at understanding the different mechanisms involved in joint work with foreign scientists, and the way that email and Internet services and capabilities are facilitating these processes would contribute greatly to the definition of national information policies.

Another research topic suggested by the present research is the definition of the roles of different types of visits abroad (such as postdoctoral, sabbatical, and other visits of different duration) and their relative usefulness for specific purposes, (such as learning techniques, updating knowledge, training of researchers, access to equipment, and implementation and realisation of joint research projects). It would also be interesting to determine the usefulness of the different types of visits at the various stages of the scientist's career.

Larger co-author and citation windows need to be taken to arrive at more conclusive findings with respect to the relationships between co-authors and citing authors and to determine the usefulness of this technique for identifying networks in which Mexican scientists participate. As well as identifying the external groups who cite the Mexican work, distinction should be made between the self-citations of the Mexican scientists and those of their co-authors in order to identify the different groups making up the network as well as to establish the links connecting up the different groups within the network. The findings of the small study carried out as part of the present project suggest that this technique is useful for identifying individual and groups members of the international networks in the Mexican scientists' research fields.

The peak in papers co-authored with sabbatical institutions that was found to occur during the two years following the sabbatical visit could provide the basis for a larger study to determine the effect of sabbaticals on the production of papers and citation rates. For comparative purposes it would be useful to look at these variables in the case of scientists with similar trajectories as the researchers in the present study but who have never taken sabbaticals abroad. The productivity and impact of their work would need to be examined in the light of other types of relationships with the international scientific community, such as contact made at international meetings and the occurrence and frequency of short visits abroad.

13.7 Final Comments

Earlier work has shown that collaboration in science is a means of enhancing productivity and visibility as well as a mechanism to advance research. It has also shown that visibility and productivity are strongly related. For scientists in DCs visibility is achieved by publication in the mainstream literature, through papers presented in international meetings and through contact and collaboration with scientists in other countries, especially those at the scientific centre. Such activities lead to gradual integration and recognition of the DC scientists by their colleagues in the international scientific community. Another important factor is that science is becoming increasingly specialised. The condition of science in DCs, such as the smallness and isolation of their scientific communities, poor research infrastructure and low investment in scientific research, implies that DC scientists often need to look abroad for expert help and for access to specialised facilities.

Results from the present study showed that all 15 scientists had played the role of global collaborator to different degrees and at different times in their scientific careers. Formal alliances were often formed as the result of special needs such as access to laboratory techniques, to sophisticated equipment or to researchers with specialised knowledge. In a few cases it was the foreign scientist who sought access to special conditions available in Mexico to form partnerships. These collaborations, especially those formed during sabbaticals and other prolonged stays abroad, often had lasting effects on the scientific careers of the 15 scientists. The normal consequences were increases in the global visibility of the scientists through co-authored publications, by the snowballing of international contacts and through more frequent foreign exchanges and other opportunities to participate in international scientific activities. Contacts established such as those with foreign researchers, with funding bodies and with journal editors, allowed the Mexican scientists to remain globally competitive in their respective fields. In the absence of these contacts it is likely that their productivity in the mainstream literature would have suffered.

Contact with and insertion into strong national groups coupled with strategic alliances with the international scientific community seem to be elements which favour high international productivity and visibility of Mexican scientists. All 15 scientists had initiated contact with scientists abroad early on in their careers, either as doctoral or postdoctoral students. Those who did their doctoral degrees in Mexico had been associated with strong local groups which had made them productive before they went abroad. However, for all of them to remain productive in an increasingly competitive international context, it was necessary for them to establish their own strategic alliances with members of the international invisible colleges and networks in their fields of expertise besides establishing their own local groups.

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APPENDIX 1. QUESTIONNAIRE ON COLLABORATION WITH FOREIGN SCIENTISTS

Please note that the information given on this form is confidential and will be published only under a code name or in aggregate form.

IMPORTANCE OF INTERNATIONAL LINKS

1. How important is contact with the international scientific community for the development of your research activity ?

unimportant 1 2 3 4 5 *essential*

2. Is contact with the international scientific community generally more important for your work than that with colleagues in the national scientific community ?

___ *yes*
___ *of equal importance*
___ *no*

3. How important is recognition from the international scientific community for the development of your research activity ?

unimportant 1 2 3 4 5 *essential*

4. Is recognition from the international scientific community generally more important for your work than that from your colleagues in the national scientific community ?

___ *yes*
___ *of equal importance*
___ *no*

5. As far as quality of research output is concerned, has it been your general experience that it is more beneficial to collaborate with foreign rather than Mexican colleagues ?

___ *yes*
___ *no*
___ *impossible to say*

6. Is publication in international journals generally your first option for publication of research papers ?

___ *yes*
___ *no*

7. When you have published research papers in Mexican journals what have been your principal reasons ? (Please mark more than one option where applicable)

___ *Mexican journal included in* Science Citation Index
___ *subject of local interest only*
___ *paper not likely to have been accepted by an international journal*
___ *to give support to national journals*

___ *requested by colleagues to contribute to national publications*
___ *to reach a specific audience*
___ *to publish in Spanish*
___ *other(s)* (please state):

COLLABORATION WITH RESEARCHERS ABROAD

8. What are the principal attributes that you look for in a foreign research collaborator ? (Please mark more than one option where applicable)

___ *reputation as a researcher*
___ *institutional position*
___ *know-how*
___ *his/her research facilities*
___ *shared research interests*
___ *ability to procure funding*
___ *good communicator*
___ *other(s)* (please state):

9. How have you generally come to know your foreign collaborators ? (Please mark more than one option where applicable)

___ *at international conferences*
___ *through his/her scientific papers*
___ *through local colleagues*
___ *through foreign colleagues*
___ *during doctoral or postdoctoral studies*
___ *during other visits to foreign institutions*
___ *other(s)* (please state):

10. What do you consider have been your principal motivations for collaborating with foreign researchers ? (Please mark more than one option where applicable)

___ *to gain their intellectual input*
___ *to gain their special competence*
___ *lack of local specialists*
___ *share workload*
___ *to carry out a comparative study*
___ *institutional links facilitating the collaboration*
___ *to obtain financing*
___ *to gain access to specialised equipment or facilities*
___ *to learn a new technique(s)*
___ *to gain access to particular local experimental environments or conditions*
___ *to embark on a new area of research*
___ *to establish collaboration with a particular country*
___ *to diminish academic isolation from the international scientific community*
___ *to ensure publication of results in an international journal*
___ *other(s)* (please state):

11. Do you consider that your career as a research scientist has benefited from collaboration with foreign colleagues ?

___ *yes*
___ *no*
___ *impossible to say*

12. If the answer is yes, then what do you consider have been the principal benefits for your research work from this type of collaboration ? (Please mark more than one option where applicable)

___ *increased productivity*
___ *increased quality of the research produced*
___ *increase in the innovative elements (methods, results, approaches)*
___ *increased international visibility of your research work*
___ *increased prestige of your research work*
___ *increase in the number of citations to your work*
___ *other(s)* (please state):

13. Has your collaboration with foreign colleagues produced other indirect benefits to your research work ? (Please mark more than one option where applicable)

___ *exchange of graduate students*
___ *visits of foreign scientists to Mexico*
___ *invitations to participate in international events, committees, etc.*
___ *widened your contacts within the international scientific community*
___ *other(s)* (please state):

14. Has your collaboration with foreign colleagues generally involved the coparticipation of your local colleagues ?

___ *yes*
___ *sometimes*
___ *no*

15. If the answer is yes, do you make a conscious effect to involve your local colleagues in collaborative projects with foreign scientists ?

___ *yes*
___ *sometimes*
___ *no*

16. Have any of the following non scientific considerations ever influenced your choice of a foreign collaborator ? (Please mark more than one option where applicable)

___ *language affinities*
___ *likeable person*
___ *personal friendship*
___ *compatible working style*
___ *ease of travel or travel distance*
___ *mutual interest in sports, hobbies, etc.*
___ *cultural, political or religious links*
___ *other(s)* (please state):

17. How important do you consider these non scientific considerations are in the choice of a foreign collaborator ?

unimportant 1 2 3 4 5 *extremely important*

18. Have you ever experienced negative consequences of collaborating with foreign scientists ?

___ *yes*
___ *no*

19. If the answer is yes, what have these negative consequences been ? (Please mark more than one option where applicable)

___ *too much institutional bureaucracy*
___ *too much money spent*
___ *results did not live up to expectations*
___ *unfair allocation of credit for the work*
___ *difficulties in interpersonal relationships*
___ *other(s)* (please state):

20. If these negative consequences are related to difficulties in interpersonal relationships, what were the major causes ? (Please mark more than one option where applicable)

___ *language difficulties*
___ *different working traditions*
___ *cultural differences*
___ *personality differences*
___ *other(s)* (please state):

21. Have all significant collaborations with a colleague abroad resulted in the publication of coauthored papers ?

___ *yes*
___ *no*

22. If the answer is no, could you state briefly the reason(s) ?

23. Have you ever coauthored a research paper with a colleague abroad that was not the result of a true collaborative research effort ?

___ *yes*
___ *no*

24. If the answer is yes, could you state briefly the reason(s) ?

LINKS WITH DIFFERENT REGIONS

25. Are you more aware of what is going on in your research field in the United States than in other parts of the world ?

___ *yes*
___ *no*
___ *possibly*

26. In which of the following regions or countries is important work being carried out in your field ? (Please mark more than one option where applicable)

___ *USA/Canada*
___ *Europe*
___ *Latin America*
___ *Japan*
___ *other(s)* (please state):

SCIENCE POLICY CONSIDERATIONS

27. Have you ever been unable to travel abroad to visit a foreign laboratory due to lack of financial support ?

___ *yes*
___ *no*
___ *cannot remember*

28. Please rate the support given by Mexican science policy initiatives to formal collaboration with foreign scientists ?

much too limited 1 2 3 4 5 *abundant*

APPENDIX 2. INTERVIEW SCRIPT

COLLABORATION WITH RESEARCH GROUPS

1. What groups or scientists from other institutions in the UNAM, in Mexico or abroad have you collaborated with (=significant interaction or input in a research activity) since 1980 ? (If possible mention these in order of importance to the development of your research work).

2. Taking the collaboration you mention as the most important, what initiated the formal collaboration ?

3. Did you encounter any logistic or other types of problems with this collaboration ?

4. What have been the most important benefits gained from this collaboration ?

5. Do you consider that the benefits of the collaboration were equal for both parties ?

6. Have there been any, perhaps unexpected, benefits (spinoffs) from this collaboration, other than those directly related to the development of your research work ?

7. Could the collaborating group or scientist have carried out the work without your participation in the project ?

8. Is the answer is no, please state the reason(s) ?

9. Could you have carried out this work without the input of the collaborating group or scientist ?

10. Is the answer is no, please state the reason(s) ?

11. Did this collaboration lead to the publication of a coauthored paper ?

12. If so, who decided in what journal the paper should be published ?

13. How did you decide on the name order of the paper ?

14. Is this collaboration still active ?

15. If so, then how long do you expect the collaboration to last ?

16. If the collaboration is no longer active, then how long did it last ?

17. Why did it stop ?

18. Was it, or is it, important for your work to continue in contact with these scientists once the stage of formal collaboration has ended ?

SABBATICALS[1]

Let me ask you about the sabbatical that you spent at ______________________

19. Did you select to spend your sabbatical at this particular institution to work with a particular scientist, group of scientists, or to work at a particular department or institution ?

20. What were your main reasons for choosing to spend your sabbatical with this particular scientist (group of scientists, department or institution) ?

[1] A few additional questions will be asked to each scientist on specific aspects of their particular sabbatical visits

21. How was the contact with this scientist (group of scientists, department or institution) initiated ?

22. How was the sabbatical financed ?

23. What was your principal objective during this sabbatical ?

24. Did you encounter any special problems (scientific, logistic, material, social, etc) which interefered with the success of the sabbatical ?

25. Do you think that the sabbatical increased your productivity (as measured by the number of papers published) ?

26. How do you rate the overall impact of the sabbatical on the development of your research ?

27. How do you rate the overall impact of the sabbatical on your research career?

28. Has the sabbatical had any continuing effects on your research activities ?

29. Did you continue collaborating in research activities (as opposed to keeping up contact) with colleagues at the sabbatical institution once the visit was ended ?

30. If so, how long did this last (or do you expect it to last) ?

31. Have you kept in close professional contact with your sabbatical colleague(s) ?

32. How important for your reseach activity has been this continuing contact with them once the stage of formal collaboration ended ?

CITATIONS[2]

33. Do you know these authors personally ?

34. How did you come to know them ?

35. Do you both form part of the same invisible colleague (come across them at meetings, publish in the same journals, etc.) ?

36. Do you exchange information, preprints or reprints with them ?

37. Do you consider their work highly relevant to your own work (or was it at that time)?

38. Have you ever considered a formal collaboration with them ?

39. If this answer is yes, what have been the obstacles to carrying out this collaboration ?

40. Is there anything you would like to add on any aspect of the questionnaire or interview, or in general about your experiences or opinion on the subject of the collaboration in science, particularly that with foreign scientists ?

[2] A few additional questions will be asked to each scientist on specific aspects of their particular citations

INTERNAL GROUP STRUCTURE

41. What is the general structure of your internal research group in terms of size, composition (research assistants, students, etc) and hierarchy (superiors, colleagues, subordinates, technicians and secretaries, others including students)

42. Has the composition or size of the group changed over the last ten or fifteen years (with respect to the composition rather than the presence of individual members)?

43. What is the nature of the interactions (internal dynamics) between the members of your group (who does what, such as literature searching, liaison with other groups, writing the papers, etc.)?

44. How does co-operation (particularly as regards formal and informal communication) work within your group (for instance, who attends national and international meetings, who appear as co-authors ?

45. What is the role of the different members of the group at the interface between internal and external interactions?

46. Do other members of the group have <u>independent contacts</u> with researchers from other institutions both at home and abroad?

APPENDIX 3. TABLES ON THE EFFECTS OF SABBATICALS

Table A3-1

Effect of sabbaticals on the total production of papers of the biomedics and the chemists

SCIENTIST		n_1 [a]	n_2	n_3	n_4	E	x^2
BIOMEDIC 2	0	11	6	8	6	7.75	
	0-E	3.25	-1.75	0.25	-1.75		
	$(0\text{-}E)^2$	10.56	3.06	0.06	3.06		
	$(0\text{-}E^{2)}/E$	1.36	0.39	0.004	0.39		**2.14**
BIOMEDIC 3	0	10	11	17	8	11.50	
	0-E	-1.50	-0.50	5.50	-3.50		
	$(0\text{-}E)^2$	2.25	0.25	30.25	12.25		
	$(0\text{-}E^{2)}/E$	0.20	0.02	2.63	1.07		**3.92**
3 x BIOMEDICS	0	24	21	31	18	23.50	
	0-E	0.50	-2.50	7.50	5.50		
	$(0\text{-}E)^2$	0.25	6.25	56.25	30.25		
	$(0\text{-}E^{2)}/E$	0.011	0.27	2.39	1.29		**3.96**
CHEMIST1	0	7	13	17	8	11.25	
	0-E	-4.25	1.75	5.75	-3.25		
	$(0\text{-}E)^2$	18.06	3.06	33.06	10.56		
	$(0\text{-}E^{2)}/E$	1.61	0.27	2.94	0.94		**5.76**
2 x CHEMISTS	0	9	20	17	12	14.50	
	0-E	-5.50	5.50	2.50	-2.50		
	$(0\text{-}E)^2$	30.25	30.25	6.25	6.25		
	$(0\text{-}E^{2)}/E$	2.09	2.09	0.43	0.43		**5.04**

[a] n_1 = Total for the two years previous to the sabbatical
n_2 = Two year period which includes the sabbatical
n_3 = Two years following the sabbatical
n_4 = Third and fourth year after the sabbatical

Table A3-2

Effect of sabbaticals on the total production of papers of the physicists, astronomers and geoscientists

SCIENTIST		n_1 [a]	n_2	n_3	n_4	E	x^2
PHYSICIST 1	0	12	17	7	7	10.75	
	0-E	1.25	6.25	-3.75	-3.75		
	$(0-E)^2$	1.56	39.06	14.06	14.06		
	$(0-E^{2)}/E$	0.15	3.63	1.31	1.31		**6.40**
PHYSICIST 2	0	5	8	9	8	7.50	
	0-E	-2.50	0.50	1.50	0.50		
	$(0-E)^2$	6.25	0.25	2.25	0.25		
	$(0-E^{2)}/E$	0.83	0.03	0.30	0.03		**1.20**
2 x PHYSICISTS	0	17	25	16	15	18.25	
	0-E	-1.25	6.75	-2.25	-3.25		
	$(0-E)^2$	1.56	45.56	5.06	10.56		
	$(0-E^{2)}/E$	0.09	2.50	0.28	0.58		**3.45**
ASTRONOMER 1	0	11	7	5	6	7.25	
	0-E	3.75	-0.25	-2.25	-1.25		
	$(0-E)^2$	14.06	0.06	5.06	1.56		
	$(0-E^{2)}/E$	1.94	0.009	0.70	0.22		**2.87**
ASTRONOMER 2	0	7	3	5	7	5.50	
	0-E	1.50	-2.50	0.50	1.50		
	$(0-E)^2$	2.25	6.25	0.25	2.25		
	$(0-E^{2)}/E$	0.41	1.14	0,05	0.41		**2.01**
3 x ASTRONOMERS	0	23	14	15	17	17.25	
	0-E	5.50	-3.25	-2.25	0.25		
	$(0-E)^2$	30.25	10.56	5.06	0.06		
	$(0-E^{2)}/E$	1.75	0.61	0.29	0.004		**2.65**
GEOSCIENTIST 2	0	6	7	8	5	6.50	
	0-E	-0.50	0.50	1.50	-1.50		
	$(0-E)^2$	0.25	0.25	2.25	2.25		
	$(0-E^{2)}/E$	0.04	0.04	0.35	0.35		**0.78**
GEOSCIENTIST 3	0	3	8	9	5	6.25	
	0-E	-3.25	1.75	2.75	-1.25		
	$(0-E)^2$	10.56	3.06	7.56	1.56		
	$(0-E^{2)}/E$	1.69	0.49	1.21	0.25		**3.14**
3 x GEOSCIENTIST S	0	11	18	19	15	15.75	
	0-E	-4.75	2.25	3.25	-0.75		
	$(0-E)^2$	22.56	5.06	10.56	0.56		
	$(0-E^{2)}/E$	5.64	0.32	0.67	0.04		**6.67**

[a] n_1 = Total for the two years previous to the sabbatical
n_2 = Two year period which includes the sabbatical
n_3 = Two years following the sabbatical
n_4 = Third and fourth year after the sabbatical

Table A3-3

Effect of sabbaticals on the production of internationally coauthored papers

SCIENTIST		n_1 [a]	n_2	n_3	n_4	E	x^2
3 x BIOMEDICS	0	2	6	16	5	7.25	
	0-E	-5.25	-1.25	8.75	2.25		
	$(0-E)^2$	27.56	1.56	76.56	5.06		
	$(0-E^{2)}/E$	3.80	0.22	10.56	0.70		**15.28** [d]
PHYSICIST 1	0	2	12	5	3	5.50	
	0-E	-3.50	6.50	-0.50	-2.50		
	$(0-E)^2$	12.25	42.25	0.25	6.25		
	$(0-E^{2)}/E$	2.23	7.68	0.05	1.14		**11.10** [b]
2 x PHYSICISTS	0	2	13	5	4	6.00	
	0-E	-4.00	7.00	-1.00	-2.00		
	$(0-E)^2$	16.00	49.00	1.00	4.00		
	$(0-E^{2)}/E$	2.67	8.17	0.17	0.67		**11.68** [c]

Table A3-4

Effect of sabbaticals on the levels of international institutional coauthorships

SCIENTIST		n_1 [a]	n_2	n_3	n_4	E	x^2
BIOMEDIC 3	0	1	2	14	6	5.75	
	0-E	-4.75	-3.75	8.25	0.25		
	$(0-E)^2$	22.56	14.06	68.06	0.06		
	$(0-E^{2)}/E$	3.92	2.45	11.84	0.01		**18.22** [d]
3 x BIOMEDICS	0	2	6	23	8	9.75	
	0-E	-7.75	-3.75	13.25	-1.75		
	$(0-E)^2$	60.06	14.06	175.56	3.06		
	$(0-E^{2)}/E$	6.16	1.44	18.01	0.31		**25.92** [d]
PHYSICIST 1	0	4	23	12	7	11.5	
	0-E	-7.50	11.50	0.50	-4.50		
	$(0-E)^2$	56.25	132.25	0.25	20.25		
	$(0-E^{2)}/E$	4.89	11.50	0.02	1.76		**18.17** [d]
2 x PHYSICISTS	0	4	24	12	9	12.25	
	0-E	-8.25	11.75	0.25	-3.25		
	$(0-E)^2$	68.06	138.06	0.06	10.56		
	$(0-E^{2)}/E$	5.56	11.27	0.005	0.86		**17.70** [d]

[a] n_1 = Total for the two years before sabbatical n_2 =Two year period including sabbatical
n_3 = 2 years following sabbatical n_4 = Third and fourth year after sabbatical

[b] Significant at a confidence level of 5%
[c] Significant at a confidence level of 1%
[d] Significant at a confidence level of 0.5%

APPENDIX 4. RESULTS OF THE QUESTIONNAIRES

Question 1: *How important is contact with the international scientific community for the development of your research activity?*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Unimportant						
1						
2	1					1
3		1				1
4					1	1
5	1		1	2	1	5
Essential	1	2	2	1	1	7

Question 2: *Is contact with the international scientific community generally more important for your work than that with colleagues in the national scientific community?*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Yes	1		2		2	5
= Importance	2	3	1	3	1	10
No						

Question 3: *How important is recognition from the international scientific community for the development of your research activity?*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Unimportant						
1						
2						
3		1		1	1	3
4					1	1
5		2	2	1	1	6
Essential	3		1	1		5

Question 4: *Is recognition from the international scientific community generally more important for your work than that from the colleagues in the national scientific community?*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Yes	2		2		2	6
= Importance	1	3	1	2	1	8
No				1		1

Question 5: *As far as quality of research output if concerned, has it been your general experience that it is more beneficial to collaborate with foreign rather than Mexican colleagues?*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Yes	1	1			1	3
No	2	2	3	1	1	9
Impossible to say				1	1	2
Other options				1 about the same		1

Question 6: *Is publication in international journals generally your first option for publication of research papers?*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Yes	3	3	3	3	3	15
No						

Question 7: *When you have published research papers in Mexican journals what have been your main reasons? (Please mark more than one option where applicable)*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Mexican journal of international standing		1		2	2	5
Subject of local interest only	1 1 (mainly)	1			1	4
Paper not likely to be accepted by int. journal	1	1				2
Give support to National journal	2	3	2	3	2	12
Requested to contribute to nat. publication	1	2	2	1		6
Reach specific audience	1		1		2	4
Publish in Spanish			1		1	2
Other(s)						

Question 8: *What are the principal attributes that you look for in a foreign research collaborator? (Please mark more han one option where applicable)*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Reputation as a researcher		1	1			2
Institutional position						
Know-how	2	2	2	1 (research abilities)	1	8
His/her research facilities		1		1	1 (capacities)	3
Shared research interests	2	2	3	3	1	11
Ability to procure funding						
Good communicator		1				1
Other(s)	1 *					1

* His interest in collaborating with a scientist from the developing world

Question 9: *How have you generally come to know foreign collaborators? (Please mark more than one option where applicable)*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
At international conferences	3	2	2 1*	3	3	14
Through his/her scientific papers	3	3	1	3	2	12
Through local colleagues	1	1	1			3
Through foreign colleagues			1	1	1	3
During doctoral or postdoctoral studies	1	1	1	2		5
During other visits to foreign institutions	1	1	1	2	1	6
Other(s)					1**	1

*Some of them organised by our group in Mexico ** Visitors to my institute

Question 10: *What do you consider have been your principal motivations for collaborating with foreign researchers? (Please mark more than one option where applicable)*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Gain their intellectual input	1		1	2	1	5
Gain their special competence	3		1	1	3	8
Lack of local specialists	1		1		3	5
Share workload	1		1	1	1	4
Carry out a comparative study						
Institutional links facilitating the collaboration		1				1
To obtain financing					1	1
Access to specialised equipment or facilities		2		1	1	4
To learn a new technique(s)	1	1	1	1	2	6
Access to local environments or conditions		1				1
To embark on a new area of research	1	1			2	4
To establish collaboration with a particular country	1* (scientist)	1				2
To diminish isolation from the int. scientific community		2	2	2		6
To ensure publication of results in an int. journal						
Other(s)						

Question 11: *Do you consider that your career as a research scientist has benefited from collaboration with foreign colleagues?*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Yes	1 1*	3	2	3	2	12
No	1					1
Impossible to say			1		1	2

*A small portion

Question 12: *If the answer is yes, then what do you consider have been the principal benefits for your research work from this type of collaboration? (Please mark more than one option where applicable)*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Increased productivity	1 1*	1	2	2	2	9
Increased quality of the research produced				2	1	3
Increase in the innovative elements	1			2	1	4
Increased int. visibility of your research	1	2	3	2	2	10
Increased prestige of your research	2	1		2	1	6
Increase in no. of citations to your work	1	1		2		4
Other(s)	1**	1***				2

*Solve specific problems of my research ** Permanence of funding *** The use of advanced instrumentation

Question 13: *Has your collaboration with foreign colleagues produced other indirect benefits to your research work? (Please mark more than one option where applicable)*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Exchange of graduate students	1		3	1	2	7
Visits of foreign scientists to Mexico	1	2	2	3	3	11
Invitations to participate in int.events, etc.		1	2	2	2	7
Widened contacts with the int. sci. community.		2	2	2	2	8
Other(s)	1**				1***	2

*Biomedic 1 did not tick any of the options **Solve specific problems ***Widened perspective of research in the field

Question 14: *Has your collaboration with foreign colleagues generally involved the co-participation of your local colleagues?*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Yes	2	1	2	1	2	8
Yes and No			1 half and half!!	1 similar fraction, no in past, yes in present		2
No	1	2		1	1	5

Question 15: *If the answer is yes, do you, as a rule, make a conscious effort to involve your local colleagues in collaborative projects with foreign scientists?*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Yes	2	1	3	1	2	9
No						
				1 maybe		1

Question 16: *Have any of the following non scientific considerations ever influenced your choice of a foreign collaborator? (Please mark more than one option where applicable)*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Language affinities	1		1			2
Likeable person	1	2	3	3	2	11
Personal friendship	1	2	1	2	2	8
Compatible working style	1	3	2	1	2	9
Ease of travel or travel distance	1	2				3
Mutual interest in sports, hobbies,etc.						
Cultural, political or religious links				1		1
Other(s)					1*	1

*Respect for Mexican culture and institutions

Question 17: *How important do you consider non scientific considerations are in the choice of a foreign collaborator?*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Unimportant						
1	1					1
2						
3		2	1	2		5
4			1	1	1	3
5	2	1	1		2	6
Extremely important						

Question 18: *Have you ever experienced negative consequences of collaborating with foreign scientists?*

	Biomedic	Chemist	Physicist	Astronomer	Geoscientist	TOTAL
Yes	1			1	2	4
No	2	3	3	2	1	11

Question 19: *If the answer if yes, what have these negative consequences been? (Please mark more than one option where applicable)*

	Biomedic	Chemist	Physicist	Astronomer	Geoscientist	TOTAL
Too much institutional bureaucracy				1		1
Too much money spent						
Results did not live up to expectations				1		1
Unfair allocation of credit for the work	1			1	2	4
Difficulties in interpersonal relationships					3	3
Other(s)						

Question 20: *If these negative consequences are related to difficulties in interpersonal relationships, what were the major causes? (Please mark more than one option where applicable)*

	Biomedic	Chemist	Physicist	Astronomer	Geoscientist	TOTAL
Language difficulties						
Different working traditions				1		1
Cultural differences				1	1	2
Personality differences					1	1

Question 21: *Have all the significant collaborations with colleagues abroad resulted in the publication of coauthored papers?*

	Biomedic	Chemist	Physicist	Astronomer	Geoscientist	TOTAL
Yes	3	3	2	2	2	12
No			1	1		2
Yes/No					1	1

Question 22: *If the answer is no, could you briefly state the reason(s)?*

Geoscientist 1: I'm behind schedule

Physicist 2: I have generally preferred to carry on my own research line within my group in local collaborators.

Astronomer 3: We lost interest in the topic, or the results were irrelevant or of little importance.

Question 23: *Have you ever coauthored a research paper with a colleague abroad that was not the result of a true collaborative research effort?*

	Biomedic	Chemist	Physicist	Astronomer	Geoscientist	TOTAL
Yes			1		1	2
No	3	3	2	3	2	13

Question 24: *If the answer is yes, could you state briefly the reasons(s)?*

Physicist 1: In a few cases, collaborations are complex in the sense that an idea can originate during a visit and be subsequently developed with other collaborators or even colleagues of these. The relative merit is difficult to gauge.

Geoscientist 3: We only provided the data but were not really interested in the research topic. For these reasons our participation was minimum.

Question 25: *Are you more aware of what if going on in your research field in the United States than in other parts of the world?*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Yes	1	2			2	5
No	2	1	2	3	1	9
Possibly			1			1

Question 26: *In which of the following regions (or countries) do you know of important work being carried out in your field? (Please mark more than one option where applicable)*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
USA/Canada	3	1	3	3	3	13
Europe	3	2	3	3	3	14
Latin America	1			2	1	4
Japan	1	1	1	2	3	8
Other(s)	1:Australia			1:Australia	1:China, New Zealand, India	3

Question 27: *Has a lack of financial support ever stopped you from travelling abroad to visit a foreign laboratory?*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Yes	1		1	1		3
No	2	2	2	2	2	10
Cannot remember		1			1	2

Question 28: *Please rate the support given by Mexican science policy initiatives to formal collaboration with foreign scientists?*

	Biomedic	*Chemist*	*Physicist*	*Astronomer*	*Geoscientist*	*TOTAL*
Too limited						
1		1				1
2						
3	1		2	½	1	4 ½
4		1		2 ½	1	4 ½
5	2	1			1	4
Abundant			1			1

APPENDIX 5. UNAM SCIENTISTS WHO PARTICIPATED IN THE STUDY

Rubén G. Barrera Pérez

Jorge Cärdenas Pérez (co-worker)

Luis Carrasco Bazúa

Laura Colombon (PhD student)

René R. Drucker Colin

Ana Flisser Steinbruch

Alejandro Frank Hoeflich

Cinna Lomnitz Aronsfrau

Herminia Pasantes Morales

Manuel Peimbert Sierra

Paris Pismis

Leovigildo Quijano

Alberto Robledo Nieto

Lydia Rodríguez Hahn

Alfonso Romo de Vivar Romo

José Francisco Sánchez Sesma

Shri Krishna Singh