COLLABORATION PATTERNS OF SPANISH SCIENTIFIC PUBLICATIONS IN DIFFERENT RESEARCH AREAS AND DISCIPLINES

Isabel Gómez and M.T. Fernández
Centro de Información y Documentación Científica. CSIC, Madrid, Spain

A. Méndez
Institut d'Etudis Avançats de les Illes Balears. CSIC/UIB, Madrid, Spain

Keywords: Collaboration, Spain, research areas

Abstract: International collaboration through co-authorship is a topic to which many recent studies have been devoted. In the last years, scientific collaboration in Spain experienced a remarkable growth at the national as well as at the international level. We are looking for indicators capable of showing the benefits that the Spanish system could obtain from that increase. Bearing this in mind, it is essential to know how the collaboration patterns have been established in the different areas or disciplines. A total of 43402 Spanish documents for the years 1990 to 1993 covered by SCI and SSCI were examined and classified according to the ISI subject categories. A series of indicators was applied to each of the scientific disciplines: degree of internationalisation of research, degree of domestic collaboration (between different Spanish institutions or geographic locations), degree of intra-institutional collaboration, co-authorship index, and basic/applied research as measured by the Narin index. These indicators differentiate scientific disciplines grouping them in research areas with characteristic patterns. Significant variations were observed in the average impact factors of journals used for publication in relation to the scope or amplitude of collaboration. The institutions originating the documents and their type of collaboration were analyzed. The consequences of international, domestic and intra-institutional collaborations and their evolution during the study period are discussed.

1. INTRODUCTION

There has been a recent boom of scientometric studies devoted to international collaboration. In Spain several studies have analyzed trends and may prove useful for prospective analysis (1, 2). Research cooperation was promoted in Spain by political measures, launched at the end of the seventies, which favoured the funding of those requested research projects which were backed up by a group of scientists. The intention was to avoid the scattering of research efforts among individual projects, which was usual till then. One of the weaknesses of Spanish science was its isolation both inside and outside the country. In the present paper we have examined the collaboration links established by Spanish scientists which can be detected through co-authored publications, covered by the SCI and SSCI. Our research provides a general overview of the results obtained through analysis of research areas and the most productive research disciplines and tries to show which type of cooperation has been developed. We are looking for answers to questions such as:

- Which type of collaboration takes place, international or domestic, and in which fields?
- Is internationality related to basic research?

- Is visibility related to the type of cooperation?
- Are we moving towards richer connections inside or outside our country?
- What can be expected from the patterns we have observed?

The present situation will be compared to the results of former studies devoted to the scientific production of the previous decade.

2. METHODOLOGY

A total of 43402 Spanish documents published from 1990 to 1993, covered by the databases SCI and SSCI in CD-ROM version were studied. Around 10% of the documents for 1993 are missing, as they will be recorded in CD-ROM 1994. All types of documents were considered, because in some areas, particularly at the domestic level, collaboration links are often revealed by "non-citable items", such as meeting abstracts.

The documents were divided into three sets: a) those presenting international collaboration (at least one foreign address); b) those presenting domestic collaboration (more than one Spanish address but no foreign address); c) those having no collaboration at all (only one Spanish address). The degree of internationalisation was defined as the percentage of documents found in group a) and the degree of domestic collaboration as the percentage of documents in group b). The degree of intra-institutional collaboration is the percentage of documents where different departments of the same institution are collaborating. A total of 4.8% of the documents presented both international as well as domestic collaboration; they were included in group a) because the influence of the foreign partner was considered more relevant.

Each set of documents was classified according to the SCI and SSCI disciplines and then aggregated in eight scientific areas, following the SCI Current Contents product codes. The area of Physical, Chemical & Earth Sciences was divided into three subareas: Physics, Chemistry, and Mathematics, due to their different characteristics as seen in previous studies (3). Multidisciplinary journals (*Nature, Science, PNAS, Experientia, La Recherche*) were considered as a separate area. Institutional addresses were standardised and codified as already described (4) and grouped as follows: universities, hospitals, Spanish Scientific Research Council (CSIC), joint university-CSIC centres and others. Integer counting was used when more than one specialty or address was present. A four level scale of journals introduced by Computer Horizons Inc. (CHI) was used as an indicator of the basic/clinical type of research (5). The visibility of journals was measured by their impact factor (IF) in JCR 1991.

3. RESULTS

The presence of Spanish documents in these international databases has grown during the period, from 8683 documents in 1990 to 12509 in 1993. Considering all four years, the collaboration pattern is as follows: 49.5% documents show no collaboration, 25.4% presenting only domestic collaboration and 25.1% with international collaboration. This general pattern will be used as a reference for comparison of the different areas. The collaboration indices have grown from 1990 to 1993: the degree of internationalisation has risen 3 points and the degree of domestic collaboration 2.3 points. Consequently, the proportion of papers with a single corporate address diminished by 5.3.

3.1 Analysis per areas

The distribution of Spanish documents per areas is shown in fig. 1. The most productive area is

Life Sciences, followed by Clinical Medicine. Chemistry and Physics are strong areas, according to the pattern of research interests of southern and eastern European countries in the early eighties (3). Anyhow, this distribution seems to be changing, as a bigger effort in Life and Medical Sciences is observed in Spain in the recent years when comparing this distribution to that of the previous decade (6).

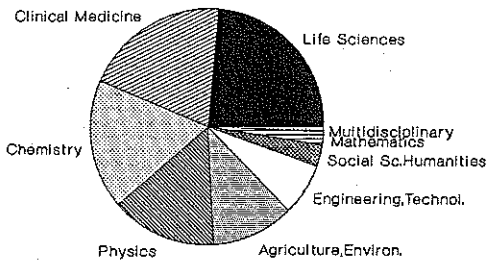

Fig. 1 Distribution of Spanish documents per areas

The scope of collaboration of the different areas is shown in table I. Two areas, Physics and Multidisciplinary, have a degree of internationalisation far above average, together with a low degree of domestic collaboration and low non-collaboration. The only area with a degree of domestic collaboration remarkably higher than average is Clinical Medicine, with 40.4% of its documents; however, its international collaboration is the lowest. The proportion of documents with no collaboration is highest in Social Sciences and Humanities -whose publication habits are different from those of experimental sciences- followed by Agriculture and Environmental Sciences. In both areas international and domestic collaboration are below average. Mathematics has more non-collaboration documents than average, together with a high internationality index and low domestic collaboration.

	Degree of internat. collab.	Degree of domestic collab.	Non-collab.	Narin level
Life Sciences	22.1	27.8	50.1	3.5
Clinical Medicine	11.5	40.4	48.1	2.2
Chemistry	24.0	21.5	54.6	3.5
Physics	47.9	17.7	34.5	3.7
Agriculture, Environ.	20.1	22.3	57.7	3.3
Engineering, Technology	28.7	19.7	51.6	2.4
Social Sciences & Humanities	20.4	16.1	63.5	2.4
Mathematics	32.8	13.6	53.6	3.5
Multidisciplinary	55.9	9.3	34.8	4.0

Table I: Degree of internationalization and degree of domestic collaboration of the research areas.

Is there any relationship between the degree of domestic collaboration and the degree of internationalisation with the basic or applied character of the different areas? In order to answer this question the Narin classification of journals in four levels according to their basic/applied level was used. The most basic area is Multidisciplinary, followed by Physics, both with a high degree of internationalisation. Mathematics, Chemistry and Life Sciences follow behind. Agriculture, Biology & Environmental Sciences is an heterogeneous group, with very basic and very applied disciplines. Only Engineering, an applied area, has high international and low domestic collaboration. Clinical Medicine has an applied Narin level and a very high domestic collaboration. The fact that basic documents have more international collaboration was first reported by Frame (7).

The evolution of the collaboration patterns of the areas is analyzed separately in fig. 2. Although the proportions vary greatly, a general trend of growth of internationality and domestic collaboration is observed in each of the separate areas, indicating more compact collaboration networks.

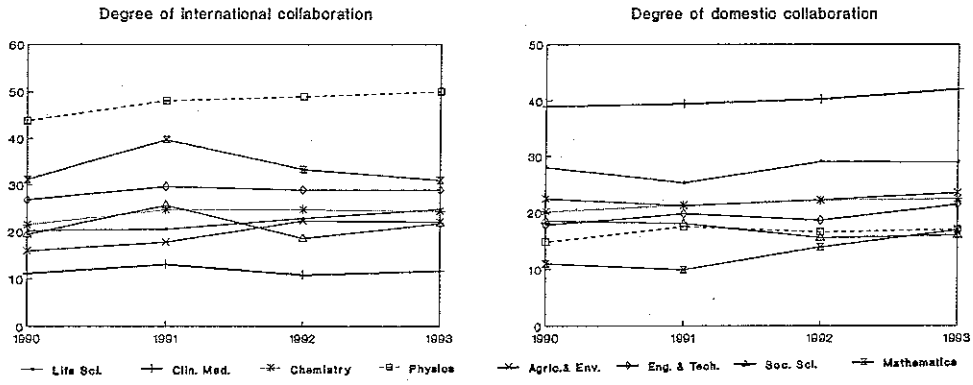

Fig.2 Evolution of the collaboration patterns per area

Other indicators studied in the different areas were the degree of inter-institutional collaboration and the co-authorship index. In general, co-authorship index and number of institutions are higher in international papers (table II).

	Internat.collab.		Domestic collab.		Non-collab.		Total	
	N.Ins	N.Aut	N.Ins	N.Aut	N.Ins	N.Aut	N.Ins	N.Aut
Life sciences	2.9	5.2	2.4	5.0	1	3.8	1.8	4.4
Clinical Medicine	4.1	7.0	2.5	5.6	1	4.3	2.0	5.2
Chemistry	2.6	5.0	2.2	4.5	1	3.4	1.7	4.0
Physics	5.2	16.2	2.3	3.6	1	2.8	3.2	9.3
Agriculture,Environ.	2.6	4.2	2.2	3.9	1	3.1	1.6	3.5
Engineering,Technology.	2.9	5.7	2.2	3.9	1	3.0	1.8	4.0
Social Sciences & Humanities	2.7	3.4	2.2	3.3	1	2.0	1.6	2.5
Mathematics	2.3	2.4	2.0	2.4	1	1.6	1.6	2.0
Multidisciplinary	3.3	5.8	2.2	3.8	1	2.8	2.4	4.6

Table II. Degree of inter-institutional collaboration and co-authorship index of the research areas

Co-authorship index is particularly high in Physics international papers (16.2 authors in average) together with a high degree of inter-institutional collaboration (more than five institutions). This suggests the existence of multinational networks that will be studied at the discipline level. In Clinical Medicine different phenomena are observed: domestic collaboration is very high (40%), with a co-authorship index of 5.6 and 2.5 institutions involved. But the co-authorship index rises to nearly 7 in the international documents, with an average of 4 institutions collaborating. The number of foreign institutions and countries involved is high, which again points to a possible multinational network, that will be studied further at the discipline level.

3.2 Analysis per disciplines

The area level of aggregation is too large and not all its features are homogeneous; therefore our analysis will concentrate at the more disaggregated level of the 176 SCI and SSCI disciplines with Spanish documents. If the disciplines are listed in decreasing frequency order, the first quartile, 44 disciplines, collects around 75% of the documents (Table III). The visibility of the journals used is measured by the 1991 Journal Citations Report impact factor (IF). In 39 cases the IF is higher in international papers; only in 3 disciplines did domestic collaboration enhance visibility and in two cases the non-collaboration papers have the highest visibility. This enhanced visibility linked to international papers was also observed by Narin (8) through citation analysis. The highly productive disciplines are mostly basic, in accordance to the bias of the database used: 34 have a Narin level $>=2.5$ (considered as basic), while only 10 have an index < 2.5 (considered as clinical or applied). The distribution of these highly productive disciplines of the first quartile in research areas is the following: 11 in Life Sciences; 10 in Clinical Medicine; 6 in Chemistry, Physics and Agriculture, Biology & Environmental Sciences; 4 in Engineering & Technology and 1 in Mathematics. No ISI discipline from Social Sciences & Humanities nor from the Multidisciplinary group are included amongst the most productive.

For each discipline, the degree of internationality, degree of domestic collaboration, average number of institutions, co-authorship index, basic-applied level and IF were studied. In fig. 3 and table IV an example of the indicators per discipline in two different areas, Physics and Clinical Medicine, is shown. The area of Physics includes basic disciplines with a high degree of internationality (particularly Nuclear Physics and Astronomy & Astrophysics), and a low degree of domestic collaboration (except for Crystallography). In the Physics discipline the co-authorship index is specially high in the international documents (43.7), together with more than 10 institutions involved, indicating a "Big Science" multinational network.

All Clinical Medicine disciplines have a small degree of internationality and a high degree of domestic collaboration. Narin level is around 2, indicating clinical research. When analyzing the number of institutions and authors involved, the discipline Internal Medicine differs from all others: its indicators are much higher in international than in domestic papers. These results were discussed with experts who analyzed the documents involved and detected a multi-national network of clinical and epidemiological research (2/3 of the documents) together with multi-centre clinical trials for drugs, probably promoted by the pharmaceutical industry (1/3 of the documents).

3.3 Scope of collaboration per institutions

Universities, research institutes and hospitals have established collaboration networks with different amplitude or scope, more local in the case of hospitals (table V). The collaboration pattern of the University is similar to the global Spanish indicators regarding internationality index and degree of domestic collaboration; intra-institutional collaboration is present in 12% of its documents. The

DISCIPLINE	INTERN. COLL.		DOMEST. COLL.		NO COLL.		TOTAL	
	DOC.	IF	DOC.	IF	DOC.	IF	DOC.	IF
BIOCHEM/MOLEC.BIOL	759	3.77	640	2.67	1541	2.65	2940	2.94
CHEMISTRY,ANALYTICAL	256	1.30	358	1.08	1352	1.16	1966	1.17
CHEMISTRY,ORGANIC	428	1.76	412	1.79	1029	1.74	1869	1.76
CHEMISTRY	401	1.58	427	1.14	1026	0.77	1854	1.03
PHARMACOLOGY/PHARM	310	1.90	572	1.46	934	1.71	1816	1.66
CHEMISTRY,PHYSICAL	520	1.62	400	1.49	843	1.46	1763	1.52
MEDICINE GENERAL/INT.	107	7.68	773	2.17	879	2.81	1759	2.83
NEUROSCIENCES	363	3.12	471	2.25	723	2.58	1557	2.61
PHYSICS	768	2.65	220	1.95	555	2.02	1543	2.32
PHYSICS,CONDENSED M.	666	2.01	299	1.78	470	1.72	1435	1.87
BOTANY	356	1.55	268	1.31	713	1.19	1337	1.31
CHEMISTRY,INORGANIC	503	1.68	294	1.70	365	1.44	1162	1.61
MICROBIOLOGY	220	2.32	292	1.91	613	1.91	1125	1.99
UROLOGY/NEPHROLOGY	45	3.42	423	3.24	595	4.27	1063	3.82
IMMUNOLOGY	185	3.68	436	2.56	424	2.77	1045	2.84
GENETICS/HEREDITY	262	3.11	241	2.31	509	2.37	1012	2.55
ASTRONOMY/ASTROPHYSIC	615	2.15	138	1.60	228	1.56	981	1.93
MATERIAL SCIENCES	311	1.28	199	1.06	389	1.00	899	1.11
PHYSIOLOGY	110	2.94	122	1.65	543	1.43	775	1.68
CITOLOGY/HISTOLOGY	184	3.59	220	1.65	365	1.93	769	2.26
CARDIOVASCULAR SYSTEM	118	3.57	268	2.68	347	2.92	733	2.94
GASTROENTEROLOGY	76	3.98	325	3.01	308	2.95	709	3.09
PHYSICS,APPLIED	287	2.01	99	1.86	314	1.73	700	1.86
BIOPHYSICS	189	3.18	162	2.66	328	2.60	679	2.78
ENDOCRINOLOGY/METABOL	129	2.81	264	2.34	276	2.40	669	2.45
FOOD SCIENCES AND TECH.	73	0.92	131	0.85	455	0.83	659	0.84
MARINE/FRESHWATER	132	1.03	142	0.93	383	0.91	657	0.94
ENVIRONMENTAL SCIENCES	111	0.95	167	0.92	362	0.95	640	0.94
PHYSICS ATOMIC,MOLEC.	280	2.55	102	2.52	256	2.46	638	2.51
HEMATOLOGY	121	4.29	242	3.05	275	3.23	638	3.37
SURGERY	28	1.05	297	1.22	310	1.06	635	1.14
MATHEMATICS	201	0.46	68	0.43	318	0.36	587	0.40
CANCER	127	2.77	257	1.97	203	2.04	587	2.17
POLYMER SCIENCE	167	1.44	107	1.42	275	1.26	549	1.34
BIOTECH./APPL.MICROB.	82	1.69	124	1.39	332	1.37	538	1.43
ZOOLOGY	109	0.69	90	0.56	294	0.68	493	0.66
MEDICINE RESEARCH	96	5.29	162	2.01	228	2.29	486	2.79
DERMATOLOGY/VENERAL.	38	1.49	204	1.13	239	0.97	481	1.08
ENGINEERING,CHEMICAL	92	1.11	78	1.03	302	0.78	472	0.89
TOXICOLOGY	75	1.31	147	1.10	240	1.12	462	1.14
PSYCHIATRY	51	1.49	130	1.42	271	0.78	452	1.04
ENG.ELECTRICAL/ELECT.	98	0.96	86	0.84	245	0.91	429	0.91
AGRICULTURE	67	0.82	96	0.79	253	0.80	416	0.80
CRYSTALLOGRAPHY	161	0.84	106	0.84	137	1.07	404	0.92

Table III. Scope of collaboration and impact factor in first quartile disciplines

	Internat.collab.		Domestic collab.		Non-collab.	
	N.Instit	N.Auth.	N.Instit	N.Auth.	N.Instit	N.Auth.
PHYSICS						
Physics	10.1	43.7	2.3	3.1	1	2.2
Solid State Physics	2.9	4.7	2.3	4.0	1	3.3
Astron/Astrophysics	3.8	5.3	2.3	3.0	1	2.5
Applied Physics	2.8	5.1	2.2	4.6	1	3.4
Atomic/Molec.Phys.	2.7	4.1	2.3	3.6	1	2.9
Crystallography	2.5	5.0	2.3	4.6	1	3.4
Nuclear Physics	4.7	11.9	2.2	3.0	1	2.3
Spectroscopy	5.8	19.8	2.1	4.2	1	3.3
CLINICAL MEDICINE						
Internal Medicine	6.8	13.5	2.6	5.1	1	3.2
Urology/Nephrology	3.4	6.2	2.3	6.3	1	6.2
Cardiovascular Syst.	3.4	6.8	2.5	6.3	1	4.9
Gastroenterology	3.4	7.7	2.5	6.8	1	5.1
Hematology	4.0	6.6	2.5	6.5	1	5.3
Surgery	3.3	5.6	2.6	6.4	1	5.1
Oncology	5.1	7.7	3.0	6.7	1	4.9
Dermatology	4.0	5.7	2.3	4.9	1	3.9
Toxicology	2.9	5.0	2.2	4.6	1	3.5
Psychiatry	3.2	4.5	2.4	4.2	1	2.7

Table IV. Number of institutions and authors involved in international and domestic collaboration

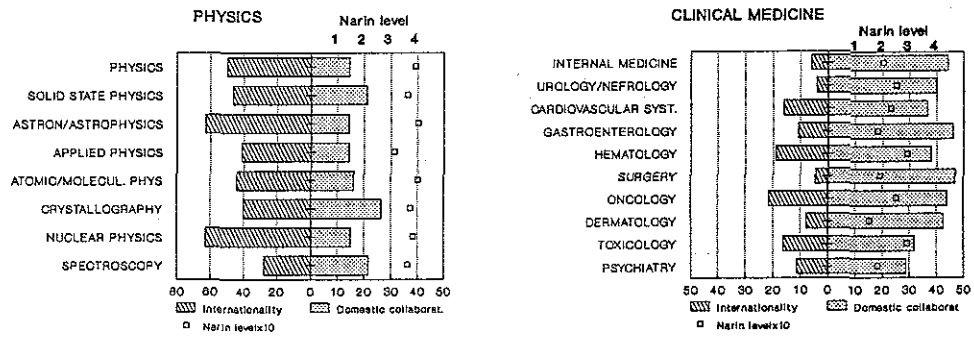

Fig. 3 Degree of internationality, degree of domestic collaboration and Narin level of the most productive disciplines in Physics and Clinical Medicine

Spanish Research Council (CSIC) has a higher internationality index with a lower intra-institutional collaboration. On the other hand, hospitals have a low internationality index (most of their production is in Clinical Medicine), and a very high degree of domestic collaboration together with a very high intra-institutional collaboration, as many hospital departments are signing the documents. The percentages of documents without collaboration are similar in all groups. Multiple counting of documents increases the degree of domestic collaboration when analyzing the separate institutions.

	N.Doc.	International-	Domestic-	Intrainstit.-index
University	26878	26.7	25.3	12
CSIC	6675	30	31.2	4
CSIC-Univ.	2303	33	31.6	5
Hospitals	10356	10.5	49.0	26
Others	1494	35.8	33.4	3
No data	2149	30.8	42.0	–

Table V Type of collaboration in the different Spanish institutions

The domestic collaboration was also studied from the point of view of the geographical network established between the different Spanish regions. Most of this collaboration took place between institutions in the same city or within the Autonomous Communities or local governments of Spain, where important local networks have been developed. Two principal poles are observed, one in Madrid and another in Barcelona. Barcelona has a very strong local network within its own Autonomous Community, whereas Madrid has established more links with the rest of the country (not shown).

4. DISCUSSION

Which type of collaboration takes place, international or domestic? This is a very important issue in the structure of every research system, even more so if the country, with medium-sized human and economic resources, is placed at the periphery of the strong research countries at a world scale or at a European scale. That is the case of Spain. Too much international collaboration and scarce domestic research links are signals of an unbalanced system, highly dependant on the outside world and with small scientific resources at home. On the contrary, few research links with foreign countries would point out an isolation difficult to understand in Science. Spain, at this moment, with 50% of its papers without any collaboration and the other 50% shared alike by international and domestic collaboration, seems to be "in the middle". Maybe, because of the beauty of the figures, this seems an equilibrium. Internationality is higher than the world average in 1990 (25 versus 20%) but similar to the EU and Canada. In general, the degree of internationalization by research area agrees with the figures presented by Leclerc for the ten most productive countries in 1990 (9). The deviation of Physics towards higher international collaboration could be related with the former Spanish scientific profile; but again the figures are not far from the EU, particularly Italy and the Netherlands. In Clinical Medicine, the low degree of international collaboration (11%) and high domestic collaboration (40%) coincide with the pattern found by Luukkonen at a world scale (10).

The international character of the discipline Physics has been pointed out in former studies. The dense network living around CERN is clearly visible due to the high co-authorship index (16.2 in average) and the high degree of inter-institutional collaboration (more than five institutions). A multi-centre international network in Internal Medicine is also detected.

A general observation is that basic disciplines have more international collaboration and that internationality enhances visibility, since international articles are published in journals with higher impact factor than articles with domestic or no collaboration. This finding has implications in science policy, as curricula are evaluated in our country taking into account the expected impact factor of the published articles.

A point of concern is the extremely low collaboration rate in all the disciplines related to Agriculture and Food Science & Technology. Questions to be checked are: how local this research is, whether there are differences in what is published at home and abroad, and whether this behaviour is usual in other countries. According to JCR, the journals of these categories never attain high impact factors. That would indicate that citations are scarce in those fields or that this scientific community uses diffusion channels other than journals (probably technical reports) and does not refer often to periodicals. In Food Science & Technology the SCI covers only around 22% of the total Spanish publications as recorded by the Spanish database ICYT (11) and the high non-collaboration rate is still much higher in Spanish than in SCI journals.

Considering the dichotomy international/domestic cooperation at specific sub-fields (or disciplines), we may compare the present results for 1990-93, with those for the first and the second half of the eighties in Materials Science, Pharmacy & Pharmacology, and Astronomy & Astrophysics (12, 13, 14). During the eighties we detected in all research fields great changes towards more collaboration, both at the domestic and at the international level. In the nineties, the situation is not so homogeneous: in some areas -Pharmacology & Pharmacy and Polymer Science- the domestic network is already established, while in others it is still increasing. A general rise in the international collaboration rate is found, though the growth rate is smaller than in the previous decade. One reason for the increase in foreign collaborations could be the stronger presence of Spanish scientists in the European programmes launched by the EU. Apparently, there is a certain stagnation in the evolution of the Spanish scientific system, since neither budgetary nor human resources grew since 1991 (15). Our results suggest that, in some disciplines, scientists are unable to establish more alliances and if forced to choose they prefer the foreign to the domestic partner. Higher possibilities of financing and more visibility of results can be expected from foreign collaboration.

5. ACKNOWLEDGEMENTS

This research was financed by the Spanish Research Plan, project PB91-0920 of the PGC. The authors want to thank A. Cabrero for his help in the elaboration of in-house software.

6. REFERENCES

1.- I. Gómez, A. Méndez. "Are peripheral countries profiting from scientific cooperation networks?". International conference on Science and Technology Indicators. Bielefeld, Germany; 10-12 June (1990).

2.- M. Bordons, P. García-Jover, S. Barrigón. "Is collaboration improving research visibility?. Spanish scientific output in Pharmacology & Pharmacy". Research Evaluation, 3 (1993) 19-24.

3.- J.F. Miquel, Y. Okubo. "Structure of international collaboration in science. Part II: Comparison of profiles in countries using a link indicator". Scientometrics, 29,2 (1994) 271-297.

4.- I. Gómez, M.T. Fernández, M.A. Zulueta, J. Camí. "Analysis of Biomedical Research in Spain". Research Policy, (1995) (in press).

5.- E. Noma, H.H. Gee, M. Harris. "Subject classification and influence weights for 3000 journals". (Computer Horizons), 1986.

6.- A. Schubert, W. Glänzel, T. Braun. Scientometric datafiles. "A comprehensive set of indicators on 2649 journals and 96 countries in all major science fields and subfields 1981-1985". Scientometrics 16, 1-6 (1989) 3-478.

7.- J.D. Frame, H.P. Carpenter. "International research collaboration". Social Studies of Science, 9 (1979) 481-487.

8.- F. Narin, K. Stevens, E.S. Whitlow. "Scientific cooperation in Europe and the citation of multinational co-authored papers". Scientometrics, 21 (1991) 313-23.

9.- M. Leclerc, J. Gagné. "International scientific cooperation: the continentalization of science". Scientometrics 31,3 (1994) 261-292.

10.- T. Luukkonen, O. Persson, G. Silvertsen. "Understanding patterns of international scientific collaboration". Science, Technology and Human Values, 17 (1992) 101-26.

11.- C. Ortega, M.C. Urdín, M.J. Martín, L.M. Plaza. "La investigación española en ciencia y tecnología de los alimentos durante el quinquenio 1986-1990 en la literatura científica nacional". Alimentaria, 30, 240 (1993) 49-53.

12.- A. Méndez, M.A. Insúa, I. Gómez, G. López, C. Refolio. "Dinámica de la investigación multidisciplinar sobre nuevos materiales en España. Un análisis bibliométrico". CINDOC. Madrid (1993).

13.- M. Bordóns. "La investigación española en Farmacia y Farmacología. Estudio bibliométrico del período 1980-89". Tesis doctoral. Universidad Complutense de Madrid (1993).

14.- A. Insúa, G. López, A. Méndez, A.M. Torres. "Indicadores bibliométricos aplicados a seis años de investigación española en Astronomía y Astrofísica". Política Científica, (in press).

15.- OCDE. "Main science and Technology Indicators 1993/2" (1994)