

LOCAL, DOMESTIC AND INTERNATIONAL SCIENTIFIC COLLABORATION IN BIOMEDICAL RESEARCH

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Collaboration practices and partners vary greatly per scientific area and discipline and influence the scientific performance. Bibliometric indicators are used to analyse international, domestic and local collaboration in publications of Spanish authors in three Biomedical subfields: Neurosciences, Gastroenterology and Cardiovascular System as covered by the *SCI* database. Team size, visibility and basic-applied level of research were analysed according to collaboration scope. International collaboration was linked to higher visibility documents. Cluster analysis of the most productive authors and centres provides a description of collaboration habits and actors in the three subfields. A positive correlation was found between productivity and international and domestic collaboration at the author level.

Introduction

Scientific cooperation seems to be an inherent characteristic of the evolution of Science. Many reasons have been argued to explain this phenomenon: from budgetary reasons (i.e. Big Science) to private ones (i.e. friendship). The results of cooperation may well become the focus of international attention (USA/Soviet satellite ventures) or hardly be noted. The fact remains that nowadays international cooperation is fostered not only by international superstructures, as is the case of the EU, but also by national organizations. In Spain, cooperation is induced by financing primarily and foremost those projects backed up by several scientists and institutes, to such an extent that one could speak of a "forced cooperation". Data from international or national cooperation is of a growing interest for policy makers, and numerous studies have been devoted to analyse scientific collaboration.^{1–4}

We have worked on this topic from a bibliometric point of view, with data from our studies on the Spanish scientific system for the last ten years. During this decade, the Spanish scientists have increased their presence in the international scene, as recorded in the *Science Citation Index (SCI)* database, and their collaborative activity

showed a growing trend, increasing both national and international links, as measured by the higher number of papers with several addresses. It seems that the impulse towards cooperation, strongly pursued by the science policy measures, did work. Scientists from different institutions are joining together to request economic support. The key issue now is to analyse the collaboration patterns of these bigger teams and their influence on the research results.

From our previous studies dealing with the analysis of the Spanish production, both at the national level⁵ or in specific subfields, Pharmacology,⁶ Astronomy⁷ and Physics of Condensed Matter,⁸ we obtained the following results:

- a trend towards higher international and domestic collaboration was observed over time, together with big differences between areas.
- scientific production from international cooperation in Spain obtains higher visibility than that from national cooperation. Statistically significant differences were found in the expected impact factors.
- documents signed by several national institutions did not obtain higher visibility than single-institution documents.

The present paper aims at performing an in-depth study of the influence of collaboration on the scientific performance, focusing the analysis on the biomedical area, as far as bibliometric indicators can shed some light on the following questions: Is there a subgroup of scientists responsible for most of the internationally coauthored documents or do all scientists contribute in some extent to international science? Which is the relationship between productivity and collaboration? Are the most productive scientists those who collaborate with foreign partners? Are there differences between subfields?

Methodology

The scientific production of Spain during 1990-93, as covered by the *Science Citation Index (SCI)* and *Social Science Citation Index (SSCI)* databases, CD-ROM edition, was studied. Three biomedical subfields, according to the ISI classification of journals, were chosen for studying the role of scientific collaboration: Neurosciences, Gastroenterology and Cardiovascular System. Only journal articles were considered.

Collaboration was classified on an institutional basis as: international (at least one foreign address), domestic (between several centres or between different departments from a given centre, several Spanish addresses) or local (inside a department, with a single corporate address). Those documents containing several Spanish addresses and also a foreign one were classified as international collaboration as the influence of the foreign partner was considered more relevant.

Three consecutive analyses can be distinguished in the present study:

1. Description of the subfields attending to several bibliometric indicators useful for collaboration assessment.
 - Quantitative features of the subfields were analysed through the following indicators: collaboration pattern (percentage of documents signed by two or more institutions), coauthorship index (average number of authors per document), co-institutional index (average number of institutions per document) and team size (average number of authors per institution).
 - Qualitative features of the subfields were described with the CHI research level,⁹ the expected impact factor of the documents and the type of institutions participating in the research.
2. Analysis of the relationship between author productivity and type of collaboration.
3. Mapping authors and centres according to their collaboration pattern. Maps were built using the average clustering method.

Several statistical tests for parametric distributions were used at different aggregation levels (correlation analysis, analysis of variance). The significance level considered was $p < 0.05$. Average values were expressed as mean \pm standard deviation. In-house programmes in dBaseIV were used for the information treatment.

Results

The scientific production of Spanish authors as recorded in ISI databases for the years 1990-93 accounted for 43,402 documents. Differences in the Spanish collaboration patterns attending to research area and to subfield have been previously described.⁵ International and domestic collaboration rates and basic-clinical research level of the most productive disciplines of Clinical Medicine and Life Sciences are shown in Fig. 1. The differences observed between disciplines led us to perform the analysis at the subfield level: we chose Gastroenterology and Cardiovascular System as clinical disciplines, and Neurosciences, as a basic discipline included in Life Sciences.

Description of collaborative aspects of subfields with bibliometric indicators

Collaborative aspects of research in the three subfields analysed were studied with some quantitative and qualitative indicators.

Collaboration patterns. Although the three subfields studied showed quite a similar local collaboration rate (37-43%), this being the predominant type in Cardiovascular

System and Neurosciences, some differences were found in domestic and international collaboration (Table 1). Neurosciences showed a high international collaboration rate, in accordance with the general behaviour of the Life Sciences area, and domestic collaboration was the highest in Gastroenterology.

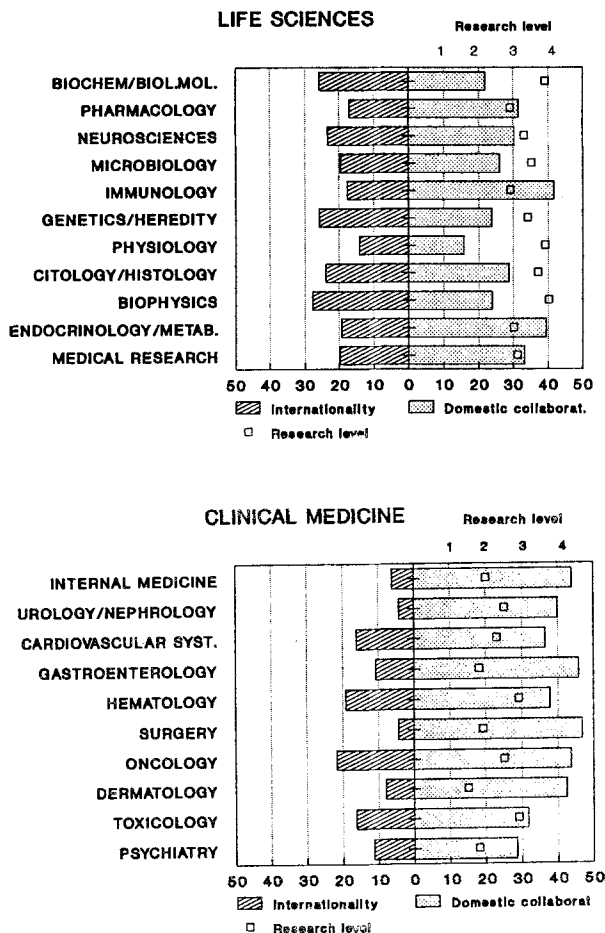


Fig. 1. International and domestic collaboration rates and basic-clinical research level of the most productive disciplines of Life Sciences and Clinical Medicine

Table 1
Collaboration patterns

Collaboration type	Gastroenterology (n=400)	Cardiovascular system (n=385)	Neurosciences (n=1332)
International	42 (10.5%)	66 (17.1%)	340 (25.52%)
Domestic	209 (52.2%)	153 (39.7%)	449 (33.7%)
Local	149 (37.2%)	166 (43.1%)	543 (40.8%)

Coauthorship index. Multi-authorship was the norm in most of the documents, although the local collaboration group showed a small percentage of single-authored papers (5-8%). The average co-authorship index was calculated for each type of collaboration (Table 2). In Gastroenterology and Cardiovascular System this index decreased as the scope of collaboration diminished, from international to domestic and local. Globally speaking, Neurosciences was the subfield with the lowest coauthorship index, which was especially low for local collaboration. The Neurosciences domestic coauthorship index was higher than the international, although this difference was not statistically significant. The remarkably high scattering in the co-authorship index in the case of international collaboration in Gastroenterology and Cardiovascular System indicated the existence of some highly co-authored documents.

Table 2
Co-authorship index

Collaboration type	Gastroenterology	Cardiovascular System	Neurosciences
International	7.78 ± 6.21	8.54 ± 12.1	4.51 ± 0.19
Domestic	7.02 ± 2.44	6.56 ± 3.25	4.77 ± 1.81
Local	5.02 ± 2.22	4.89 ± 2.65	3.5 ± 1.36
Total	6.36 ± 3.16	6.18 ± 5.81	4.19 ± 2.34

Significative differences

Gastroenterology: local vs. international and domestic

Cardiovascular System: local vs. international and domestic; international vs. domestic

Neurosciences: local vs. international and domestic

Number of institutions. The co-institutional index also increased with the scope of collaboration in the three subfields, though the difference between collaboration types was smaller in Neurosciences (Table 3). In Cardiovascular System a remarkably high number of institutions as well as a high deviation from the international collaboration average were observed, indicating a large number of papers with many different corporate sources participating: 121 documents with 10-72 authors and up to 60 different corporate sources, principally European hospitals and medical schools, corresponded to multicentre studies. In Gastroenterology 17 documents with 10-38 authors and up to 13 corporate sources were found, many of which were clinical trials.

Table 3
Co-institutional index

Collaboration type	Gastroenterology	Cardiovascular System	Neurosciences
International	3.57 ± 2.12	4.86 ± 8.88	2.81 ± 1.26
Domestic	2.55 ± 0.91	2.66 ± 1.76	2.48 ± 0.82
Local	1	1	1
Total	2.08 ± 1.29	2.32 ± 4.06	1.96 ± 1.13

Significative differences

In the three subfields: international vs. local and domestic; local vs. domestic

Team size. Team size can be measured either through the co-authorship index, i.e. the total number of authors signing a document, or by trying to determine the average number of authors from each institutional source. The number of authors per institution can be used as an approach to the size of research groups inside each institution (Table 4). Both the mode and the average number of participants per institution were highest when just one institution was involved, and decreased as the scope of collaboration grew. This difference was more remarkable in both clinical disciplines, whilst in Neurosciences team size varied less. It might be due to a different type of research, or maybe to a more strict control of co-authorship in international cooperation, to avoid too large a number of co-authors. There will probably be more authors from the same institution signing a paper, even though their contribution may be small, when it is the only institution involved.

Table 4
Team size

Collaboration type	Gastroenterology	Cardiovascular System	Neurosciences
International	2.17 ± 0.81 (Mo=2)	1.99 ± 0.8 (Mo=2)	1.65 ± 0.69 (Mo=1)
Domestic	2.93 ± 1.15 (Mo=2)	2.69 ± 1.21 (Mo=3)	1.98 ± 0.69 (Mo=2)
Local	5.02 ± 2.22 (Mo=5)	4.89 ± 2.65 (Mo=6)	3.5 ± 1.36 (Mo=3)
Total	3.63 ± 1.94 (Mo=2)	3.52 ± 2.27 (Mo=3)	2.52 ± 1.31 (Mo=2)

Significative differences

In the three subfields: international vs. local and domestic; local vs. domestic.

Research level. The research level changed gradually from clinical research in Gastroenterology and Cardiovascular System, to basic research in Neurosciences.

According to our previous studies⁵ we were expecting a more basic research done in international collaboration. In the present study, international collaboration showed a higher research level in all disciplines, although this difference was not always statistically significant. It is remarkable that in Neurosciences local collaboration presented a significantly higher research level than domestic collaboration, and very close to the international level (Table 5). A further analysis of the most active institutions might explain this finding.

Table 5
Research level

Collaboration type	Gastroenterology	Cardiovascular System	Neurosciences
International	1.95±0.22	2.39±0.64	3.59±0.73
Domestic	1.77±0.42	2.19±0.79	2.82±1.17
Local	1.76±0.43	2.19±0.66	3.47±0.91
Total	1.78±0.41	2.22±0.71	3.27±1.03

Significative differences

Gastroenterology: international vs. domestic and local

Neurosciences: international vs. domestic and local; local vs. domestic

Expected impact factor (EIF). The average EIF for Spain in each of the three disciplines was considered as that of an average journal. The position of this journal was looked up in the *JCR* list of journals by category and by impact factor.¹⁰ For Gastroenterology, the Spanish publications corresponded to the journal in position 5 out of 32, in Cardiovascular System to journal 12 of 70 and in Neurosciences to journal 36 of 142. In the first two cases the EIF corresponded to a journal in the first quartile of each discipline, while in Neurosciences it corresponded to a journal located in the top margin of the second quartile.

The average EIF of the Spanish scientific production was significantly higher for international collaboration in all three disciplines (Table 6). This result was consistent with our previous data. As to local collaboration in Neurosciences, once again it showed a different pattern: its EIF was higher than that of domestic collaboration, as was its research level.

Table 6
Expected impact factor

Collaboration type	Gastroenterology	Cardiovascular System	Neurosciences
International	3.65 ± 1.75	3.27 ± 2.25	3.00 ± 1.99
Domestic	2.73 ± 1.8	2.41 ± 1.94	2.08 ± 1.3
Local	2.24 ± 1.59	2.21 ± 1.69	2.26 ± 1.34
Total	2.64 ± 1.76	2.47 ± 1.93	2.39 ± 1.56

Significative differences

Gastroenterology: international vs. local and domestic; local vs. domestic

Cardiovascular System: international vs. domestic and local

Neurosciences: international vs. domestic and local

Institutional pattern. The Spanish institutions involved were grouped as university (U), hospitals (H), National Research Council (C), industry (I) and others (O) (Table 7).

Gastroenterology and Cardiovascular System showed a similar distribution in their institutional pattern, with hospitals signing around 90% of all documents, versus 14-20% signed by the university, and very little from other institutions. In accordance with the clinical character of these specialties, hospitals were also the most productive centres in all collaboration types, followed by the university.

Neurosciences showed quite a different pattern, with three institutions as principal actors: university (58% documents), hospitals (38%) and Research Council (15%). However, the pattern of domestic collaboration differed clearly: hospitals were the first producers (64%, with multiple different hospital departments participating), while

university and Research Council had a lower relative activity. The productivity distribution per institutional sector explains the results observed for the EIF and research level: the high activity of university and Research Council in both international and local collaboration was associated to basic research (level=3.6-3.8), with an EIF of 2.45-3.24, meanwhile hospitals were the most active in domestic collaboration, that showed mainly clinical research (level=2.2) with a lower EIF (EIF=2.13).

Table 7
Institutional contribution to the different types of collaboration

Collaboration type	Gastroenterology				
	U	H	C	I	O
International	32	69.2	5.8	-	-
Domestic	15.3	96.9	4.2	5.0	1.1
Local	8.8	88.4	1.4	1.4	-
Total	14.2	91.1	3.0	3.0	-
	Cardiovascular System				
	U	H	C	I	O
International	22.4	78.9	3.9	1.3	2.6
Domestic	24.7	95.6	2.9	2.4	-
Local	15.5	82.4	1.2	-	0.8
Total	20.1	87.1	1.0	1.3	1.7
	Neurosciences				
	U	H	C	I	O
International	66.0	18.4	19.2	1.3	1.8
Domestic	55.8	64.0	13.8	0.9	2.5
Local	55.3	28.3	15.1	0.1	0.9
Total	58.1	38.1	15.6	0.7	1.7

Note: percentages in rows. The total of rows may be higher than 100% due to inter-institutional collaboration.

Institutional sectors: U = university; H = hospitals; C = Scientific Research Council; I = industry; O = others.

Relationship between productivity and collaboration scope

Is productivity related to a certain scope of collaboration? The total number of documents of the most productive authors was compared to the number of documents in each type of collaboration through a correlation analysis (Table 8).

In Gastroenterology, a positive correlation was found between the total production of authors and their international/domestic/local production. It seems that the three types of collaborative activities tend to increase almost systematically, when scientific production rises. In Cardiovascular System and Neurosciences a positive correlation was found between the total production of authors and that performed in international and in domestic collaboration.

Table 8
Correlation coefficient between productivity and collaboration type

Collaboration type	Total Number Documents/author		
	Gastroenterology (30 authors)	Cardiovascular System (34 authors)	Neurosciences (29 authors)
International	0.8018*	0.6258*	0.3954*
Domestic	0.8186*	0.4968*	0.6225*
Local	0.7346*	0.264	-0.2154

* Significant differences

Mapping authors and centres according to their collaboration patterns

Up to this point we have analysed the collaboration pattern at the subfield and institutional level. However, we have tried to descend to lower units of analysis: centres and authors. Is there some kind of specialization at this level? Are there centres/authors working only in one type of collaboration?

Authors. The most productive authors considered were usually group leaders (following the criteria already described¹¹), so very few of them were members of the same group. When clustering these authors according to their collaboration pattern, a specific picture was obtained for each subfield (Table 9). A very similar map of authors was found in Gastroenterology and Cardiovascular System. In these subfields, the international activity was distributed in a very homogeneous way among all the authors, being the rates of local and domestic collaboration the most useful variables to separate subgroups of authors. The opposite may be said in relation to Neurosciences, in which the international collaboration rate was the most discriminant variable.

Using a three or four-cluster map, a large main cluster containing 60-80% of authors was obtained in the three subfields analysed. Figure 2 shows a two-dimensional map for the Gastroenterology subfield. The collaboration pattern of cluster 1, so called "main cluster", represents the behaviour of the majority of the top authors in the subfield. The other clusters differ from the main one because of over or under-average weight of some type of collaboration, as specified in the group description (Table 9).

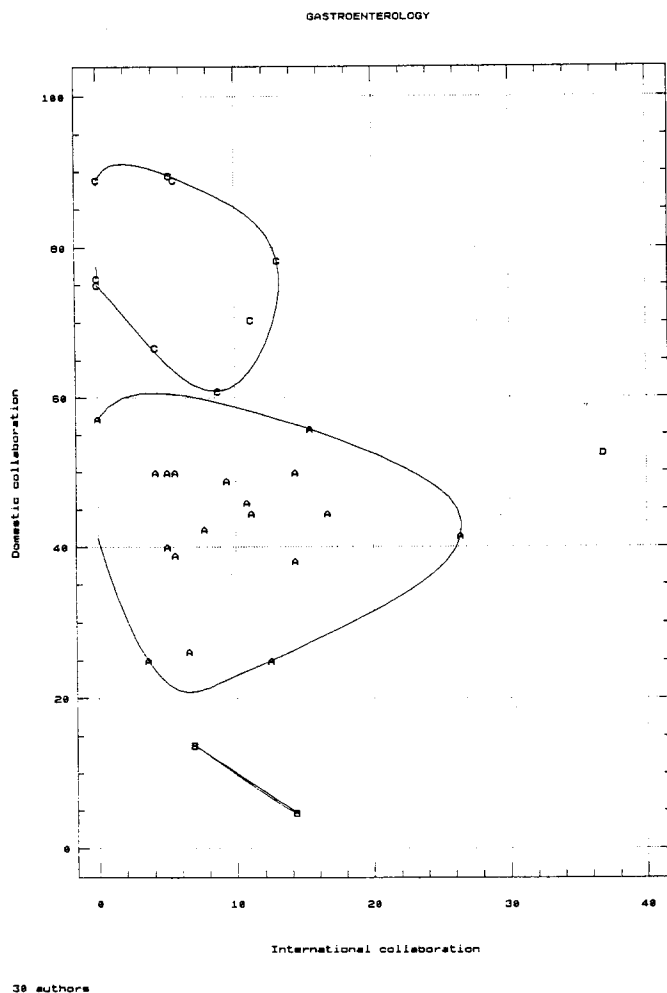


Fig. 2. Map of the most productive authors in Gastroenterology according to their collaboration patterns

Table 9
Grouping the most productive authors according to their collaboration pattern

Subfield	Cluster	Authors (%)	Description
Gastroenterology (30 authors)	Cl.1	60 %	20-70% Local 25-60% Domestic 0-25% International
	Cl.2	30 %	60-90% Domestic
	Cl.3	7 %	80% Local
	Cl.4	3 %	10% Local 35% International
Cardiovascular System (34 authors)	Cl.1	62 %	10-70% Local 20-80% Domestic 0-30% International
	Cl.2	18 %	80-100% Domestic
	Cl.3	15 %	80% Local
	Cl.4	6 %	100% Local
Neurosciences (29 authors)	Cl.1	79 %	0-80% Local 0-80% Domestic 0-20% International
	Cl.2	14 %	50% International
	Cl.3	7 %	90% International

The characterization of the clusters indicated that there was no significative difference between the average production per author in any of the clusters within the three disciplines analysed. Therefore, the most productive authors were not in one particular cluster.

One of the questions we asked ourselves was whether the same population was involved in the three types of collaboration. Our findings showed that most of the authors included in the "main cluster" worked at the same time at the local, domestic and international level. However, there were some subgroups of authors devoted preferably to local and domestic collaboration in Gastroenterology and Cardiovascular System, as well as some authors with a specially high performance with international partners in Neurosciences.

Research centres. The most productive centres in the three subfields were clustered according to their collaboration pattern. In all three disciplines, the majority of centres were grouped in a big main cluster that represented the average behaviour in the discipline. In the other clusters, the features that differed the most from this average

are shown in Table 10. It has to be pointed out that no exact coincidence could be expected between author and centre subfield maps, due to the differences in the samples selected in each case.

In Gastroenterology, the degree of international and local collaboration was useful to separate those groups of centres that differed more from the average. Clusters 2 and 3 had a much greater than average percentage of internationally co-authored papers, whilst local collaboration was the main type in cluster 4.

Table 10
Grouping the most productive centres according to their collaboration pattern

Subfield	Cluster	% Centres	Description
Gastroenterology (27 centres)	Cl.1	85%	0-80% Local 30-100% Domestic 0-20% International
23 H 4 U	Cl.2	7%	35% International
	Cl.3	4%	50% International
	Cl.4	4%	100% Local
Cardiovascular System (22 centres)	Cl.1	64%	10-50% Local 20-60% Domestic 0-40% International
19 H 3 U	Cl.2	18%	60-80% Local
	Cl.3	9%	80% Domestic
	Cl.4	9%	80% Domestic 0% Local
Neurosciences (34 centres)	Cl.1	74%	15-55% Local 20-65% Domestic 5-45% International
18 U 13 H 3 C	Cl.2	18%	60-80% Domestic
	Cl.3	6%	60-70% Local
	Cl.4	3%	0% Local

H= hospital; U= university; C=Spanish Scientific Research Council (CSIC)

In Cardiovascular System and Neurosciences the resulting maps were similar, in spite of the differences observed between these disciplines as to institutional contribution, research level and collaboration pattern. International collaboration was present in all clusters, although in varying proportions, while domestic and local collaboration rates proved more useful for separating clusters. An inverse relationship was found between domestic and local collaboration in cluster 1. In Cardiovascular System this cluster was formed only by hospitals, while in Neurosciences it grouped 8 hospitals, 14 university Faculties and 3 Research Institutes (Fig. 3).

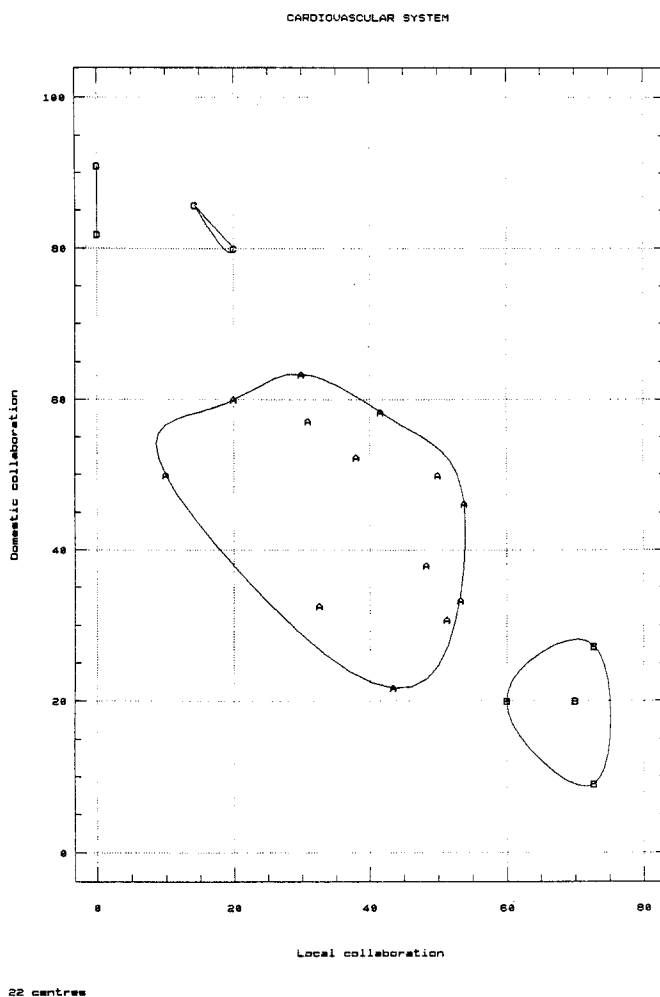


Fig. 3. Map of the most productive centres in Cardiovascular System according to their collaboration patterns

The institutional sector was a key element in determining the position of a centre in the map. This was specially true in Gastroenterology, in which the main cluster only included hospitals, while the few universities participated in separate groups. In Cardiovascular System hospitals also showed a trend to share the same collaboration pattern. Neurosciences appeared in the other end of the range, since different types of institutions were mixed in all groups. This can be due to the minor differences between the type of research carried out by the different institutions in this subfield.

Discussion

The differences among subfields in relation to the collaborative activity are clearly evidenced by the bibliometric indicators used, in spite of the subject closeness between the three subfields analysed, all of them biomedical disciplines. A gradual transition from the relatively applied research mostly performed in Gastroenterology to the very basic research activity done in Neurosciences, with Cardiovascular System somewhere in-between, was observed with the indicators used. The applied character of the research done in Gastroenterology was associated to a higher domestic collaboration rate and higher coauthorship index; whereas the basic character of the Neurosciences research was associated to a high international collaboration rate and lower coauthorship index.

On the other hand, cluster analysis of samples of authors or centres based on their collaboration patterns provides a complementary description of a subfield. The elements (authors/centres) sharing a similar behaviour in collaboration habits are grouped together. Cluster analysis stands as an exploratory technique useful for defining the main behaviour of a subfield, and for identifying atypical elements that do not follow the general collaboration pattern. However, there are no fixed rules in the interpretation of results; each map has to be analysed separately. When looking at our maps of scientists, the question of discerning whether there were two communities, one involved in international and another in domestic collaboration is not so clear. Most likely, the same scientists were participating simultaneously in both types of collaboration. A few subgroups of authors were found doing mostly local/domestic research in Gastroenterology and Cardiovascular System, and international research in Neurosciences. A certain rate of international collaborative activity spread out over the whole community appears as a very interesting issue, because it enables a smooth flow in the exchange of information, skills, etc. between the domestic and foreign communities. The existence of some groups doing mostly international collaboration in Neurosciences is coherent with the more basic character of this subfield.

The most productive authors did not share the same collaboration pattern, in spite of the fact that most of them were team leaders. Neither did they show the highest rate of international collaboration, although contact with foreign colleagues has been mainly attributed to team leaders. Maybe other factors, such as research topics, influence the rate of international collaborative activity.

Collaboration has been said to enhance productivity and visibility.¹² Our data suggest that both international and domestic collaboration are correlated with productivity at the author level in the three subfields analysed. Different reasons could explain this fact: collaboration may enable scientists to work on a higher number of projects simultaneously, and allows authors to increase the range of their research topics combining expertise from different fields.

Concerning visibility, we found that international collaboration enhanced the visibility of Spanish scientists. By publishing together with a foreign partner they used journals with higher impact factor than when publishing by themselves. The same was observed by some authors using citations,² while others¹³ point out that "excellent centres" are not affected in their visibility by international partners. In our case, internationality enhanced visibility in all three disciplines, in spite of their different basic-applied character. International collaboration of Spanish scientists evidences they are sharing scientific interests with other countries (usually the USA or EU countries). The question that remains is whether these international topics are priorities for Spain.

Why do Spanish scientists need a foreign author to achieve a greater visibility? Are they involved in more hot topics when collaboration takes place across frontiers? This can be the case of the multicentre clinical trials in Gastroenterology and Cardiovascular System. But, for other cases, in which the same authors are able to publish in higher impact journals when co-signing a paper with a foreign partner, usually from a more scientifically advanced country, another reason must be found. Maybe Spanish science has not attained international acknowledgement, or perhaps there are not enough Spanish researchers holding the keys to the top journals.

According to the number of authors and institutions co-signing a document, the team size tended to grow from local to domestic and to international collaboration in the three subfields analysed. However, both variables are inter-dependent, so it was especially useful to consider a third one as a better indicator of the team size: the number of authors per institution. It increased from international to local collaboration, the opposite trend observed for coauthorship index and number of institutions. Bearing in mind that the documents coauthored by Spanish and foreign partners showed a more basic character, it could support the finding of a lower research group size as described by some authors for basic research.¹⁴ On the other hand, social reasons related to the

criteria followed by the groups when signing documents could also be argued: maybe coauthorship is more strictly assigned in collaborative papers.

The new approaches we introduced to study the collaboration process provide an interesting insight into the problem, but some questions remain unsolved, mainly because of the limitations of bibliometric indicators. Due to the social implications of the scientific collaboration process, further studies dealing with sociological aspects, such as motivations and collaboration influence on research results from the point of view of the researchers themselves could be especially useful.

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References

1. M. BRIDGSTOCK, The quality of multiple authored papers; an unresolved problem. *Scientometrics* 21 (1991) No. 1, 37-48.
2. F. NARIN, K. STEVENS, E. S. WHITLOW, Scientific cooperation in Europe and the citation of multinational co-authored papers. *Scientometrics* 21 (1991) 313-323.
3. H. F. MOED, R. E. DE BRUIN, A. J. NEDERHOF, R. J. W. TUISSEN, International Scientific co-operation and awareness within the European Community: Problems and perspectives. *Scientometrics* 21, (1991) No.3, 291-311.
4. T. LUUKKONEN, O. PERSSON, G. SILVERTSEN, Understanding patterns of international scientific collaboration. *Science, Technology and Human Values* 17 (1992) 101-126.
5. I. GÓMEZ, M. T. FERNÁNDEZ, A. MÉNDEZ, Collaboration patterns of Spanish scientific publications in different research areas and disciplines. *Proceedings of the Fifth Biennial Conference of the International Society for Scientometrics and Informetrics*. Learned Information. Medford, 1995, pp. 187-196.
6. M. BORDONS, F. GARCÍA-JOVER, S. BARRIGÓN, Is collaboration improving research visibility? Spanish scientific output in Pharmacology and Pharmacy. *Research Evaluation* 3 (1993) No.1, 19-24.
7. A. INSÚA, G. LÓPEZ, A. MÉNDEZ, A. M. TORRES, Indicadores bibliométricos aplicados a seis años de investigación española en Astronomía y Astrofísica. *Política Científica* 43 (1995) 49-53.
8. 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.
9. E. NOMA, *Subject classification and influence weights for 3000 journals*. CHI Research/Computer Horizons, Inc. Report. New Jersey, 1986.
10. *Journal Citation Reports*. Institute for Scientific Information. Philadelphia, 1992.
11. M. BORDONS, M. A. ZULUETA, A. CABRERO, S. BARRIGÓN, Identifying research teams with bibliometric tools. *Proceedings of the Fifth Biennial Conference of the International Society for Scientometrics and Informetrics*. Learned Information. Medford, 1995, pp. 83-92.
12. D. DEB. BEAVER, R. ROSEN, Studies in scientific collaboration. Part II. Scientific co-authorship, research productivity and visibility in the French scientific elite. *Scientometrics* 1 (1979) No. 2, 133-149.
13. H. HERBERTZ, Does it pay to cooperate? A bibliometric case study in molecular biology. *Scientometrics* 33 (1995) No.1, 117-122.
14. K. SATYANARAYANA, K. V. RATNAKAR, Authorship patterns in Life Sciences, preclinical basic and clinical research papers. *Scientometrics* 17 (1989) No.3-4, 363-371.