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Research Policy 24 (1995) 459–471

research policy

Analysis of biomedical research in Spain

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Final version received January 1994

Abstract

Production in Spanish biomedical main-stream science in the years 1986–1989 was studied. A series of bibliometric and socioeconomic indicators were applied to determine the geographical distribution, the institutions involved and the most active centres per speciality using their scientific output, their impact and their basic–clinical type of research. A great heterogeneity was observed between the autonomous communities, with Madrid and Cataluña being in an outstanding position. This bifocal centralization is stronger when the main-stream research output of hospitals is considered in contrast to the more homogenous distribution of hospital care. The consequences of these observations are discussed. The average level of the Spanish research output is basic; clinical papers are mostly published in national journals which are scarcely covered by the database used. This might be the reason for the non-correlation observed between research output per speciality and causes of mortality and morbidity. The indicators for each particular centre are compared with those of the whole of Spain for each speciality in order to find 'centres of excellence'. The results of Spanish research are published in journals of a similar impact to those used by other European Union countries, although the number of citations received is much smaller, as has already been observed for other disciplines in Spain and peripheral countries.

1. Introduction

The gross expenditure on R&D (GERD) in Spain grew from 65 090 million pts (508 million ECUs) in 1980 to 339 324 million pts (2651 million ECUs) in 1989, while the amount devoted to medical sciences grew from 7160 to 40 380 million pts (from 60 to 315 million ECUs) in the same period (Instituto Nacional de Estadística, 1993). In constant pesetas, the investment in R&D in medical sciences grew by a factor of 2.5 in the period 1980–1989.

The distribution of the medical sciences GERD by execution sectors (according to the Frascati Manual for the Measurement of Scientific and Technical Activities) shows that 29% goes to the higher education sector, 28% to the government sector and 40% to the business enterprise sector, mostly the pharmaceutical industry. More than 72% of current expenditure is invested in salaries. When excluding this concept and considering only research projects, there are several sources in the government sector as well as important private sources from the pharmaceutical industry that

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SSDI 0048-7333(94)00777-5

can provide funding. The Ministry of Health, through its Agency for Health Research (FIS), distributed 3 500 million pts (27 million ECUs) in the period 1986–1989 for medical research projects. Other public financing sources (whose data are not easy to break down in order to determine the amounts devoted to biomedical research) are the National Plan for Scientific Research and Technological Development through its basic research and mission oriented projects, the Ministry of Industry through the Centre for Industrial Technological Development (CDTI) and the autonomous communities or regional governments of Spain.

The industrialised Western countries devote a very high percentage of their scientific activity to the life sciences as a whole. In the case of Spain, the life sciences represent 45% of its output in basic research compared with 55.7% for the European Union (EU) countries for the period 1981–1985 (Schubert et al., 1988).

Several bibliometric studies have considered biomedicine in both an international and a national context, e.g. the classic paper of Narin et al. (1976) who studied the international medical literature and classified the journals in a scale from basic to clinical, and the work of Schubert et al. (1985) who studied medical production in a series of medium-sized countries. In Spain, Terrada et al. (1981) published a very comprehensive study of the Spanish medical literature in years 1973–1977, in both its national and international aspects. An interesting study on the life sciences was published by Pestaña (1990) and other authors have analyzed other medical topics in Spain (Méndez et al., 1987; Gómez et al., 1990; Bordons and Barrigón, 1992; Bordons et al., 1992).

The Agency for Health Research (FIS) distributes a large amount of money for biomedical research projects in Spain. It needed information on the output of biomedical research at a meso-level (hospitals, faculties and research institutes) and at the micro-level of individual research centres in the National Health System. It was particularly interested in an analysis of performance per speciality in comparison with other EU countries. Therefore the FIS Agency supported this research project in order to obtain a series of bibliometric indicators of the output of Spanish biomedical research which will be useful as a tool in the evaluation of present and future biomedical research. A report with full results (Camí and Gómez, 1992) and a paper for the Spanish medical sector (Camí et al., 1993) have been produced. The most interesting results for science policy purposes are presented in this paper.

2. Methodology

The biomedical field was defined through a set of journals selected by the authors with the help of Spanish professionals in clinical and basic biomedical research who were experts in their scientific areas. Clinical disciplines as well as biomedical research journals were included and classified in specialities according to Journal Citation Reports (JCR). Biomedical papers in the multidisciplinary journals *Nature*, *Science*, *Proceedings of the National Academy of Science US*, *Experientia and La Recherche* were also selected and classified as 'multidisciplinary'.

Items from 1986 to 1989 with at least one Spanish address were retrieved from the Science Citation Index (SCI) tapes. These data, together with indicators comparing the Spanish output with that of the other EU countries (except Luxembourg)—observed and expected citations; activity and attractivity indexes per speciality—were provided by the Information Science and Scientometrics Research Unit (ISSRU) from the Library of the Academy of Sciences in Budapest, headed by Professor Tibor Braun.

Institutional addresses are standardised only to a limited extent in this database, causing serious problems in detecting organizations, cities or regions (Moed et al., 1992). An in-house codification system was used which has been described in a previous contribution (Fernández Frial et al., 1990). A one-to-one correspondence code was assigned to each individual research centre in Spain. It is structured with several levels of information: institutional dependency (university, research council, hospital, central or local administration, enterprise, etc); mnemonic acronym to identify each research centre; UNESCO International Nomenclature Code of scientific activity; the geographical location using the postal code. Foreign institutions that cooperate with Spanish authors were also codified at a more general level. This codification allowed automatic classification by region, autonomous community (presently responsible for health activities in Spain), institution and research centre.

For the purposes of this study, the following institutions were considered: universities, hospitals, the Scientific Research Council (CSIC), joint CSIC–university centres, industries and other institutions (foundations, local administrations, etc.). University hospitals were classified as hospitals.

Other characteristics of scientific production were also studied, e.g. its visibility and degree of 'basicness'. The impact factor (IF) of journals from the JCR was taken as a measure of visibility and attributed to each of the articles as an expected IF. A four-level scale introduced by Computer Horizons Inc. (CHI) was used as indicator of the basic–clinical type of research. This classifies journals as follows: $L = 1$, clinical observations; $L = 2$, clinical mix; $L = 3$, clinical investigation; $L = 4$ basic scientific research (Noma et al., 1986).

In order to be able to detect 'centres of excellence' a relative impact factor (RIF) was introduced, using the average IF of a speciality at the national level as a standard (RIF = IF of the centre in a certain speciality/national IF in that speciality). When RIF > 1 the expected IF of that centre was better than the Spanish average in that speciality.

The different specialities in biomedical sciences (based on the Institute for Scientific Information, Inc. (ISI) journal classification) were studied separately. Multidisciplinary journals were grouped as one speciality. Integer counting was used when more than one address or speciality was present. For international comparisons, observed and expected citations, and activity and attractivity indexes were calculated according to

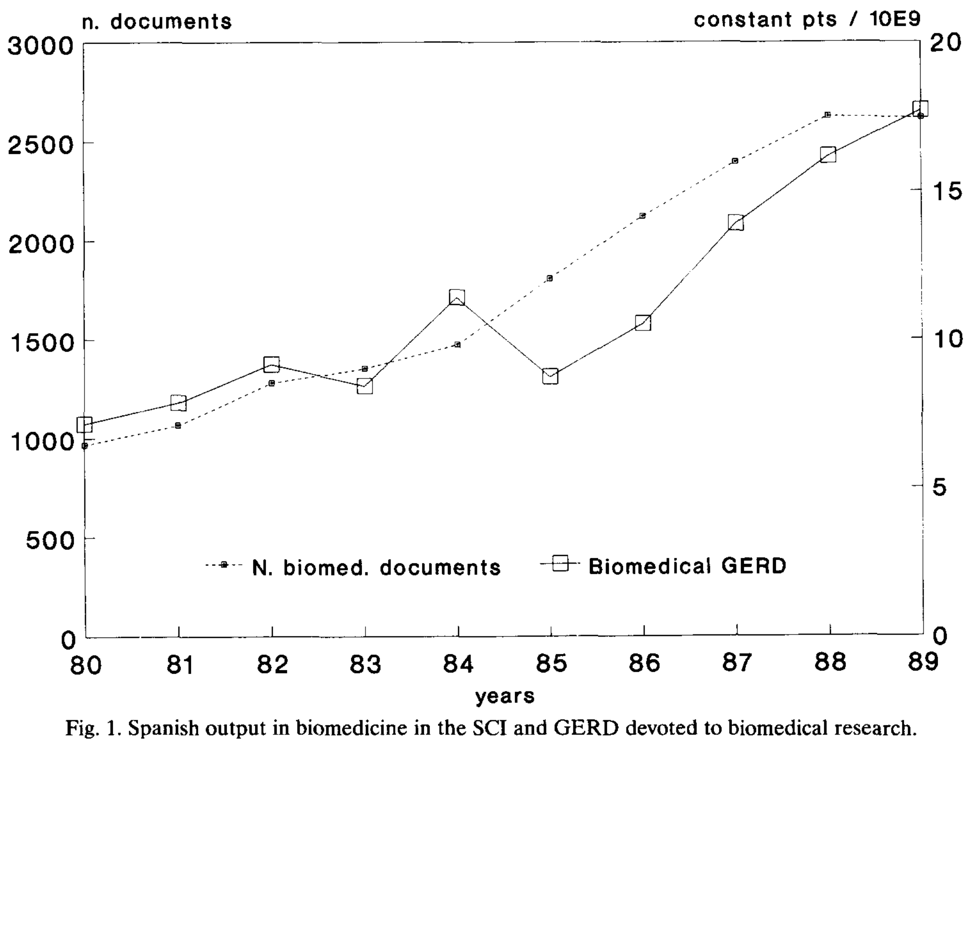

Fig. 1. Spanish output in biomedicine in the SCI and GERD devoted to biomedical research.

Hungarian methodology (Schubert et al., 1988) where both source and citation periods are identical, i.e. 1986–1989.

3. General overview

Spanish biomedical production as covered by SCI grew strongly during the last decade: it increased from a contribution of only 966 documents (0.55% of the whole database) in 1980 to 2618 documents (1.21%) in 1989 (Fig. 1). The GERD devoted to medical research grew similarly in the same period, (also shown in Fig. 1), correlating quite closely ($r = 0.8375$) considering a 1 year lag between investment and research results.

Focusing on the period 1986–1989, a comparison of the Spanish output to that of other EU countries showed that while Spain ranked seventh when considering the absolute number of publications, it dropped to eighth position when considering production versus GDP, and to ninth position (above only Greece and Portugal) when considering production versus the population of each of the countries (EUROSTAT, 1991). In this last criterion the most active countries in the biomedical fields were Denmark and the United Kingdom, followed by the Netherlands (Table 1).

Table 1
Biomedical scientific production in the European Community. Period 1986–1989

Country	Articles	Art./ GDP [a]	Art./ population [b]
United Kingdom	106521	183.9	18.76
Germany	56220	64.6	9.21
France	46730	65.8	8.43
Italy	28295	48.0	4.94
Netherlands	22272	129.5	15.29
Denmark	11836	148.7	23.11
Spain	11358	50.0	2.94
Belgium	9956	90.9	10.10
Ireland	1996	80.9	5.63
Greece	1887	45.3	1.90
Portugal	647	22.8	0.63

[a] GDP was calculated as an average of years 1984–1987 in 10^9 ECUs.
[b] Active population from 1986 expressed in 10000 inhabitants.

A total of 12706 biomedical items with at least one Spanish address were retrieved from the SCI tapes for years 1986–1989. Following the Schubert criteria (Schubert et al., 1988), they were separated into 'citable items' that included articles (8478), letters (1077), notes (1007) and reviews (144), representing 84% of the total; meeting abstracts represented 15.6% and other types (book reviews, editorials, corrections, discussion papers, etc.) represented 0.4%. When not specified, the analysis was carried out on 'citable items' only, and hereafter these will simply be called articles.

4. Publication journals

The 12706 documents were published in 1086 biomedical journals. When only articles are considered, a total of 1056 journals were used. In general, a regularity was observed in the use of the various diffusion channels, which indicates the stable publication habits of the researchers and stable research lines.

The Bradford core of the 49 most productive journals, covering 33% of the articles, was analyzed. The two leading journals used by Spanish biomedical researchers were Spanish, but most of the rest (up to 67%) were from USA, Netherlands and UK, which is the international academic literature considered to be most influential in the scientific world (Barre, 1992)

Only five Spanish journals (four of them in the core) were covered by the database in the period 1986–1989; two of them are written in English and the other three publish articles in either Spanish or English, which explains why only 2.7% of the total number of items were written in Spanish versus 96% in English. An increasing trend to publish in English was observed, which may be a consequence of the pressures of the evaluation procedures of the Spanish scientific community and is not attributable to the slight changes in the coverage of Spanish biomedical journals by the SCI database in the period studied.

Through the SCI, we could locate Spanish biomedical research activity as published in international journals with an average research level of 2.98, mostly basic, following the CHI scale (see Section 2). This level is significantly more basic than that of biomedicine as a whole in the SCI database (χ^2,P < 0.0001), as most Spanish clinical research is published in Spanish journals not covered by the SCI.

Table 2
Institutions per document type

Institutions	Articles	Meeting abstracts	Others	Total
University	5550	559	16	6125
Hospital	4396	1334	27	5757
CSIC	783	52	5	840
CSIC–University	757	59	4	820
Industry	258	27	1	286
Others	396	66	2	464
Total	12140	2097	55	14292

5. Institutions and their geographical distribution

The institutions producing this biomedical research were studied first at a general level as productive sectors: universities; hospitals (including university hospitals); Scientific Research Council (CSIC); industry; others. Joint CSIC-university centres were considered separately. When considering number of articles, the university was the most active sector, followed by hospitals. Hospitals were the most active in meeting abstracts, showing a different attitude towards the diffusion of research results (Table 2).

The basic–clinical types of research carried out per execution sector differed. Hospital research was clinically orientated ($L = 2.14$), while research in universities, CSIC and joint CSIC–university centres was basically orientated ($L =$ 3.19–3.75). A similar distribution of research levels by execution sector was observed for US biomedical performance (Narin and Rozek, 1988).

The geographical distribution of research activity by Spanish autonomous communities (AACC) was studied through the research centre codes (see Section 2). A bifocal distribution was observed, as already described for other research

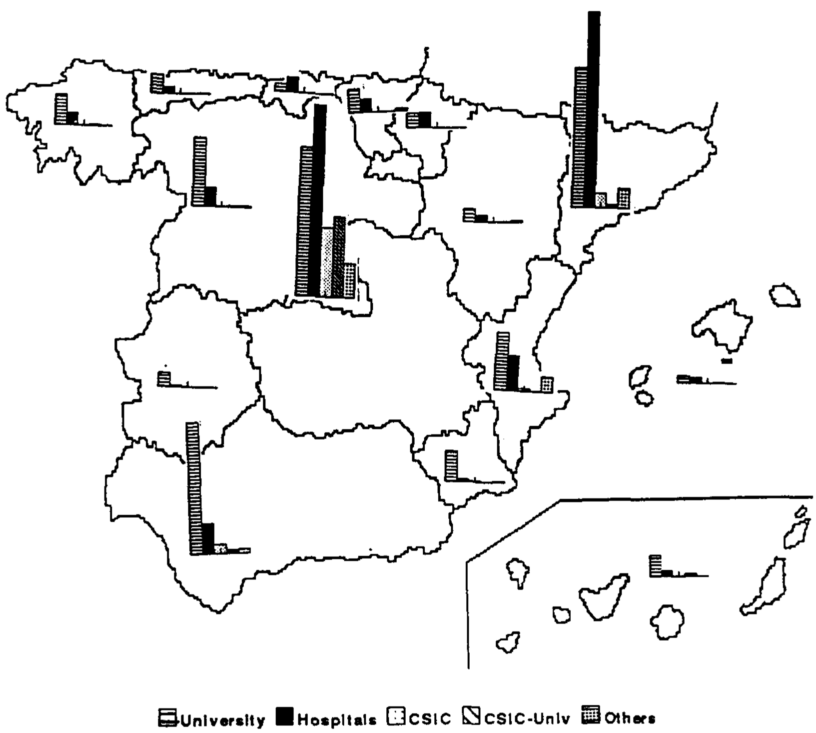

Fig. 2. Output of the institutions per autonomous community.

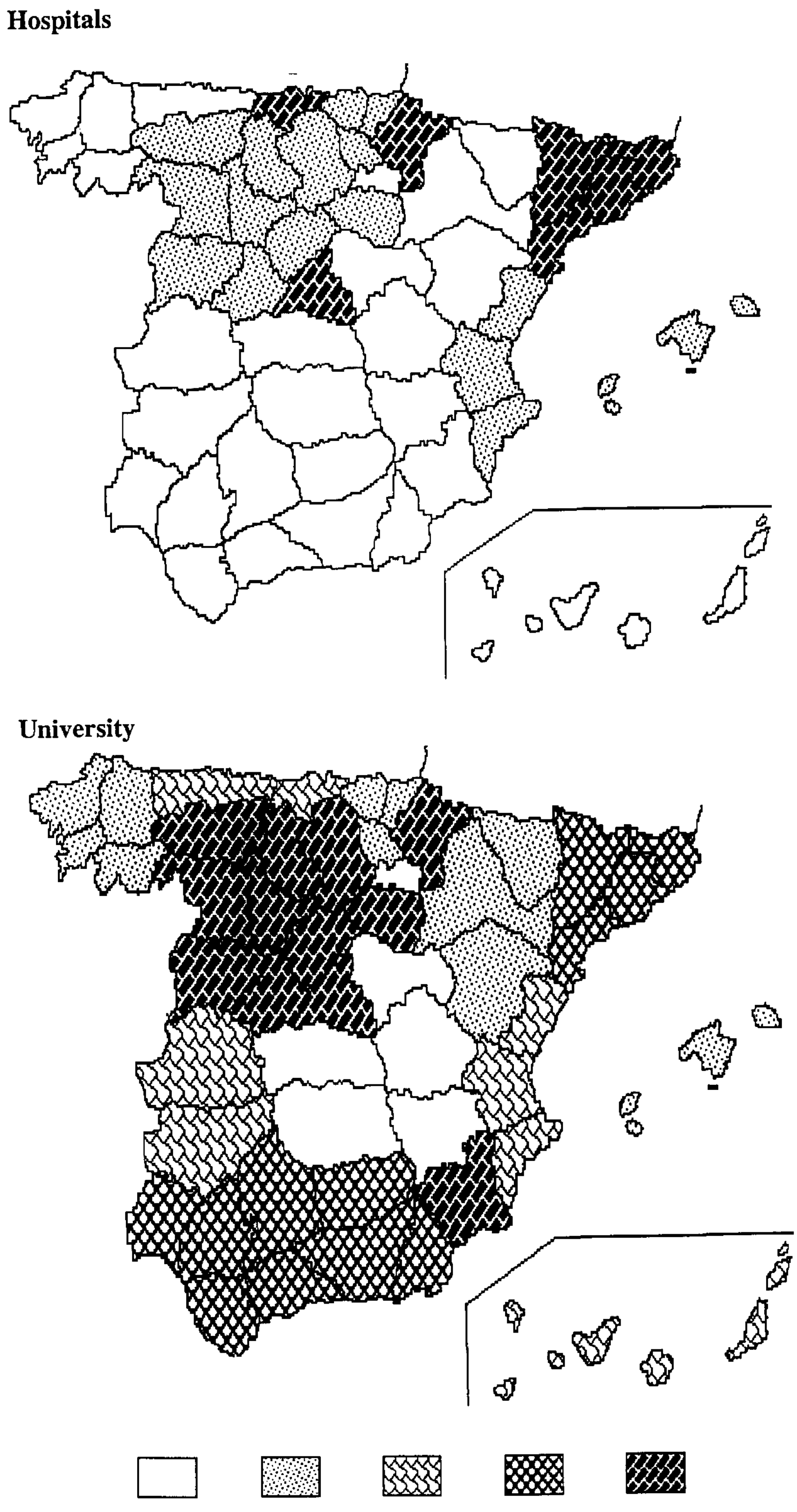

Fig. 3. Distribution of hospital and university output per million population in the autonomous communities.

fields (Pestaña 1992; Larraga, 1993), with Madrid and Cataluña being the most active regions in absolute values (representing 59% of the total output), followed by lower production from Andalucía, Comunidad Valenciana and Castilla–León (Fig. 2).

When studying which institutions are behind this irregular distribution, we found that while 71% of hospital output is produced in Cataluña and Madrid, three AACCs with similar production are responsible for 61% of the university output: Madrid, Cataluña and Andalucía. The CSIC has the majority of its institutes in Madrid, thus contributing to the observed centralization.

Scientific production was studied relative to the population and GDP of the AACCs. A great difference was observed between the distribution of university and hospital output per million of population (Fig. 3). Considering universities, a homogeneous distribution is shown, with Madrid, Navarra, Murcia and a very big but low-populated region, Castilla–León, being the most productive. Cataluña and Andalucía are second. The output of hospitals presents a very skew distribution: the big producers are the two strong AACCs, Madrid and Cataluña, together with two small AACCs with important hospitals, Navarra and Cantabria. A huge gap separates them from the rest, where no important research output per million of population is found. Research activity in the health system differs greatly from the distribution of hospital beds, which is highly correlated with population ($r = 0.9740$) (not shown).

When considering scientific output versus GDP a more homogeneous distribution was found: $r = 0.9413$ in the case of universities and $r = 0.8826$ for hospitals (Fig. 4). Madrid, Andalucía, Castilla–León and Murcia are above average regarding university output, while Cataluña and Valencia are slightly below average. In the case

Table 3
Production, research level, IF and RIF of the Centre for Molecular Biology

Specialities	Molecular Biology Centre			RIF	Spain		
	Total documents	Research level	IF		Total documents	Research level	IF
Biochem./mol. biol.	217	3.9	3.92	1.73	2162	3.9	2.26
Virology	56	4.0	3.73	1.35	143	3.6	2.75
Immunology	41	3.0	5.60	2.06	575	2.6	2.71
Microbiology	27	3.7	2.78	1.64	839	3.7	1.69
Genetic/heredity	25	4.0	3.61	1.79	500	3.7	2.01
Neuroscience	25	3.9	2.42	1.23	1000	3.0	1.96
Cytology/histol.	20	3.9	3.23	2.24	518	3.7	1.43
Pharmacol./pharm.	17	3.1	1.90	1.40	1111	2.8	1.35
Multidisciplinary	13	4.0	11.40	1.45	86	4.0	7.84
Embryology	7	4.0	3.48	1.62	55	3.9	2.14
Anatomy	6	4.0	3.75	3.95	231	3.9	0.95
Endocrinol./metab.	5	2.4	1.56	0.85	529	3.0	1.82
Parasitology	5	3.0	1.94	2.32	109	3.3	0.84
Rheumatology	5	2.0	1.37	0.67	130	2.0	2.02
Internal medicine	4	2.6	4.62	0.52	419	1.7	8.85
Medicine (misc.)	4	3.6	1.78	1.05	368	2.7	1.69
Cancer	3	4.0	2.73	1.35	281	2.4	2.01
Geriatrics/gerontol.	2	3.0	1.07	1.11	20	2.6	0.96
Surgery	1	3.0	2.98	2.58	402	1.6	1.15
Tropical medicine	1	2.0	0.96	0.88	26	1.7	1.09
Veterinary medicine	1	3.0	0.93	1.29	166	2.1	0.72
Obstetrics/gynecol.	1	1.0	1.51	1.52	116	1.8	0.99
Pediatrics	1	1.0	1.51	1.40	239	1.8	1.08
Total	487						

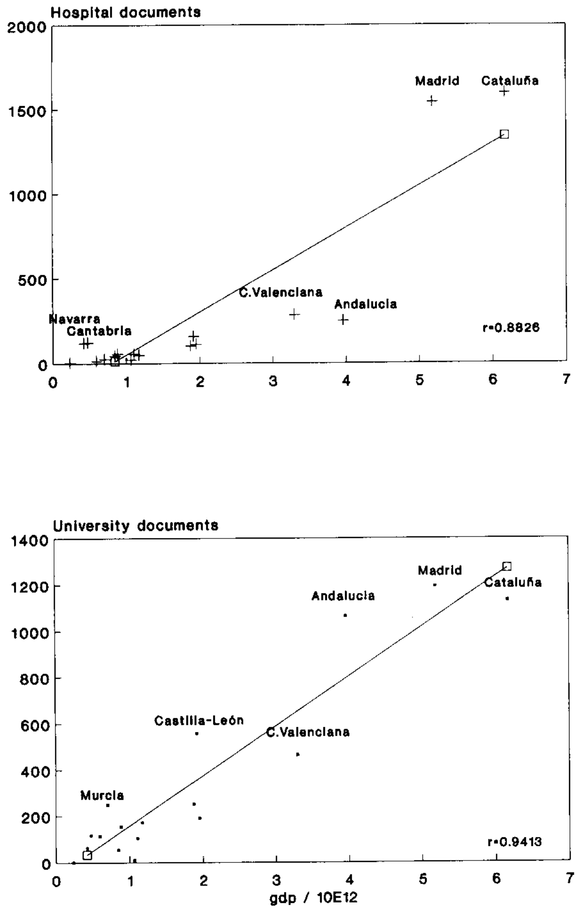

Fig. 4. Plot of hospital or university output against GDP per autonomous community.

of hospital output versus GDP the distribution is similar to hospital output versus population: Madrid, Cataluña, Cantabria and Navarra are above average; two large AACCs, Valencia and Andalucía, are clearly below average.

6. Research centres involved

Institutions were also studied at a deeper level, looking at individual research centres, hospitals or university faculties. The activity of each individual centre was split into each of the SCI specialities, and as well as its production, other indicators were used to describe the type of research being carried out: the expected impact factor (average IF of the publication journals used) as a measure of influence in the scientific community, and the CHI research level to determine whether the nature of the research was basic or clinical. The Spanish average IF in each speciality was used for comparison through the RIF.

An example of the analysis of a research centre is shown in Table 3. The Centre for Molecular Biology is a very active joint centre of the CSIC and the Autonomous University in Madrid. In all specialities with more than ten documents, this centre has a higher than average IF (RIF > 1) and a purely basic research level ($L > 3$). It can therefore be considered as a 'centre of excellence' in its field of basic biomedical research. Almost 50% of its production belongs to the biochemistry and molecular biology subfields (217 articles), with an IF much higher than the Spanish average and research level $L = 3.99$ of purely basic research. Its production is also important in virology and immunology.

7. Biomedical specialities

Spanish biomedical research was distributed over 47 specialities, the most active being biochemistry and molecular biology (14.7%), pharmacology and pharmacy (7.6%), neuroscience (6.8%), microbiology (5.7%), physiology (4.6%), urology (4.2%), immunology (3.9%), endocrinology (3.6%), gastroenterology (3.6%), cytology (3.5%), genetics and heredity (3.4%) and the cardiovascular system (3.3%).

Following journal classification into four research levels, the most productive specialities could be separated into two groups: those mostly basic ($L = 3$ or 4) and clinical specialities ($L = 1$ or 2) (Fig. 5). The most active productive sector in basic specialities is the university, except for immunology (whose $L = 2.7$ is halfway between basic and clinical), where hospitals are especially productive. In neuroscience, hospitals are comparable in scientific performance to universities, although they publish in more clinical journals. The CSIC, which is active in basic research, is especially productive in biochemistry. When considering clinical specialities, hospitals are the largest producers, as would be expected.

An attempt was made to detect whether the hospital scientific production in clinical specialities was orientated towards causes of morbidity or mortality in Spain, but no correlation was found ($r = 0.0247$). The same observation was made in Mexico (Licea de Arenas, 1990) relative to main-stream science. No data were available to compare research output per speciality with disease treatment at the level of individual hospitals.

Each speciality was studied separately as regards its geographical distribution and the institutions involved. Individual research centres, faculties or hospitals were analysed, showing their output, expected IF, RIF and basic–clinical level. Even with the limitations of the specialities being defined as a set of journals, these data identify the most active and highest impact research centres in the speciality, together with an indicator of the type of research being done. An example of the most productive centres in gastroenterology, a clinical speciality, is shown in Table 4: hospitals in Barcelona, Madrid, Valencia and Navarra, together with some medical faculties are listed.

A selection of the most influential Spanish papers in each speciality was prepared following two criteria: on the one hand, those papers published in journals whose IF was at least double the average of the field (8.9%); and on the other hand, those papers that in the period studied received at least three times as many citations as the average paper of the journal used for publication (2.5%). The percentage of papers that met the criteria varied greatly from one speciality to another.

In the case of allergy, seven papers meet the first criterion and only one meets the second. When studying the groups involved, four of these papers were from the Allergy Department of a Madrid hospital, which is the most productive in the speciality with 17 documents. The two complementary visibility indicators used, together with the absolute output and RIF, point out an excellence group in allergy.

The activity of each speciality in Spain was compared with that of other EU countries in both its absolute output and its expected and observed citation indexes (Schubert et al., 1988). In most specialities the expected IF was similar to that of

Table 4
Most productive centres in gastroenterology

Type of documents: Articles
No. of documents: 276
Average IF: 2.66
Average level: 1.6

Centres	No. of Doc.	Level	IF	RIF
Hospital Clínico (Barcelona)	77	1.8	3.65	1.37
Fac. Medicine UCB (Barcelona)	58	1.8	3.59	1.35
Fac. Medicine UAB (Barcelona)	29	1.5	2.50	0.94
Hospital 'Santa Cruz y San Pablo' (Barcelona)	22	1.3	1.78	0.67
Hospital 'Vall D'Hebron' (Barcelona)	19	1.7	3.06	1.15
Ctr. Esp. 'Ramon y Cajal' (Madrid)	18	1.1	1.98	0.74
Ciudad Sanitaria 'La Fe' (Valencia)	17	1.5	2.58	0.97
Fundación 'Jimenez Diaz' (Madrid)	16	2.0	2.81	1.05
Fac. Medicine UAM (Madrid)	14	1.7	2.65	1.00
Hosp. 'Germans Trias Pujol' (Barcelona)	14	1.2	2.12	0.79
Hospital '12 de Octubre' (Madrid)	13	1.5	2.15	0.81
Fac. Medicine UCM (Madrid)	13	1.4	1.96	0.73
Clinica Universitaria Navarra (Navarra)	10	1.5	2.99	1.12
Clinica 'Puerta Hierro' (Madrid)	9	1.6	4.18	1.57
Hospital 'Bellvitge' (Barcelona)	7	1.4	2.30	0.86

other EU countries, because similar IF journals are used. In research into the cardiovascular system, virology and otorhinolaryngology, journals with an IF higher than the EU average were used. On the other hand, in cytology, haematology, tropical medicine and veterinary medicine, low IF journals were used.

In general, the observed citations were much lower than expected. This is a general problem of science in peripheral countries (Arunachalam and Garg, 1985; Velho, 1986), which can partly be attributed to the fact that their researchers do not belong to the invisible colleges or share the widespread recognition of scientists and scientific institutions in the predominantly Anglo-Saxon main-stream of science (Luukkonen, 1991). An example is shown in Fig. 6 for published work on the cardiovascular system, where in spite of the high IF journals used, the small number of citations received was very much lower than expected.

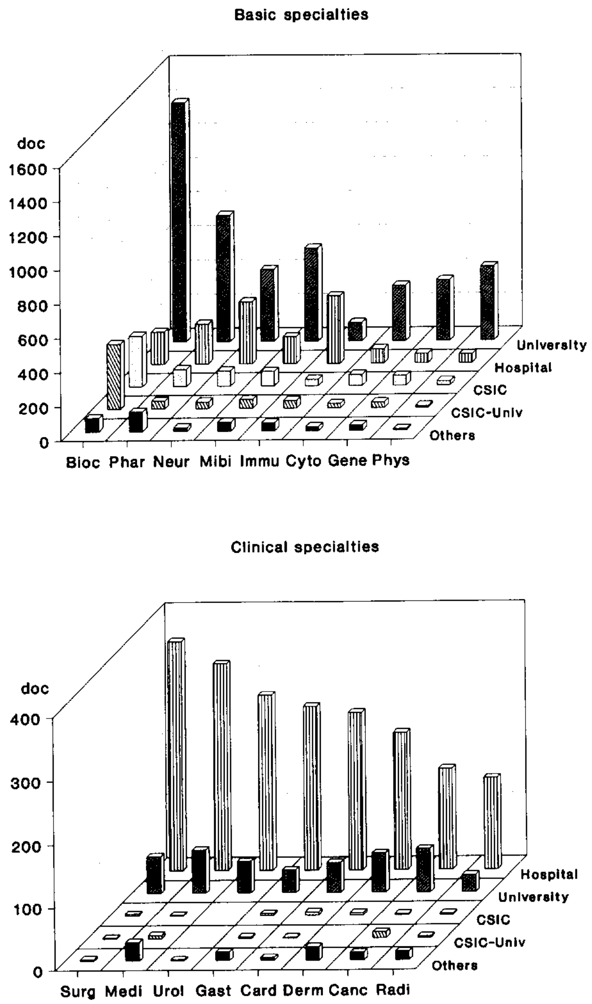

Fig. 5. Production of the different institutions in basic and clinical specialities.

Activity and attractivity indexes of specialities in all EU countries were also studied. Using these relative indicators, the most active and frequently cited specialities in Spain in 1986–1989 were anatomy, dermatology, drugs/addiction, gastroenterology, genetics and heredity, mycology, microbiology, rheumatology, and urology and andrology. The results were compared to those of the period 1980–1985 (Schubert et al., 1988). Fig. 7 shows the specialities with more than 200 documents that did not change position, as well as those specialities that moved from one area to another.

8. Concluding remarks

A big research effort has been made in Spain during the last decade, although we are still far from the research level of the most advanced countries. Many more papers have been published in international biomedical journals, in some cases at the expense of the Spanish journals and under pressure to obtain good 'academic curricula' for professional promotion.

Research performance is not a good indicator for clinical medicine, as financial reward is more related to medical care than to research output in this field (Spangenberg et al., 1990). Furthermore, clinical medicine is locally orientated and published mostly in Spanish journals covered only by the Spanish medical database Indice Médico Español (IME). Perhaps through this database a correlation could be found between scientific production and causes of morbidity or mortality, which would indicate that applied research is being focused to those topics of direct interest for the country's social benefit.

The strong centralization of biomedical activity in only two Spanish regions had already been

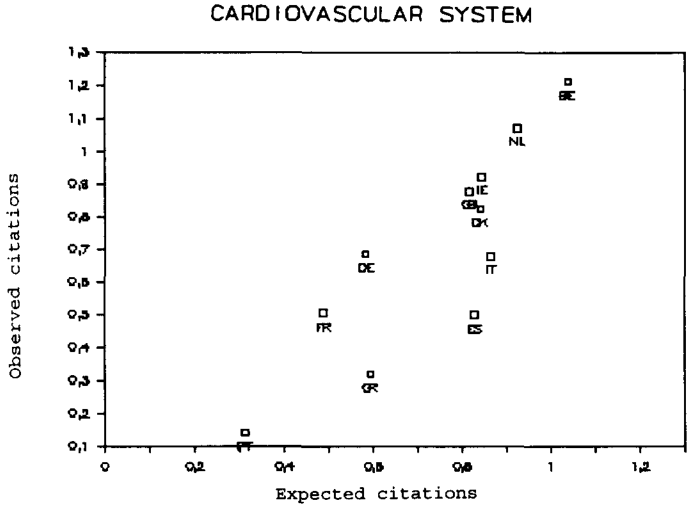

Fig. 6. Expected versus observed citations in published work on the cardiovascular system. BE, Belgium; DE, Germany; DK, Denmark; ES, Spain; FR, France; GB, United Kingdom; GR, Greece; IE, Ireland; IT, Italy; NL, Netherlands; PT, Portugal.

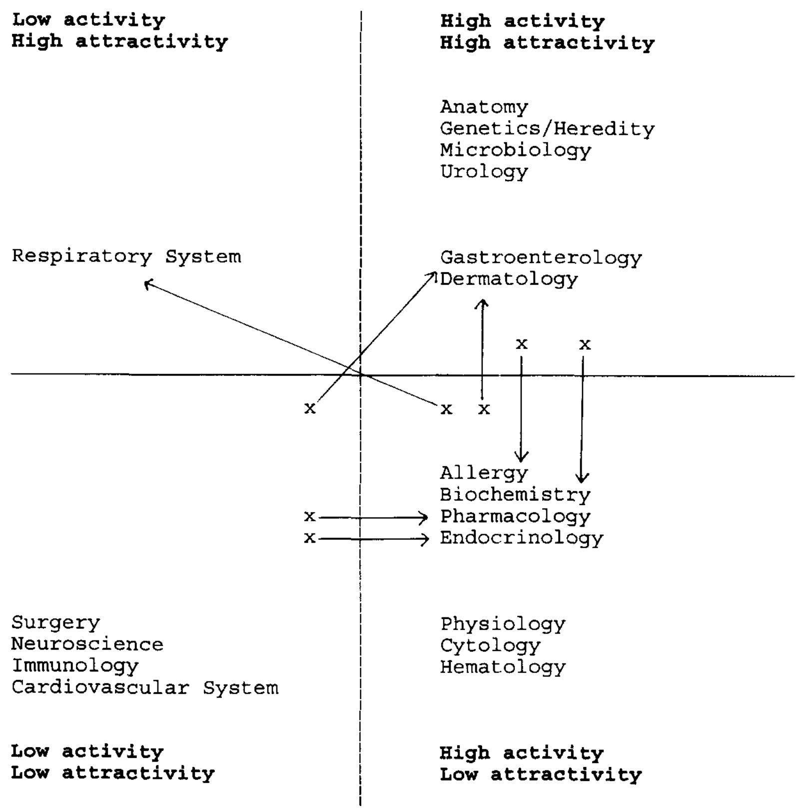

Fig. 7. Most active specialities classified according to their activity and attractivity indexes in the period 1986–1989 (X indicates their position in the period 1981–1985).

observed in previous papers in different scientific areas (Méndez et al., 1987; Gómez et al., 1990; Pestaña, 1990, 1992). This is more extreme in the case of hospital research, which raises an important problem for the Spanish health authorities. Medical students have to specialise while working for 4 years in hospitals, and apparently only those entering hospitals in Madrid, Barcelona, Navarra and Cantabria, with few exceptions from other AACCs, are able to get a research training in the different specialities. Is hospital practice up to date in those hospitals where no main-stream international research is being done?

During the 1980s, the Spanish Central Government transferred the responsibility for health to the AACCs. While the medical care of the population is homogeneously distributed among the different AACCs, this is not the case for biomedical research activity, particularly in hospitals. The AACCs will have to make an effort to promote local research centres in order to change this situation. It is not likely that the money coming from the Central Government through research projects will modify the present centralized distribution, as most of it goes to prestigious groups.

The information provided here could also prove useful for science policy makers to help them decide whether it is more profitable to lend financial support to projects of already established groups with a strong research background, or whether new groups should be fostered in the less active AACCs.

9. Acknowledgements

The authors want to thank Aurora Cabrero for her great help with the software and Balbina Ugena for the collection of data, as well as the referees of this journal for their constructive suggestions. This research was supported by a grant FIS, 90/4001.

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