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forum

Chemistry research in Catalonia: 1996-2002*

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The seven-year period studied here differs very little from the six-year period described in the previous *Report* (1990-1995) [1]. Sustained growth was observed in almost all the indicators used to evaluate the resources invested and the scientific results obtained.

Human resources

We will first review the consolidation of how research is organized, in the form of declared research groups, and then comment on the evolution of human resources over the seven-year period.

Organization of research personnel

We should highlight here the efforts that have been made by the Catalan administration to coordinate research. The structure, size, objectives and affiliation of consolidated research groups (CRGs) have not changed significantly since the previous six-year period (see Table 2). Nor has specific financing changed, continuing to be quite modest. These groups have become organisational bodies rather than coordinating or actually carrying out research.

Thematic networks have also been consolidated in terms of making information available, but they remain unable to carry out research in a coordinated fashion. The 2nd Research Plan promoted by the Autonomous Government of Catalonia has put into operation the Network of Centres of Support for Technological Innovation, a new instrument that seeks to improve companies' access to the scientific knowledge being developed in universities.

Table 2 summarizes the numbers of CRGs doing research in chemistry, according to the census carried out by DURSI at the

Table 1. Names and acronyms of Catalan and Spanish institutions appearing in the text, and their equivalents in English.

Centre d'Investigació i Desenvolupament, CID (CSIC)	Centre for Research and Development, CSIC in Barcelona
CDTI, Centro para el Desarrollo Tecnológico e Industrial	Centre for Technological and Industrial Development, Madrid.
Comisión interministerial para Ciencia y Tecnología, CICYT	Inter-ministry Commission for Science and Technology, Spanish funding agency, Madrid
Comissionat d'Universitats i Recerca, CUR	Universities and Research Commission, Autonomous Government of Catalonia
Consejo Superior de Investigaciones Científicas, CSIC	Spanish National Council for R&D activities, Madrid
Dirección General para la Innovación Científica y Técnica, DGICYT	Directorate for Scientific and Technical Innovation, Spanish funding agency, Madrid
Departament d'Universitats, Recerca i Societat de l'informació, DURSI	Department of Universities, Research and Information Society, Government of Catalonia
Fundación COTEC	Private foundation dedicated to the promotion of R&D activities in Spain, Madrid
Generalitat de Catalunya	Autonomous Government of Catalonia
IDESCAT, Institut d'Estadística de Catalunya	Catalan Statistics Institute, Barcelona
Institut d'Estudis Catalans, IEC	Institute of Catalan Studies, Barcelona
Institut de Ciència dels Materials de Barcelona, ICMAB (CSIC)	Materials Science Institute of Barcelona, CSIC at Bellaterra
Institut Químic de Sarrià, IQS	Chemical Institute of Sarrià, Barcelona

1. Universitat Autònoma de Barcelona.
2. Universitat de Barcelona.
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Instituto Nacional de Estadística, INE	Spanish Statistics Institute, Madrid
Institut de Recerca I Tecnología Agrícola, IRTA	Institute for Food and Agricultural Research and Technology, Government of Catalonia
Ministerio de Educación y Ciencia, MEC	Ministry of Science and Education, Madrid
Universitat Autònoma de Barcelona, UAB	Autonomous University of Barcelona, Bellaterra
Universitat de Barcelona, UB	University of Barcelona, Barcelona
Universitat de Girona, UG	Girona University, Girona
Universitat de Lleida, UL	Lleida University, Lleida
Universitat Politècnica de Catalunya, UPC	Polytechnic University of Catalonia, Barcelona
Universitat Pompeu Fabra, UPF	Pompeu Fabra University, Barcelona
Universitat Ramon Llull, URL	Ramon Llull University, Barcelona
Universitat Rovira i Virgili, URV	Rovira i Virgili University, Tarragona

end of the seven-year period (data coming from directly enquiring group coordinators). The table also indicates personnel categories, doctorate level (D) and graduate level (G). A preliminary observation that can be made from the overall figures is that most people pertaining to public research in chemistry can be assigned to a consolidated research group. A second observation is the average size of such a research group – 16 people, 8 at post-doctoral level, and 8 graduates.

Table 2. Number of Consolidated Research Groups, supported by DURSI, divided by main fields. Number of predoctoral (G) and post-doctoral personnel (D), and the G/D ratio (figures correspond to year 2002).

Field	*No. Groups*	*D*	*G*	*G/D*
Analytical Chemistry	9	93	106	1.14
Physical Chemistry	14	104	93	0.89
Inorganic Chemistry	9	65	47	0.72
Organic Chemistry	16	124	141	1.14
Total	48	386	387	1.00

Research personnel

In terms of the human resources of the public research bodies in Catalonia, there has been a mean cumulative growth of at least 4.7% per year during the seven-year period studied.

Table 3 shows the overall figures for personnel in the more relevant research centres in Catalonia, mostly public. For ease of comparison, the data have been grouped under the categories: "permanent personnel", P (full professors and associate professors in the case of universities, and research professors, research fellows and scientific collaborators in the case of the CSIC); and "personnel in training", T summing contracted personnel (assistant professors, laboratory assistants, and visiting professors in the case of universities, and specialised personnel, contract research fellows and research assistants at the CSIC);

Table 3. Research personnel at the main Catalan public research centres working in chemistry (1996-2002). P, permanent personnel; T, personnel in training (contract\research fellows).

Centre	*1996*		*2002*	
	P	*T*	*P*	*T*
Universitat de Barcelona, Faculty of Chemistry	136	20\58	145	16\73
Universitat de Barcelona, Faculty of Pharmacy	48	7\23	55	1\30
Universitat Autònoma de Barcelona	56	27\34	76	14\64
Universitat Politècnica de Catalunya	19	0\5[1]	15	0\4[1]
Universitat de Girona	15	13\0	29	1\19
Universitat Rovira i Virgili	63	12\2	69	0\48
Universitat de Lleida	7	0\1[1]	8	0\2
Universitat Pompeu Fabra	3	0\0[1]	8	0\1[1]
Universitat Ramon Llulll	10[1]	0\9[1]	10	0\14
Centre d'Investigació i Desenvolupament, CID (CSIC)	45[1]	0\61	61	0\135
Institut de Ciència dels Materials de Barcelona, ICMAB (CSIC)	13[2]	0\30	19	0\24
Totals	415	79\223	510	32\409
		717		951

1. Estimated value.
2. According to the Annual Report of this centre (1998-2000).

Table 4. Global R&D expenditure in Chemistry by funding source, 1996-2002, in thousand €. (Includes all public funding to Universities and the CSIC, as well as companies and other organisms).

	1996	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*Total*	*%*
EU (1)	750	2,028	617	375	4,934	6,026	5,374	20,104	*14.54*
Ministries (2)	8,050	8,767	10,427	12,749	11,853	13,057	15,290	80,193	*57.99*
Generalitat (3)	1,777	2,258	1,976	2,395	2,410	3,072	1,591	15,479	*11.19*
Contracts/Other (4)	1,717	1,538	2,481	2,752	3,652	4,766	5,603	22,509	*16.28*
Total	12,294	14,591	15,501	18,271	22,849	26,921	27,858	138,285	*100.00*

(1) Source: CORDIS. Figures include funding for research university projects, CSIC, industry, IRTA, etc.
(2) Apart from university research funding, includes CDTI funding to industrial research projects.
(3) Includes funding for university research, organizations and the Catalan chemical industry.
(4) Data provided by Catalan universities and CSIC.

plus graduate students doing Masters or Doctorate research (these have been specified when possible). No data concerning auxiliary personnel have been included because of their very small number, which is not even included in official reports.

The increase is similar to that reported in the previous study, but there seems to have been a certain slowing of growth during the last few years. Growth has been relatively more significant for personnel in training than for permanent staff. In the private sector, approximately 25% of all R&D personnel work in the chemical-pharmaceutical industry. This is a highly significant percentage, given that the private sector accounts for 82% of R&D personnel in chemistry (3532) and 13 % of all the personnel working in research in Catalonia.

Research expenditure

Public sector

Financing for research in general in Catalonia is clearly insufficient, but this shortage is particularly notable in public financing. The analysis of the data indicates that Spain is still far behind the EU-15 and even farther behind the OECD. Figures for Catalonia are much closer to averages for Spain than to those for the EU-15. Only in figures for the private sector, which double those for the public sector, does Catalonia approach averages for Europe. Table 4 shows all public expenditure directed to chemistry in Catalonia during the considered period. The table includes the research funds allocated by European, Spanish and Catalan agencies to all institutions engaged in research activities in chemistry. It also includes data for research contracts received by the universities. The greatest portion of public financing consisted of funds from government ministries, whilst the contribution from the Autonomous Government of Catalonia was never more than modest. This difference contrasts with the *Report (1990-1995)* in which the contributions of the two administrations were about the same. The growing amount of financing coming from agreements and contracts with companies and institutions should be noted, since this demonstrates the potential chemical research being done in Catalan academic institutions has for technology transfer. As regards European financing, a high degree of variability can be observed from year to year. For the whole of the seven-year period it represents almost 15% of total public financing, but it is important not to forget that an important part of this capital goes to companies.

Further details on funding from public institutions are presented in Tables 5 and 6. Table 5 shows the distribution of funding according to research organism and destination of funds. The largest university, UB, and the CSIC, which is de-

Table 5. Overall R&D chemistry funding (1996-2002) for Catalan universities and the CSIC (in thousand €) according to the destination of the funds.

Organism	*Projects (1)*	*Contracts (2)*	*Equipment (3)*	*Personnel (4)*	*Other (5)*	*Total*	*%*
UB	12,319	6,669	948	2,967	1,742	24,645	*31.72*
CSIC	17,668	6,549	116	720	325	25,378	*32.66*
UAB	6,113	2,573	1,193	5,237	634	15,750	*20.27*
URV	1,658	907	510	570	272	3,917	*5.04*
UdG	938	101	225	480	157	1,901	*2.45*
URL	1,197	2,476		321		3,994	*5.14*
UL	1,738	124	160		89	2,111	*2.72*
Total	41,631	19,399	3,152	10,295	3,219	77,696	*100.00*
%	*53.58*	*24.97*	*4.06*	*13.25*	*4.14*	*100.00*	

(1) Sum of national and European research projects. Data provided by institutions.
(2) Data provided by institutions.
(3) Data correspond to PIR programme from DURSI only, except for UAB, which includes all sources. PIR expenditure for universities without significant weight in chemistry is not included (UPF, UPC and UVic) - only 0.124 thousand € for the three put together.
(4) Research Fellowships, visiting professors, incorporation of doctors and other personnel actions managed by DURSI. Expenditure for universities without significant weight in chemistry is not included (IMIM, UPF, UPC) - only 0.100 thousand € for the three put together. The exceptional figure for UAB is due to the inclusion of Research Fellowships from all Ministries, data not available for the remaining institutions.
(5) Only includes data from grants managed by DURSI (SGR programme, special actions, etc.)

Table 6. Distribution of R&D chemistry funding (in thousand €) for Catalan universities and the CSIC, 1996-2002.

	UB	*CSIC*	*UAB*	*URV*	*URL*	*UG*	*UL*	*Total*	*%*
Analytical Chem.	3,343	7,867	5,740	1,157	2,604	325	97	21,133	*27.20*
Physical Chem.	4,076	4,659	2,901	884	30	819	296	13,665	*17.59*
Inorganic Chem.	2,263	4,590	1,366	853		524		9,596	*12.35*
Organic Chem.	9,044	8,263	5,309	1,022	1,360	233	1,479	26,710	*34.38*
Pharmaceutical/Therap.Chem.	5,029							5,029	*6.47*
Physicochemistry	889							889	*1.14*
Other / Unspecified			434				239	673	*0.87*
Total	24,644	25,379	15,750	3,916	3,994	1,901	2,111	77,695	*100.00*
%	*31.72*	*32.66*	*20.27*	*5.04*	*5.14*	*2.45*	*2.72*	*100.00*	

voted purely to research, take the largest shares. Table 6 shows the global funding for the different chemistry departments of Catalan universities and the CSIC, with Analytical and Organic chemistry research groups drawing the most funds.

Private sector

In the private sector, the general tendency is to substantially reduce internal expenditure on R&D in the chemical industry. This observation can be drawn from the general trend highlighted in the figures in Table 7. At the same time, there has been a rapid increase in payments abroad for technology transfers (also cited on the table), surpassing R&D expenditure during the latter years. It appears that the substantial Catalan chemical industry has begun to outsource research and development work abroad, explicitly abandoning in their own facilities the development of the technological advances that are necessary in order to be competitive in the future.

Research outcomes

Three indicators have been selected to illustrate the productivity of research activities in Catalonia: the number of graduates and doctorates, figures corresponding to published research papers and the share of patents reported.

Personnel training

Considering the number of graduates in chemistry as an indicator of the vitality of the sector, it was observed that, though the overall number has grown both in Catalonia and throughout Spain during the period studied, the percentage of Catalan graduates has decreased to 16% of the Spanish total, from the 20% reported in the earlier *Report.* A similar situation can be observed with regard to the number of doctoral theses. It should also be pointed out, that the number of new doctorates awarded, both in Catalonia and in the whole of

Table 7. R&D expenditure by Catalan chemical companies, 1996-2002 (absolute values in thousand €).

	1996	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*
Production value (factory outlet)	10,730,074.00	12,396,160.00	12,678,703.00	13,216,591.00	15,237,579.00	15,978,200.00	16,108,050.00
Intermediate Consumption	7,415,375.00	8,493,960.00	8,883,260.00	9,211,339.00	10,916,700.00	11,686,909.00	11,566,412.00
Added value-gross (factory outlet)	3,314,699.00	3,902,200.00	3,795,443.00	4,005,252.00	4,320,880.00	4,291,291.00	4,541,637.00
Taxes (neat of grants)	10,637.00	9,315.00	2,985.00	4,640.00	5,675.00	11,726.00	1,137.00
Added Value-gross (factor costs)	3,304,061.00	3,892,885.00	3,792,458.00	4,000,612.00	4,315,205.00	4,279,566.00	4,540,500.00
Personnel expenditure	2,080,440.00	2,119,588.00	2,184,641.00	2,249,582.00	2,378,353.00	2,515,437.00	2,567,176.00
Surplus of exploitation	1,223,622.00	1,773,297.00	1,607,818.00	1,751,030.00	1,936,852.00	1,764,128.00	1,973,324.00
As percentage[2]							
	1996	*1997*	*1998*	*1999*	*2000*	*2001*[3]	*2002*
R&D expenditure/Added value (%)	2.65	2.78	3.55	2.60	1.91	1.52	n.d.
Payments to foreign countries for technology transfer / Added value (%)	1.09	1.80	1.48	2.44	3.81	3.70	n.d.
Grand total[4]							
	1996	*1997*	*1998*	*1999*	*2000*	*2001*[3]	*2002*
R&D expenditure	87,557.62	108,222.20	134,632.26	104,015.91	82,420.42	65,049.40	n.d.
Payments to foreign countries for technology transfer	36,014.26	70,071.93	56,128.38	97,614.93	164,409.31	158,343.94	n.d.

(1) Data from the section "Catalan Chemical Industries. Macromagnitudes" (Source: IDESCAT) available at http://www.idescat.es/scripts/enqind.dll?TC=2&v0=1&v1=070&v2=20022001.
(2) Data from the annual report on Catalan industries "Informe Anual de l'Empresa Catalana 2001" (Chemical Industries), Generalitat de Catalunya, Departament d'Economia i Finances, Direcció General de Programació Econòmica.
(3) 2001 values obtained from the CD-ROM 2002 edition.
(4) Sum of data in bold type above.

Spain, continues to be lower than that of other more developed nations.

Publication of the research

In general terms, an increase can be observed in the number of research papers published. The absolute number of research papers has been sourced from the Science Citation Index (Institute for Scientific Information) databases, as shown on Table 8. This table collects the 6,898 chemistry papers published by Catalan researchers during this period, classifying them according to the main categories in the database. These figures have been compared with the world research outcome, and also with selected countries - Spain, Ireland, Italy and Sweden; as in the 1990-95 report. Ireland and Italy were chosen as their relative R&D effort (as measured by expenditure and personnel involved in R&D) is comparable to that in Catalonia, while Sweden represents an country with an advanced R&D system. Figure 1 presents graphically the percentile distribution of the papers found among the different categories for the countries considered, where it can be seen that Catalan publication output closely resembles that of Spain, and that the main chemistry knowledge areas show a higher production in all cases.

Table 8. Number of publications in the categories studied in the countries under consideration (1996-2002).

Category	World	Catalonia	Spain	Ireland	Italy	Sweden
Chemistry	145,323	816	3,309	434	3,103	1,299
Analytical Chemistry	93,430	1,400	5,964	563	4,370	1,919
Applied Chemistry	51,506	319	2,762	272	1,806	656
Inorganic Chemistry	67,900	792	3,496	298	3,737	678
Medicinal Chemistry	32,050	257	1,027	74	1,872	475
Organic Chemistry	107,769	1,069	5,019	403	5,424	1,164
Physical Chemistry	150,476	1,029	6,706	559	6,592	2,981
Electrochemistry	24,100	207	785	117	889	415
Physicochemistry	74,290	465	2,557	648	3,680	1,910
Total	869,295	6,898	35,010	3,639	36,868	13,010

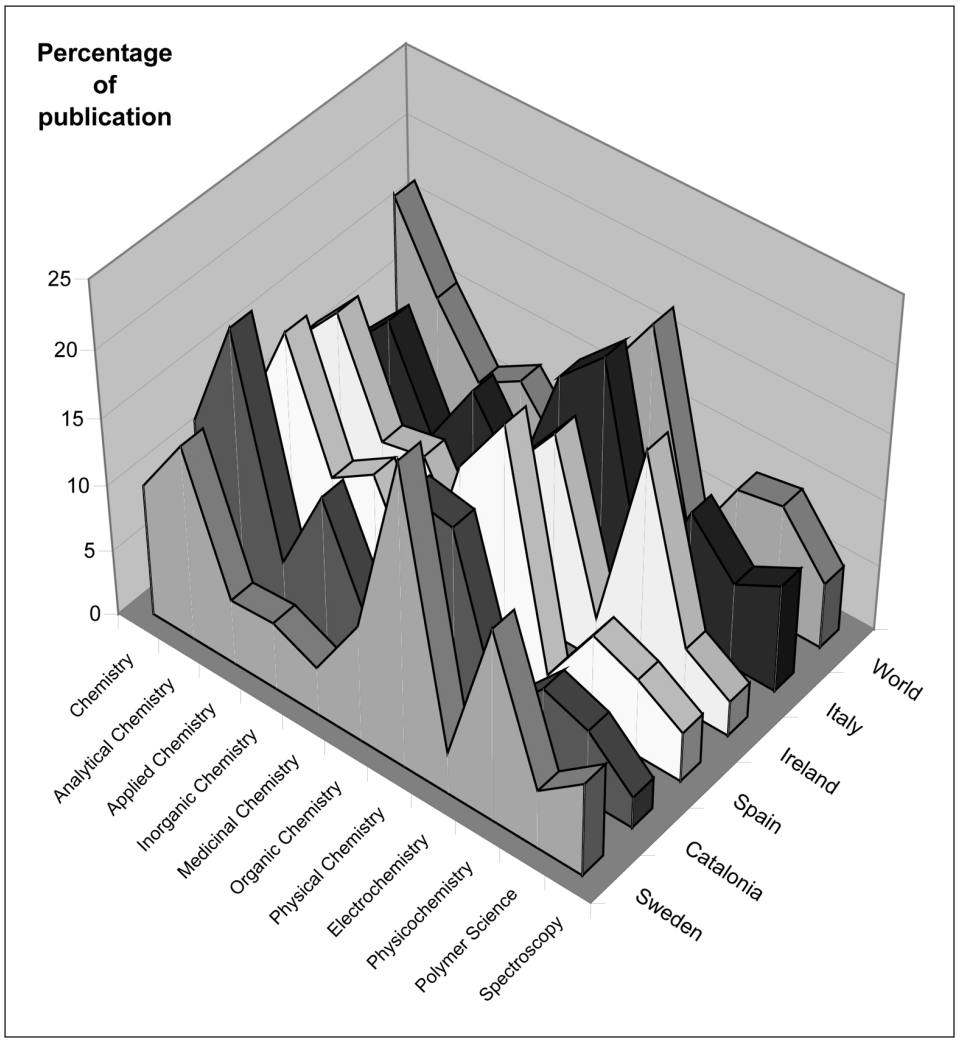

Figure 1. Relative distribution of overall scientific production among the eleven categories for the considered countries.

Table 9. Focus of the publications in each category for the considered countries in relation to world-wide ouptut. Values relative to the average world-wide production are given in brackets.

Category	*Catalonia*		*Spain*		*Ireland*		*Italy*		*Sweden*	
Chemistry	0.56	(0.71)	2.28	(0.57)	0.30	(0.71)	2.14	(0.50)	0.89	(0.60)
Analytical Chemistry	1.50	(1.90)	6.38	(1.58)	0.60	(1.43)	4.68	(1.10)	2.05	(1.37)
Applied Chemistry	0.62	(0.78)	5.36	(1.33)	0.53	(1.26)	3.51	(0.83)	1.27	(0.85)
Inorganic Chemistry	1.17	(1.48)	5.15	(1.28)	0.44	(1.04)	5.50	(1.30)	1.00	(0.67)
Medicinal Chemistry	0.80	(1.02)	3.20	(0.80)	0.23	(0.55)	5.84	(1.38)	1.48	(0.99)
Organic Chemistry	0.99	(1.26)	4.66	(1.16)	0.37	(0.89)	5.03	(1.19)	1.08	(0.72)
Physical Chemistry	0.68	(0.87)	4.46	(1.11)	0.37	(0.88)	4.38	(1.03)	1.98	(1.32)
Electrochemistry	0.86	(1.09)	3.26	(0.81)	0.49	(1.16)	3.69	(0.87)	1.72	(1.15)
Physicochemistry	0.63	(0.79)	3.44	(0.85)	0.87	(2.08)	4.95	(1.17)	2.57	(1.71)
Polymer Science	0.48	(0.61)	2.60	(0.65)	0.22	(0.52)	3.00	(0.71)	0.73	(0.49)
Spectroscopy	0.38	(0.48)	3.07	(0.76)	0.22	(0.53)	6.97	(1.64)	2.15	(1.43)
Total average. Country/world	0.79	(1.00)	4.03	(1.00)	0.42	(1.00)	4.24	(1.00)	1.50	(1.00)

Table 9 shows the relative output (in %) compared to world-wide output for each category as well as (in brackets) the relative values in relation to the overall average output for each country. Thus, in relation with the world as a whole, the publication of papers from Catalonia has increased from 0.52% in the previous study to 0.79%.

Another feature continuing from the previous report is the correlation between scientific output, financial effort in R&D (in terms of percentage of GNP), personnel effort (given by the percentage of the total population engaged in research) and the combined effort (given by the geometrical average of the financial and personnel effort) considering different countries around the world, and including in this case the most significant countries in research and industry (USA and Japan). All mentioned quantities are given in Table 10, taking the Catalan values as reference. The last column in the table shows the output / combined effort ratio which can be taken as a measure of R&D efficiency, on the assumption that different countries invest more or less the same percentage of their overall R&D budget in chemistry. Inspection of this column shows that both Catalonia and Spain as a whole are far less efficient than the leading countries in science and technology, and recommends a further effort is needed in order to correct inflationary aspects of scientific output.

With regard to the quality of the research done, the tendency is similar to that found in the prior *Report,* and has even improved. This issue is summarized in Table 11, where a quartile analysis of the impact factor of published papers among 533 journals has been performed. Thus it is observed that the percentage of publications from Catalonia corresponding to the first quartile have gone from 52.1 to 57.9%. The corresponding figures for Spain as a whole show the same trend, but with a slighter increment from 49 to 50.3%. As for an analysis of the number of times the published articles are cited, it can be observed that values for Catalonia are above the world average in the six categories corresponding to the main knowledge areas. Figure 2 shows the distribution, in percentages, of published papers by Catalan authors appearing in journals of the first quartile, among the whole set of considered categories.

Practically all publications are the result of research carried out in public centres, both in Catalonia and in Spain in general,

Table 10. Productivity, Personal effort, Investment effort, Combined effort and Productivity/Combined effort Ratio for the countries considered, in relation to the values for Catalonia.

Country	*Productivity effort*	*Personal effort*	*Investment effort*	*Combined effort*	*Productivity/ Combined effort*
Catalonia	1.0	1.0	1.0	1.0	1.0
Spain	4.4	5.2	4.3	4.7	0.9
Ireland	0.3	0.5	1.2	0.8	0.3
Italy	4.5	5.1	9.2	6.9	0.7
Sweden	1.6	2.7	7.4	4.5	0.4
Germany	10.5	15.9	37.0	24.3	0.4
Austria	0.8	0.9	2.6	1.5	0.6
Belgium	1.4	1.6	3.1	2.2	0.6
Denmark	0.8	1.2	2.6	1.8	0.5
France	7.1	10.8	24.4	16.3	0.4
Greece	0.6	0.7	0.5	0.6	1.0
Portugal	0.6	1.1	0.5	0.8	0.8
UK	7.7	10.7	21.9	15.3	0.5
Japan	12.8	42.6	116.4	70.4	0.2
USA	24.4	78.5	211.1	128.7	0.2

Table 11. Quartile distribution of the chemistry journals reported in the SCI according to their impact factor, and distribution of the papers from Catalan authors.

Quartile	*Journals*	*Impact factor*	*Papers in quartile*	*Corresponding Journals*	*% Papers*
1st	1-133	21.044-1.852	3409	99	57.9
2nd	134-267	1.845-0.966	1714	105	29.1
3rd	268-401	0.966-0.502	495	79	8.4
4th	402-533	0.5-0	274	44	4.6

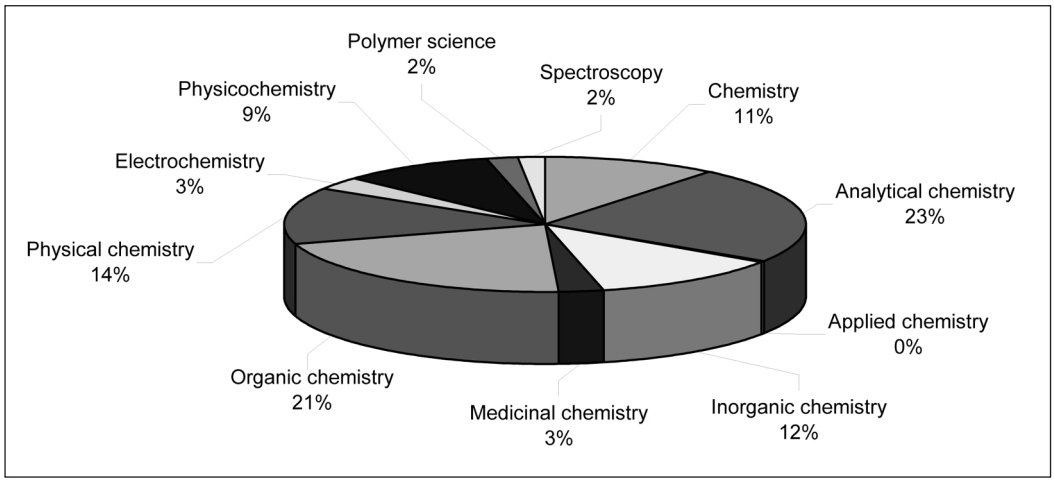

Figure 2. Distribution of papers by Catalan authors in journals of the first quartile among the categories studied.

whilst the contribution of comparable research coming from private centres is extremely limited. Hence, in spite of R&D expenditure in the private sector, direct results in terms of publications are not observable, thus it is public research centres that have continued to maintain the ongoing progress and visibility of research in chemistry in recent years.

Patents

Productivity as measured by the number of patents continues to be minimal compared to other more developed countries. It can be observed that the number of patents per year in Catalonia has remained essentially constant, while in Spain as a whole it has appreciably increased as compared to the previous *Report*. On the basis of a somewhat more detailed analysis of the number of patents in Catalonia - and very possibly the same is true of Spain as a whole - the majority of patents come from the private sector and are of an industrial nature. The number of patents coming from public research centres is not significant.

Conclusions

The public sector of chemistry research in Catalonia functions as an R&D system comparable to that of neighbouring countries in spite of a relatively lower level of financing. With respect to the private sector, traditionally considered to be well-consolidated in our country, a reduction in internal expenditure in R&D has been detected, as this is gradually replaced by public financing. The lack of cooperation between the public and private sectors continues to be a weak point in our chemistry R&D network, although indicators point to a slight increase in activity of technology transfer from university to industry.

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