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forum

Mathematics in Catalonia:1990-1996*

The aim of this article is to present the main conclusions of the Report on research in Catalonia for the area of mathematics**. The report was prepared by Joaquim Bruna, Marta Sanz, Joan de Solà-Morales and the author of this text, and published by the Institute for Catalan Studies in 1998.

In the report, scientific activity in the area of mathematics was measured essentially by examining two parameters: papers published in specialised journals and doctoral theses read. It should be recognised that a considerable amount of activity in the field of mathematics consists of applying existing knowledge to the resolution of practical technological problems that arise in particular companies. This kind of scientific activity was not measured in any way in the report due to the difficulty of obtaining objective data.

This article is divided into the following sections: human resources, scientific production, funding, research publications, research centres, and conclusions.

Human resources

Most research in mathematics is carried out at universities. In the academic year 1994-95, Catalan university instructors and fellowship holders in mathematics were distributed among 5 universities (the University of Barcelona, the Autonomous University of Barcelona, the Polytechnic University of Catalonia, the University of Lleida and the University of Girona) as indicated in Table 1.

During the period of the study, there was an increase in the number of teaching staff employed in the mathematics departments of Catalan universities. At the University of Barcelona, this increase was by a factor of 1.41; at the Autonomous University of Barcelona by a factor of 1.2; and at the Polytechnic University of Catalonia by a factor of 1.98. The University of Lleida and the University of Girona are not included here as they did not have mathematics departments in 1990.

Scientific production

Doctoral theses

Table 2 shows the number of doctoral theses read in the specified departments during the 1990-1995 period. In the case of UB, the source of these figures is the *report of activities* for these years; for the other universities, the figures are drawn from the corresponding research reports.

The doctoral theses read at the University of Barcelona (UB) and the Autonomous University of Barcelona (UAB) led to the granting of doctoral degrees in mathematics. We do not know if this was the case for the theses read in the departments at the Polytechnic University of Barcelona (UPC), the University of Lleida (UdL) and the University of Girona (UdG), given that, as a general rule, the universities grant doctoral degrees in areas in which they offer degree programmes. However, the 42 theses read at UPC are classified as corresponding to the mathematics area according to UNESCO codes. They should, therefore, be included in an analysis of mathematics research in Catalonia.

Table 1

	Stable teaching staff	*Term contract teaching staff*	*Fellowship holders*	*Total*
U. of Barcelona	75	23	11	109
Autonomous U. of Barcelona	48	32	11	91
Polytechnic U. of Catalonia	193	102	8	303
U. of Lleida	15	4	0	19
U. of Girona	13	12	1	26
Totals	344	173	31	548

Figures in this table include only teaching staff in mathematics departments. If mathematicians hired by other departments were counted, the total number of mathematicians in the universities would be 570.

Relationship between stable personnel and theses read: the number of theses read in the 1990-1995 period must be examined in relation to the number of researchers available to act as thesis supervisors. We have introduced the index *T*

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**An extended version of this report is available in Catalan on request: piec@iecat.net [*Reports de la recerca a Catalunya: Matemàtiques, Barcelona, Institut d'Estudis Catalans, 1998*].

Table 2. Doctoral theses read in mathematics departments at Catalan universities. 1990-1995 period

University of Barcelona	
Dept. of Applied Mathematics and Analysis	12
Dept. of Algebra and Geometry	9
Dept. of Statistics	9
Dept. of Logic, History and the Philosophy of Science	10
Total	40
Autonomous University of Barcelona	
Dept. of Mathematics	29
Total	29
Polytechnic University of Catalonia	
Dept. of Applied Mathematics I	4
Dept. of Applied Mathematics II	7
Dept. of Applied Mathematics III	11
Dept. of Applied Mathematics and Telematics	8
Dept. of Statistics and Operative Research	12
Total	42
University of Lleida	
Dept. of Mathematics	4
Total	4
University of Girona	
Dept. of Information Science and Applied Mathematics	3
Total	3
Total theses read: 118	

Table 3. Relationship between theses read and stable personnel

	UB	*UAB*	*UPC*
$T = \frac{\text{Theses read 90-95}}{\text{Stable teaching staff}}$	0.75	0.96	0.72

to indicate the relationship between theses read in the 1990-1995 period and stable personnel for the academic year 1989-90.

Scientific publications

We have used the database of the journal *Mathematical Reviews* to analyse the publication of research papers in mathematics produced in Catalonia for the study period. This journal is published by the American Mathematical Society (AMS) and includes reviews of almost all mathematics papers published around the world. It must be borne in mind that on average slightly more than a year passes between the publication of a given paper and the appearance of the corresponding review in *Mathematical Reviews*. If we also consider the fact that two or three years may pass between the time that a paper is sent to a journal and its publication, it is clear that the review of a paper appears three to four years after its production. We will analyse papers that were reviewed in the 90-96 period (which were produced three or four years before).

The total number of papers produced by authors associated with Catalan institutions and reviewed in *Mathematical Reviews* in the 90-96 period is 1429. The total number of reviews of publications globally for this period is 355916. Catalan production in mathematics represents 0.4% of global production (bear in mind that Catalonia has 0.11% of the global population).

Table 4 compares the total production of mathematics papers in the 1990-96 period with the production of other countries.

A certain degree of correlation between the last two columns of Table 4 can be observed («Number of papers/population» and «GDP/population»). Figure 1 offers a clearer view of this correlation.

The horizontal axis represents GDP/population and the vertical axis number of papers/population. Each country in Table 4 corresponds to a point on the graph (indicated by a small square). Catalonia is represented by a slightly larger square to distinguish it better from the other countries. To identify any country represented in the graph, keep in mind that the order of the countries in the table corresponds to the order of its ordinates from the largest to the smallest in the graph. For example, Canada, which is the first country in the table, corresponds to the highest ordinate point in the graph. The cloud of points on the graph, corresponding the totality of countries considered, has a determinate form that is certainly not linear. The curve that appears in the graph corresponds to the graph of the third degree polynomial that best approximates the cloud of points by the minimum squares method. Observation of the curve reveals that as per capita GDP increases, the production of mathematics papers per person increases, but that the rate of increase in

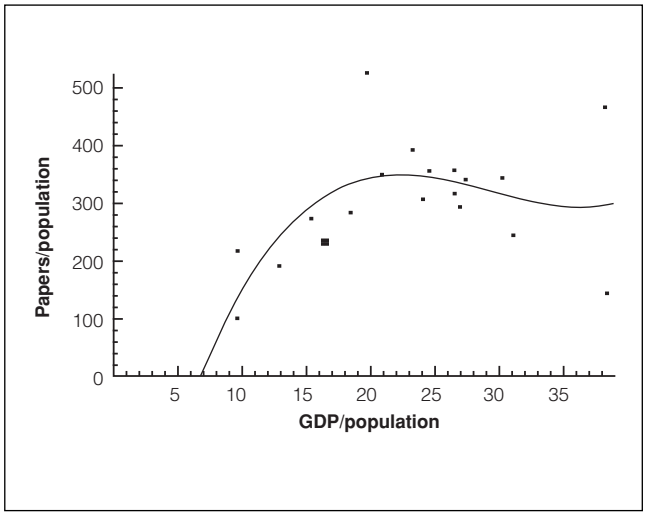

Figure 1. Comparison of countries. Total papers.

Table 4. Comparison of countries - total papers

Country	*1995 population*	*1995 GDP*	*Total number of papers*	*Number of papers/population*	*GDP/population*
Canada	29.6	586.6	15667	529.29	19.82
Switzerland	7.04	270.4	3301	468.89	38.41
Netherlands	15.45	361.6	6095	394.50	23.40
Belgium	10.11	269.2	3634	359.45	26.63
France	58	1432.1	20749	357.74	24.69
Finland	5.11	107.3	1805	353.23	21.00
Denmark	5.23	158.7	1811	346.27	30.34
United States	263.2	7246	90321	343.16	27.53
Austria	7.97	212.4	2544	319.20	26.65
Sweden	8.83	214	2728	308.95	24.24
Germany	81.6	2207.8	24165	296.14	27.06
United Kingdom	58.3	1080.1	16664	285.83	18.53
Italy	57.2	885	15717	274.77	15.47
Norway	4.36	136.3	1074	246.33	31.26
Catalonia	6.1	100.7	1429	234.26	16.51
Greece	10.45	102	2291	219.23	9.76
Spain (excluding Catalonia)	33.1	430	6408	193.60	12.99
Japan	125.1	4818.4	18366	146.81	38.52
Portugal	10.8	103.2	1084	100.37	9.56

In this table, the 1995 population is given in millions of persons and the 1995 gross domestic product (GDP) in billions of US dollars. The total number of papers refers to those reviewed in *Mathematical Reviews* during the period 1990-96. The column «Number of papers/population» indicates the number of mathematics papers published per million population. The column «GDP/population» indicates thousands of US dollars of GDP per person (quotient of the columns for GDP and population). The countries in the table are ordered according to the figures for the column «Number of papers/population» from greater to lesser. Catalonia (234.26) is below most of the countries in the table, and ahead of only Greece, Spain (excluding Catalonia), Japan and Portugal. It should be noted that the countries in the table (to which Catalonia is compared) are highly developed. The extremely low production of mathematics papers for Japan is very surprising. The United States is in the mid-area of the table. It should be kept in mind that these figures refer to the total number of papers published: they do not take into account the quality of these papers, which we will examine in section *Analysis of quality of publications.*

papers produced diminishes as GDP increases. The slight decrease in the number of papers after a certain level of GDP is not real: it is caused by the extreme data for Japan, which affect the form of the final part of the curve. The square representing Catalonia is below the graph curve, which indicates that production of mathematical papers is low in relation to that which would be expected for its level of GDP. It can be observed, though, that the United States is very close to the curve. The U.S. is, therefore, at a level of production that corresponds to its GDP (but not much above that level).

Analysis of quality of publications

In the preceding section, we have considered all papers published of mathematics research in Catalonia and the world, taking into account only the quantity, not the quality of these papers. We will now turn our attention to the quality of production.

One indicator of the quality of a scientific paper is the influence that it has on the subsequent development of the science: the number of times that the paper is cited by other authors provides a measure of this influence. Citations of good mathematics research papers may continue to occur over a very extended period. In this respect, the field of mathematics is distinct from other branches of the sciences: the initial impact of a publication may be less, but its influence can be extremely long-lasting. Bearing in mind these considerations, we have concluded that a methodology involving counting of citations would not be an appropriate approach for measuring the quality of mathematics research papers published in such a recent period. Lacking any better alternative, we have chosen to use an indirect measure of the quality of papers: the level of prestige of the journal in which they are published. Needless to say, this approach may fail to consider papers that have a high level of intrinsic quality and have had (or may yet have) a major impact on later work. From a statistical perspective, however, as a measure not of the quality of work done by a particular researcher or research group, but of that done in an entire country, focusing on the prestige of the journal where papers are published provides a good criterion for comparison.

The question which must now be addressed is that of how to select these «prestigious» journals that will serve as a basis for comparing the quality of mathematics research in different countries. We prepared a list of general mathematics journals by applying objective criteria (selecting the journals with the highest impact index from among those with an index of duration greater than ten years). We then added to this list a limited number of specialised journals in particular areas to ensure that these areas were represented. We

would like to stress that there may be other journals we have not included that have a level of quality similar to that of the thirty-five we have selected (some cut-off point was inevitable). We are confident that, statistically, the results of our study would not have changed much had we lengthened or shortened the list slightly.

The thirty-five journals (in alphabetical order) are the following:

- *Acta Mathematica*
- *Advances in Mathematics*
- *Annals of Mathematics*
- *Artificial Intelligence*
- *Biometrics*
- *Celestial Mechanics*
- *Commentarii Mathematici Helvetici*
- *Communications on Pure and Applied Mathematics*
- *Duke Mathematical Journal*
- *Econometrica*
- *Ergodic Theory and Dynamical Systems*
- *Inventiones Mathematicae*
- *Journal de Mathématiques Pures et Appliquées*
- *Journal für die Reine und Angewandte Mathematik*
- *Journal of Algebra*
- *Journal of Differential Equations*
- *Journal of Differential Geometry*
- *Journal of Functional Analysis*
- *Journal of Mathematical Analysis and Applications*
- *Journal of Mathematical Biology*
- *Journal of Number Theory*
- *Journal of the American Statistical Association*
- *Mathematics of Computation*
- *Mathematische Annalen*
- *Nonlinearity*
- *Probability Theory and Related Fields*
- *Proceedings of the London Mathematical Society*
- *Siam Journal on Numerical Analysis*
- *Siam Journal on Applied Mathematics*
- *Siam Journal on Control and Optimization*
- *Siam Journal on Discrete Mathematics*
- *Studies in Applied Mathematics*
- *The Annals of Probability*
- *The Annals of Statistics*
- *Topology*

Table 5. Comparison of countries (outstanding papers)

Country	*1995 population*	*1995 GDP*	*Number of outstanding papers*	*Number of papers/population*	*GDP/population*
Canada	29.6	586.6	1148	38.784	19.818
United States	263.2	7246	371	35.604	27.530
Switzerland	7.04	270.4	225	31.960	38.409
Denmark	5.23	158.7	152	29.063	30.344
France	58	1432.1	1562	26.931	24.691
Australia	18.1	336.3	450	24.862	18.580
Netherlands	15.45	361.6	355	22.977	23.405
Belgium	10.11	269.2	214	21.167	26.627
United Kingdom	58.3	1080.1	1217	20.875	18.527
Norway	4.36	136.3	91	20.872	31.261
Sweden	8.83	214	184	20.838	24.236
Germany	81.6	2207.8	1696	20.784	27.056
Austria	7.97	212.4	163	20.452	26.650
Catalonia	6.1	100.7	117	19.180	16.508
Finland	5.11	107.3	96	18.787	20.998
Iceland	0.27	7	4	14.815	25.926
Hungary	10.22	39.01	150	14.677	3.817
Italy	57.2	885	815	14.248	15.472
Ireland	3.58	60.1	47	13.128	16.788
Greece	10.45	102.3	117	11.196	9.789
Spain (excl. Catalonia)	33.1	430	364	10.997	12.991
Czech Republic	10.33	33.05	86	8.325	3.199
Bulgaria	8.77	10.26	73	8.324	1.170
Poland	38.6	94.6	317	8.212	2.451
Japan	125.1	4818.4	814	6.507	38.516
Portugal	10.8	103.2	55	5.093	9.556
Romania	22.68	27.92	94	4.145	1.231
Russia	147	392.5	248	1.687	2.670
Brazil	155.8	536.3	246	1.579	3.442
Argentina	34.59	275.66	42	1.214	7.969
Mexico	94.8	368.7	79	0.833	3.889
Ukraine	51.64	80.92	34	0.658	1.567
China	1221	630.2	771	0.631	0.516
Turkey	61.9	149	22	0.355	2.407
India	935.7	278.7	317	0.339	0.298

During the 1990-96 period, a total of 117 papers by authors associated with Catalan institutions were published in these journals. Bear in mind that the total number of papers published in Catalonia in this period is 1429. In other words, the papers published in the selected journals represent slightly more than 8% of total papers, and can therefore be qualified as *outstanding papers*.

A count was made of the number of papers published in these journals by authors of different countries. The results are shown in the Table 5.

Data for GDP and population are expressed in the same units as in Table 4, *Comparison of countries (total papers).* Given that, in our view, quality is a far more important factor to consider than quantity, a greater number of countries have been included here for comparison. The table is ordered according to the figures in the column «Number of papers/population». The country (of those in the table) that produces the most outstanding papers per person is Canada, and that which produces least is India. The United States, which in the table concerned with total papers was in the mid-area, now occupies the second position after Canada. As you will recall, Canada occupied the first position in Table 4, followed by Switzerland, which maintains a leading position in this comparison. In this table, Catalonia is situated in the upper half, ahead of many European countries (Finland, Iceland, Hungary, Italy, Ireland, Greece, rest of Spain, Czech Republic, Bulgaria, Poland, Portugal, Romania, Russia and Ukraine) and near the level of Sweden, Germany and the United Kingdom.

The results for Japan are surprising. Japan ranked poorly in terms of the number of papers published, and, in this measure of the excellence of the papers produced, it is once again to be found near the bottom of the table. In many areas of mathematics, however, there are outstanding Japanese researchers. Possibly, the explanation lies in the fact that Japan's population is twenty times greater than that of Catalonia: though the level of mathematical activity may be far lower than expected, Japan still has far more researchers than Catalonia, and among these there are a small number who stand out for the excellence of their work.

Table 6 below shows the percentage of outstanding papers produced in various countries in relation to the total number of mathematics research papers published.

We will now examine a graph of the relationship between a country's GDP and its production of high-quality papers, taking the same approach applied in the case of total papers. In Figure 2, *Comparison of countries. Outstanding papers,* the horizontal axis indicates GDP/population, and the vertical axis number of outstanding papers divided by population.

Each country in the preceding table is represented by a point on the graph (indicated as a small square). Catalonia is represented by a square slightly larger than the others so that it may be easily distinguished. As in the previous graph, each country is easily identified: in Table 5 countries are ordered by number of papers/population which is the ordinate of the graph. For example, Canada is the first

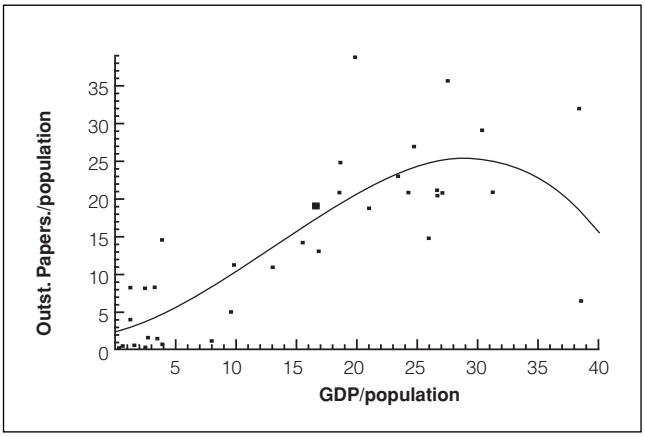

Figure 2. Comparison of countries. Outstanding papers.

Table 6. Comparison outstanding/total

Country	*Number of outstanding papers*	*Total published papers*	*Percentage outstanding /total*
United States	9371	90321	10.4
Norway	91	1074	8.5
Denmark	152	1811	8.4
Catalonia	117	1429	8.2
France	1562	20749	7.5
Canada	1148	15667	7.3
United Kingdom	1217	16664	7.3
Germany	1696	24165	7.0
Switzerland	225	3301	6.8
Sweden	184	2728	6.7
Austria	163	2544	6.4
Belgium	214	3634	5.9
Netherlands	355	6095	5.8
Spain (excl. Catalonia)	364	6408	5.7
Finland	96	1805	5.3
Italy	815	15717	5.2
Greece	117	2291	5.1
Portugal	55	1084	5.1
Japan	814	18366	4.4

country in the table, and is represented in the graph by the highest point.

It can be observed (as was the case when total publications were compared) that the form of the cloud of points is not linear. In this case, we have also approximated (by the minimum squares method) the cloud of points in the graph with a third degree polynomial, which is indicated by the curve drawn on the graph. As occurred in the comparison of total papers, as GDP increases so does the production of quality papers in mathematics; however, the rate of increase diminishes as GDP increases. The decrease in quality papers after a certain level of GDP is reached has no logical explanation: as in the case of Figure 1, the extreme position of Japan is the cause of this illogical downward turn of the curve.

Contrary to the results when «total papers published» was the criterion for comparison, when only outstanding papers are considered, Catalonia is positioned significantly above the curve. This implies that the quality of its mathematical production is higher than expected in relation to its GDP.

Many countries are represented in Figure 2 - 35 to be precise. Many of these have characteristics quite distinct from those of Catalonia (e.g. India, China, Mexico...). It is interesting to re-examine the same graph, but excluding countries that are not located in Europe. The countries that are left, in order of number of published papers per person are Switzerland, Denmark, France, the Netherlands, Belgium, the United Kingdom, Norway, Sweden, Germany, Austria, Catalonia, Finland, Iceland, Hungary, Italy, Ireland, Greece, Spain (excluding Catalonia), the Czech Republic, Bulgaria, Poland, Portugal, Romania, Russia and Ukraine. The resulting graph, when only these countries are considered, is shown in Figure 3.

In this case, the cloud of points has a linear form. The cloud of points has been approximated by a third degree polynomial as in the preceding graphs, and the result is close to a straight line. In other words, within our geographical area, the production of outstanding papers is a linear function of per capita GDP. Catalonia is once again above the curve in this graph, indicating that the quality of its mathematical production is higher than expected in relation to its per capita GDP.

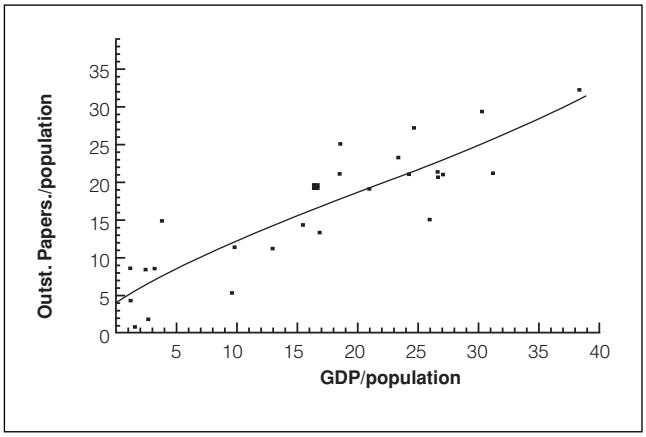

Figure 3. Comparison of countries. Outstanding papers.

Evolution of outstanding mathematical production over the last ten years

In order to examine how the production of outstanding mathematics research papers in Catalonia has evolved over the last ten years, we made a count of the number of papers published in Catalonia in the thirty-five journals mentioned in the preceding section during the 1980-86 period. This figure was then compared with that for the 90-96 period. The computerized *Mathematical Reviews* database for the 80-86 period does not include information about the centre that the author of each paper is associated with. For the 80-86 period, therefore, we used the database of *Science Citation Index* for most of the thirty-five selected journals. For a few that are not covered by this index, a manual consultation was carried out. References to papers take longer to appear in *Mathematical Reviews* than in *Science Citation Index*. Given the change in the database used, the comparison is, in fact, being made between two periods more than ten years apart (possibly eleven or eleven and a half years). One of the thirty-five selected journals (*Nonlinearity*) did not exist during the 80-86 period. We therefore excluded data related to this journal from the 90-96 period, and proceeded to make the comparison on the basis of the thirty-four remaining publications.

In the 80-86 period, thirty-four papers by authors associated with Catalan centres were published in these journals, and 110 by authors associated with centres in the rest of Spain. In the 90-96 period, 112 papers were published in the same journals by authors associated with Catalan centres, and 363 by authors associated with centres in the rest of Spain. Over a period of ten years, Catalan production of outstanding papers increased by a factor of 3.3. The proportion of Catalonia's production of such papers in relation to that of the rest of Spain remained virtually unchanged over this period: in the course of this ten-year period, Catalonia did not advance more than the rest of Spain. It should be borne in mind, however, that during this period overall global production of mathematics papers increased by a factor of 1.34. If Catalonia had increased its production of outstanding papers by a factor of 1.34, this would not really have constituted any advance in relation to other countries. In fact, its production increased more than three fold.

Having now referred to the growth in the production of mathematics papers around the world over the last ten years, it is perhaps of interest to examine this growth over a longer period (though this represents a departure from the aim of our study). Table 7 (below) indicates the number of papers reviewed in the journal *Mathematical Reviews* in the years 1943, 1953, 1963, 1973, 1983 and 1993, and gives a long-term view of this trend:

From 1943 to 1953, production of papers increased by a factor of 2.55; from 1953 to 1963, by a factor of 1.96; from

Table 7. Evolution of mathematics production since 1943

Year	*1943*	*1953*	*1963*	*1973*	*1983*	*1993*
Number of papers	2834	7219	14147	29808	40195	54019

1963 to 1973, by a factor of 2.11; from 1973 to 1983, by a factor of 1.35; and from 1983 to 1993, by a factor of 1.34. All of these figures, as mentioned above, are based on reviews appearing in *Mathematical Reviews*. The major increases in the first ten-year periods may be the result of increases in the number of journals reviewed by *Mathematical Reviews*, or other factors such as World War II (the number of papers reviewed in 1943 is very low). It can be observed, however, that over the last 20 years there has been a sustained growth of 34% every ten years.

Funding

There are essentially three sources of subsidies for research groups in Catalonia: the Spanish Ministry of Education and Culture, the Autonomous Government of Catalonia and the European Union. Groups receiving these subsidies use them to cover expenses related to areas such as travel, attendance of congresses and meetings, invitation of researchers from abroad, and acquisition of reference and IT material. Of these subsidies, only those provided by the European Union can be used for remuneration of staff. Funding from the Spanish Ministry of Education and Culture reaches mathematics research groups through the DGICYT (the Directorate of Scientific and Technical Research) «Programme for the Promotion of Knowledge by Sectors». In the 90-96 period, this funding amounted to 201 million pesetas . During the same period CICYT (the Inter-Ministerial Committee on Science and Technology) provided 336 million pesetas for funding of projects with UNESCO codes corresponding to mathematics areas. The majority of these projects, however, involve engineering or computer science research groups working on matters that also involve mathematics (graphic computing, computer robotic vision, bioengineering). It would, therefore, be erroneous to include these resources in the quantification of mathematics research funding. In the 90-96 period, the Autonomous Government of Catalonia provided 35 million pesetas in research funding, specifically for projects subsidised by CIRIT (the Inter-Departmental Committee on Research and Technological Innovation). European Union project funding amounted to 130 million pesetas. Based on these figures, it can be concluded that 54.9% of funding for mathematics research groups came from the Ministry of Education and Culture, 35.5% from the European Union, and only 9.6% from the Autonomous Government of Catalonia. The ratio of the direct research group funding provided by the Autonomous Government of Catalonia to that provided by the Ministry of Education and Culture is 1 to 5.7. Clearly, Catalonia carries little weight in the administration of resources allocated for research. Many other autonomous regions of Spain also provide funding for research groups. The Basque region, for example, allocated 24 million pesetas in direct assistance for mathematics research groups in the 90-96 period, while Catalonia provided 35.2 million pesetas. On a per capita basis, Catalonia provided only half the resources that were dedicated to this area by the Autonomous Government of the Basque region.

In addition to direct funding of research groups, both the Ministry of Education and Culture and the Autonomous Government of Catalonia have provided significant financial resources in the form of indirect assistance. This includes training for researchers, subsidies for stays by visiting professors, assistance to improve infrastructure, etc.

For the 90-96 period, the total direct funding for Catalan research groups in mathematics (from DGICYT, CIRIT and European projects) was 366 million pesetas. This amount was allocated in the following manner to the different areas of mathematics as defined by UNESCO:

Logic	17.5	Numerical analysis	5.2
Algebra	35.9	Probability	17.3
Analysis and differential equations	85.2	Statistics and operative research	92.2
Computer science	32.2	Geometry and topology	35.6
Number theory	33.9	Other specialisations	11.3

Funding provided for mathematics libraries is another area to consider. There are currently three libraries of this type in Catalonia: the libraries of the faculties of mathematics at the University of Barcelona (UB) and the Polytechnic University of Catalonia (UPC), and the Department of Mathematics library at the Autonomous University of Barcelona (UAB).

The purchase of books and journals by the UB library constituted an investment of 128.4 million pesetas in the 90-96 period. For UAB, investment in this area amounted to 71.5 million pesetas, and for UPC, 20.2 million. These amounts are comparable to the direct funding for research groups discussed above, and, in a very high proportion, are provided by the universities themselves.

Publication of research papers

Five journals and a collection of books warrant mention for their regular publication in Catalonia of works in the mathematics field during the 1990-96 period. These publications focus largely on the work of authors from abroad: they publish few papers by Catalan mathematicians, who generally prefer to publish in journals based outside of Catalonia.

Journals

Collectanea Mathematica
First published in 1948, this is the Catalan mathematics research journal with the longest history. The journal is now published by the University of Barcelona (ISSN: 0010-757). Volumes 41, 42, 43, 44, 45, 46 and 47 were issued during the 1990-96 period. These contain a total of 162 research papers, four of which were written by authors associated with Catalan institutions, 35 by authors associated with institutions in the rest of Spain, and 123 by authors from the rest of the world.

Mathware & Soft Computing
This journal was created in 1994 and is published by the Mathematics and Computing Science Section of the Barcelona Higher Technical School of Architecture (ISSN: 1134-5632). The journal focuses on the use of mathematical tools and models that could be relevant in the cognitive sciences, pure or applied logic, and artificial intelligence. A volume of approximately three hundred pages, containing between twenty and thirty research papers, is published about once a year. Each volume consists of three issues.

Publicacions Matemàtiques
Published by the Autonomous University of Barcelona's Department of Mathematics, this journal was started in 1976 (ISSN: 0214-1493). Volumes 34, 35, 36, 37, 38, 39 and 40 were published in the 1990-96 period. These contain 272 research papers, 32 of them by authors associated with Catalan institutions, and 43 by authors associated with institutions in the rest of Spain. It should be noted that many of the papers by Catalan authors are contained in volume 36, which was dedicated to Pere Menal, a mathematician who worked at UAB, and who was killed in a traffic accident in 1991.

Qüestió
This journal, which ceased to be published in 1987, initiated a new stage in its existence when it reappeared in 1992. It is published by the Catalan Institute of Statistics with the support of the University of Barcelona, the Polytechnic University of Catalonia and the Catalan Institute of Statistics itself. Between 1992 and 1996, the journal published 84 papers, of which 26 were by authors associated with Catalan institutions.

Stochastica. Revista de Matemàtica Pura i Aplicada
The last issue of this journal appeared in 1992 (volume 13, ISSN:0210-7821). Before its disappearance, this journal produced one volume each year (made up of three issues), and was published by the Mathematics and Computing Science Section of the Higher Technical School of Architecture of Barcelona.

Book collections
Since 1993, the Ferran Sunyer i Balaguer Foundation, with the support of the Institute for Catalan Studies, has been awarding an annual prize in honour of the Catalan mathematician Ferran Sunyer i Balaguer. The prize supports the publication of an informative monograph dealing with the latest developments in an active area of mathematics research. Under an agreement with the publisher Birkhäuser, each year the winning monograph is published in a sub-collection of the collection «Progress and Mathematics». This sub-collection bears the coat of arms of the Institute of Catalan Studies on its cover, and includes a brief biography of Ferran Sunyer in its first pages. Since 1996, two books have been published in this sub-collection, corresponding to the first two editions of the prize (issues 125 and 128 of «Progress and Mathematics»).

Research centres

Centre for Mathematics Research
In 1984, the Institute for Catalan Studies created the Centre for Mathematics Research (Catalan acronim: CRM). The annual reports of this centre include the following description of its objectives: *to provide Catalan mathematicians with a research centre that will promote the development of mathematics research in Catalonia, both qualitatively and quantitatively. To achieve this objective, CRM invites distinguished scientists from around the world to spend time as visiting researchers in Catalan centres; provides young Catalan researchers with opportunities for contact with these visiting researchers and with scientific institutions; carries out research programmes; organises congresses, seminars and other scientific gatherings; and disseminates the results of research.*

CRM's research infrastructure is horizontally organised: it does not have its own research staff or directly sponsor any research group. It does sponsor postdoctoral fellowship holders and researchers from abroad, who, in most cases, are in contact with Catalan research groups. Similarly, many of the activities with which CRM is involved (congresses, seminars, courses, etc.) are jointly organised with Catalan research groups.

CRM is part of a European network that links it with similar groups such as the Newton Institute, the Mittag-Lefler Institute, the Max Planck Institute and others. It also participates in the Leibnitz programme, which provides postdoctoral fellowships in the mathematics field.

The Centre for Mathematics Research is located in the Faculty of Sciences building of the Autonomous University of Barcelona's Bellaterra Campus, under the terms of an agreement between the Institute for Catalan Studies and UAB.

CRM's infrastructure is a highly valuable complementary element in the development of mathematics research in Catalonia.

Table 8 outlines the centre's main activities, and shows how these evolved in the 1990-96 period.

In 1995, CRM became involved in a new area of activity - the regular organisation of courses dealing with advanced re-

Table 8. CRM activities in the 1990-96 period

	1990	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*
Number of researchers	56	48	55	60	59	58	56
Number of conferences or seminars	104	106	135	180	230	169	178
Number of publications	23	21	45	57	36	39	31
Congresses organised	2	3	0	2	7	3	1

Table 9. Sources of funding (thousands of pesetas)

	1990	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*
Carried forward and others	1,995	1,581	1,580	–	–	–	5,692
CIRIT	8,000	8,820	22,300	20,000	20,000	20,000	15,000
DGICYT	13,105	9,605	14,035	13,530	21,900	21,440	17,950
Institute for Catalan Studies	8,198	9,500		2,432	–		
OCSA		3,000					
CCHNA		0.3	0.2		–		
Intern. Coop.		0.56	0.24		–		
UAB			5,200	5,600	3,300	3,300	3,400
Autonomous Government (conv.)				12,815	17,276	7,420	5,775
EU				1,750	8,960	9,570	14,730
Totals	31,299	33,366	43,555	55,127	71,435	61,730	62,547

OCSA: Cultural Olympics, S.A.; CCHNA: Comité Conjunto Hispano Norteamericano.

search topics. The courses offered in 1995 were «Elliptic Cohomology» and «Complex Dynamics»; and in 1996, «Geometry and Physics», «Commutative Algebra» and «Homotopy Theory».

Table 9 shows the sources of funding for CRM. Funding from main sources (CIRIT and DGICYT) evolved favourably up until 1995 and then declined significantly in 1996. The recent and progressive benefit obtained from EU funds should also be noted.

Artificial Intelligence Research Institute

The Artificial Intelligence Research Institute (IIIA), based at the UAB campus since 1994, grew out of the Artificial Intelligence Research Group and is now part of the Scientific Research Council (CSIC).

In contrast to CRM, this institute does have its own personnel and includes a fairly homogenous research group distributed in two departments (intelligent systems and formal methods). Currently, the stable IIIA staff is made up of approximately fifteen researchers, mainly doctors in computing science with contractual ties to CSIC.

There is, without doubt, a strong mathematical component to the research done by this group. This is a clear example of the phenomenon referred to in the introduction to this article: the activity of this group is on the border between the field analysed in this report and other areas of research activity.

The research activity of this group essentially involves the production of publications, participation in projects and technology transfer. It should be noted that not all regular publications in the field of artificial intelligence are covered by *Mathematical Reviews*.

In the 90-96 period, IIIA received 110 million pesetas in funding from the European Union, and it is part of various European networks and networks of excellence.

Mathematics researchers are also trained at IIIA: there are fellowship holders, and doctoral theses are supervised. These fellowship holders and theses are not included in the tables because they are formally associated with computing science departments. At present, there are about ten fellowship holders. In the 90-96 period, nine these were read.

Other institutions related to mathematics

This section offers a brief description of the activity of other institutions related to mathematics research in Catalonia. Some contribute to this activity as research centres, and others are involved in promoting such research or disseminating its results.

One of the key institutions in the world of mathematics in Catalonia is the Catalan Mathematical Society, an affiliate society of the Institute of Catalan Studies. This society's objectives include the promotion of pure and applied research, as well as awareness raising and the dissemination of results. It is virtually the only link between mathematics at the universities and teaching staff at the secondary school level. Each year, in co-ordination with other countries, the society organises the Mathematics Olympiad and the Kangaroo Mathematics Competitions. These events are part of a highly effective campaign to promote mathematics at the pre-university level. The many public events (conferences, courses, etc.) held by the society contribute a great deal to the promotion of mathematics and the dissemination of knowledge in the field. As a member of the European Mathematical Society, the Catalan society was delegated the task of organis-

ing the European Mathematics Congress, that took place in Catalonia in the year 2000. Particularly noteworthy among its publications in the 90-96 period are a volume covering the work of the Catalan mathematician Pere Menal i Brufau (1994), the Catalan translation of *Disquisicions Aritmètiques* by C. F. Gauss (1996), and the regular publication of *Butlletí de la Societat Catalana de Matemàtiques*.

In 1996, the National Centre of Scientific Research in France, in conjunction with the Autonomous Government of Catalonia's Commission on Universities and Research, set up a «European Associated Laboratory» in the area of Intelligent Systems and Advanced Control (LEA SICA). The Associated Laboratory placed four existing groups under the same direction, and established a shared scientific programme. The four groups were the Symbolic Automatics Group (AS) of the LAAS of Tolosa, the Distributed Systems Automatics Group (ASD) of the IMP of Perpinyà, the Advanced Automatics Group (SAC) of the Polytechnic University of Catalonia (UPC), and the UPC's Knowledge Engineering Research Group (GREC). The GREC is an applied mathematics group created by Professor Núria Piera Carreté (who sadly was killed while this report was being prepared). At the time that LEA SICA was founded, GREC was made up of five researchers. Funding of this laboratory is provided primarily by the CNRS of UPC.

Also worth mentioning is the Catalan Institute of Statistics, which was created in 1989 and is under the authority of Autonomous Government of Catalonia's Department of the Economy and Finances. One of the institute's objectives is to promote research in statistics and the development of this field in the various subject areas in which the institute is involved.

Conclusions

- The state of mathematics research in Catalonia is similar to that in other advanced countries. In terms of the number of outstanding papers published, Catalonia is practically on a par with countries traditionally regarded as highly advanced, such as Germany, the United Kingdom, Sweden and Austria. Catalonia is ahead of Italy - a country with a long tradition in the mathematics field - though still far from the level of France, Switzerland, Canada and the United States.
- In the last ten years, Catalonia has increased the number of outstanding papers published by a factor of 3.3. The number of papers published for the rest of Spain has increased by the same factor. The impressive development that has taken place here has been uniform throughout the state.
- Very few Catalan mathematicians are members of the editorial boards of prestigious research journals. This lack of representation is not consistent with the quantity and quality of research done in Catalonia. Catalan mathematicians are also significantly underrepresented in the international bodies responsible for the design of scientific policy. This may be due to the lack of a long mathematics tradition in Catalonia (only for a relatively short time has a significant amount of activity in this field been going on). Initiatives should be undertaken to increase Catalan influence in international forums.
- Of the direct funding provided for research groups by the Ministry of Education and Culture, the Autonomous Government of Catalonia and the European Union, only 9.6% comes from the Autonomous Government. The ratio of funding provided by the Autonomous Government to that provided by the Ministry of Education and Culture is 1:5.7. Clearly, Catalonia currently carries little weight in the administration of resources allocated to research. Bearing in mind that all of the autonomous regions allocate funds for mathematics research and that the university structure is the same throughout the state, it is not surprising that the development of research activity has been uniform throughout Spain over the last ten years.
- Direct assistance for research groups provided by the Ministry of Education and Culture is, for the most part, channelled through the DGICYT «Programme for the Promotion of Knowledge by Sectors». Within the limits marked by a general scarcity of resources, funding policy over the years has been based on a consistent set of principles: assistance has been provided to Catalan researchers in a manner that accurately reflects the quality of their production.
- University library policy should be clearly co-ordinated, and based on adequate economic resources.
- Data concerning the economic resources allocated to mathematics research in recent years lead us to conclude that this research has been carried out at a very low cost. The level of research funding has been very limited, despite the fact that basic research of this type is fundamental to the technological development of a country.
- In the 90-95 period, the stable teaching staff at Catalan universities for the mathematics area grew by a factor of 1.81. UAB experienced the lowest level of growth in stable teaching staff (just a 1.2-fold increase).
- UAB also has the lowest proportion of stable teaching staff in relation to total teaching staff.
- The number of fellowship holders is low at all of the universities, and particularly at UPC. An effective policy of incentives for research would involve a significant increase in the number of fellowship holders, an increase in the amount of fellowships, creation of a sufficient number of positions for assistant instructors, and the disappearance of «false» adjunct instructors (instructors hired as adjuncts who in fact have all the characteristics of assistant instructors).
- Strong incentives should be provided for any initiatives intended to apply theoretical mathematics research to specific problems that arise in other sciences, engineering or economics, even if these applications do not lead immediately to the production of research papers.
- Among professors at Catalan universities, there are still potential researchers who have not participated in research projects that are regarded as competitive.
- In general, the areas of mathematics specialisation that

have the highest number of global publications (the most productive) are well represented in Catalonia, with the exception, perhaps, of partial differential equations and numerical analysis, areas in which few Catalan researchers are working. These areas of specialisations should, therefore, be promoted.

– It would be highly beneficial to try to attract papers of unquestionable quality for publication in Catalan journals. In this manner, the level of international regard for these journals (already well-considered) could gradually be raised. Catalonia now has the research potential necessary to publish a high-quality research journal.
– A number of institutions have emerged that have played an important role in the development and promotion of research activity. Strengthening these institutions would help encourage these activities in the future.