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RESEARCH OUTPUT EVALUATION OF TWO UNIVERSITY DEPARTMENTS IN GREECE WITH THE USE OF BIBLIOMETRIC INDICATORS

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The results of a study for evaluating research performance of two Greek University Departments of Mathematics are presented. In order to achieve this elements from the Sussex and Leiden methodologies of constructing and using bibliometric indicators were used. Comparison of the two groups were based on their similarities. The convergence of bibliometric indicators procedure as applied in Leiden methodology together with a number new bibliometric indicators were used. Results shown that bibliometric indicators if applied properly may give very interesting information on the research performance and nature of research carried out in University Departments.

Introduction

A number of published[1,5] studies have produced results which prove that, despite their limitations, bibliometric indicators may play an important role in science policy decisions and in evaluations of research performance. In the case of basic or pure research there is considerable evidence that bibliometric indicators may play an important role as evaluative tools of individual scientists or research groups.[2]

In order to investigate the applicability of bibliometric indicators in practical situations we compared and evaluated two Departments of Mathematics of Greek Universities with the use of bibliometric indicators. Bibliometric data may produce a number of interesting items of information such as the degree of collaborative research in groups under evaluation, the local or international character of impact produced, etc. The present study aims at revealing all these features of research in these two departments.

Given the controversy surmounting the publication of evaluation studies which proposed specific science policies based on their findings[3] we shall refrain from attempting to draw explicit policy conclusions.

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It is believed that the results of research evaluations do not by themselves offer a solution to the perennial problems of science policy, not even to those specific to the difficult decisions in increasing or decreasing research funding. Concequently, results of evaluations like this may be used for supporting traditional processes of evaluating research, which in the case of basic research in the peer-review method. If seen in such a context it is certain that bibliometric indicators and bibliometric techniques will be more widely accepted and the confidence in their relevance to science policy issues and in their reliability will be strengthened.

Methodology

In evaluations or comparisons of the performance of research groups we face a number of methodological and practical problems. The scientific field in which a group is doing research has specific norms and special characteristics which affect the nature and importance of every bibliometric indicator used. Together with these features inherent to scientific fields, a number of social, economic, or even political factors may affect the validity of bibliometric indicators as evaluative tools. For example if we try to compare research performance of two research groups which are doing research in the same discipline but publish their research output in different languages or using a different set of journals, it is certain that results of this comparison will not reveal the actual importance of their research output.

Research output comparison of research groups can be done only when they have specific common characteristics. Groups under evaluation must do research in the same field or even better, the same speciality, publish their research output in the same set of journals using the same language and must be affected by similar social and economic factors.

The two university departments concerned in this study are those of mathematics at the Greek Universities of Ioannina and Patra. The decision for their selection was based on the need for matching as many requirements and factors which affect bibliometric indicators as possible. The common characteristics of these two departments are:

1. They are located in two peripheral cities of Greece: Ioannina is the largest city and the main economic and social centre in the North West region of the country, while Patra plays a similar role in the South West region. It is estimated that the social factors which may affect research productivity are almost identical in these two cities.

2. Both departments are state controlled and their faculty members are subject to the same pressures for publishing and achieving reputation and recognition among scientists working in similar research fields.

3. Scientists in the two departments devote to research activities the same amount of time as they have similar teaching and administration requirements.

4. In most cases a mathematician does not need supporting staff during his research activities. Research groups in these two departments are supported by the same number of administration staff and equal research facilities such as computers, etc.

5. In both departments scientists publish their research output in international journals or technical reports. Language of their publications is almost exclusively English.

6. The two research groups are supported by libraries and information services of nearly equal quality. The fact that the Ioannina group may now use foreign databases for bibliographic on-line searches does not make any difference as its on-line facilities were not in existence during the evaluation period of this study.

7. The two groups are doing research in the same scientific field.

A number of differences also exist and have been taken into account during this study. The Ioannina department includes a group of scientists who are doing research on mechanics, and there is no equivalent to this group in the Patras department. On the other hand the Patras department includes a group of astrophysicists, and there is no such group in the Ioannina department. As every research field has its own publication and citation practices these two groups (mechanics and astrophysics) were excluded from this study. It is believed that by doing so a better matching of their publication output could be achieved.

In order to perform better comparisons of research performance of the two groups and to be able to test the validity of existed methodologies, elements from the Sussex[4] and the Leiden[5] methodologies were used. The "like" to like" comparison feature of the Sussex methodology together with its convergence of bibliometric indicators principle is thought to be useful for the needs of this study. However, as every evaluation situation has its own characteristics and having in mind objections voiced to Sussex methodology, a number of different bibliometric indicators and procedures were used. The trend-analysis features of the Leiden methodology is a useful and interesting method of presenting bibliometric indicators. Elements of this methodology are employed in this study.

Evaluation of research performance and comparisons of the two groups are based on a number of publication and citation indicators. Whenever we count publications or citations for construction of bibliometric indicators we must decide how to treat multi-authored publications. Despite the difficulties we face when we try to allocate credit to every co-author of a multi-authored publication it seems reasonable to adjust publication and citation counts and to give a fraction to every co-author. For this study adjusted counts of publications and citations were done. Decisions of how to treat self and in-house citations may also affect bibliometric indicators produced. For this reason separate counting of self and in-house citations were done.

The time frame for this study was the period 1975 – 1984. There are number of reasons for this decision. First when we have data for a time period – instead of for one year only – it is easier to estimate not only the relative position of a research group for a specific year but to have also an indication of publication and impact trends for a number of years. In order to reveal these trends, tables of data and graphical presentations are very useful. Other reasons have to do with specific developments in the university education in Greece. During this period a number of laws for university education were introduced. The idea was that the evaluation period had to cover all these developments. A further research may reveal the effect – if any – of this legislation on the research performance of the Greek academic community. When we count citations we need a longer time period in order to allow a minimum number of years for each publication to accumulate citations. For this study the publication counting period is 10 years (1975 – 1984) and the citation counting period 13 years (1975 – 1987).

After the construction of bibliometric indicators an examination of their behaviour must follow. In order to estimate trends in the publication output of each research group, graphs of numbers of publications against the year of their publication were made. The idea in using these graphs is to show that if the graph increases (decreases) the scientific output of that research group must have increased (decreased) during the corresponding time period. Estimation of impact trends is done by using graphs of number of citations received or number of citations per publication or per scientist against the corresponding year. It is assumed that interpretations similar to research output graphs may be done.

Examination of the trends of bibliometric indicators constructed for each research group cannot demonstrate the relative position of each group. This can only be done by comparing bibliometric indicators produced for each group. If bibliometric indicators for one group shows a convergence to the same points we

may estimate the relative position of this group in relation to the other. In a different way comparisons of actual with expected impact may be done. For this purpose counts of citations received by a research group may be compared with average citation scores of the journals in which each group has published its research output. It is assumed that comparisons of expected with actual impact will indicate the international level of this research group's work. Efforts for applying this methodology in this study was done.

Input indicators

Before considering bibliometric indicators of scientific progress and output, a closer look at the basic inputs of the research activity of each department is given. In Greece a very low percentage of research in mathematics is financed by research funding bodies. As a result financial resources – except salaries of researchers – do not play any real role as inputs of mathematical research. In some subfields of applied mathematics computer (CPU) time may be used as an input but the absence of comparative data prevented us from using it. Research output in mathematics is almost exclusively the result of the intellectual effort of the scientists involved. Quantification of intellectual effort is impossible. Consequently the absolute number of scientists is the main input in research in these departments.

It would be misleading to compare scientific progress made by research groups without taking into account their size. Annual numbers of scientists are needed for construction of many bibliometric indicators. Numbers of researchers for the two departments are shows in Table 1.

Table 1
Research manpower of the two departments (Visiting staff is not included)

Department	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Average
Ioannina	25	31	38	34	41	41	44	43	42	35	37.4
Patra	20	25	26	29	28	30	31	30	30	29	27.8

Figures in Table 1 are calculated using official publications of the two universities. However for some years these figures may be slightly different due to incomplete data in these publications. From Table 1 it can be seen that on average the Ioannina group is 35% bigger than Patras. Using this fact we can conclude that scientific

activity – in terms of scientists involved in research – in Ioannina is greater. It is evident that a further study would reveal the degree of scientific activity for each member of every group. However, lack of such data forced us to use "mean values" of research activities.

Output indicators

In every evaluation of basic research we want to measure the extent to which scientists have fulfilled their primary goal, namely the production of new scientific knowledge. It is evident that every quantification of knowledge contributions must be linked to scientific production. Output bibliometric indicators are used for this purpose. Indicators produced with the use of publication data reveal levels of publication production and productivity while those produced with the use of citation data show impact and visibility produced by this output.

Publication counting indicators

The first bibliometric indicator used is the number of publications produced by the two research groups during the evaluation period. For construction of this indicator articles to properly refereed scientific journals, conference proceedings and monographs are collected. Unpublished works, preprints and technical reports are excluded. The justification for excluding these informal forms of communication of research is that most of these are subsequently published in the same or revised form as journal articles. To include them would introduce a significant element of double-counting.

First step for making lists of publications produced by the two groups was the creation of a list of all scientists belonging to these groups during all or part of the evaluation period. Using official university publications, annual lists of scientists belonging to each group were created. When we have lists of scientists in languages different than English and want to count publications or citations related to them we face, together with synonym and homonym problems the problem of Latin transliterations of scientists' names. As the original lists were in Greek the next step was to find the Latin transliterations of their names. For this purpose a number of sources were used.

Having created of researchers in Latin the next step was the counting of their publications. For this purpose the *Mathematical Reviews* volumes of the period 1975

– 1984 were scanned. In this way publications produced by the two groups during the evaluation period were found. It is difficult to estimate the number of publications lost from using only one large index such as the "Mathematical Reviews" for collection of publications. However, it is certain that much better results are produced this way than by using the *Corporate Index* of the *Science Citation Index*. In fact, use of the *Corporate Index* of *Science Citation Index* – an exclusively used source in other studies – would give only 40% of Patra's and 48% of Ioannina's publications output. In a separate counting journals articles only were allocated to the journals in which they appeared. Lists of this kind were needed for comparisons of actual and expected impact. Allocation of journal articles to journals in which they appeared reveals a number of interesting features of the publication production of the two groups.

1. Articles written by members of the two groups appeared in 116 scientific journals (94 for Ioannina and 47 for Patra's group).

2. From these journals 25 are common for the two groups. This means that despite the fact that the two groups are doing research in the same fields of mathematics they publish their research findings in different journal sets. A separate study would reveal the effect of this fact on bibliometric indicators constructed.

3. Only 30% of the journals in which the two groups published their research findings are included in the Source Index of the *SCI*. This shows that *SCI* covers only a limited number of mathematical literature. When this kind of literature is needed the value of the *SCI* as an information retrieval tool is limited.

When we use figures related to publications we must have in mind that a publication appears in a journal months or even years after its production. This means that publication production of one year is related to research activities of previous years. However, if we assume that this "waiting time" is equal for the two groups we would compare them using publication counts of every year.

The publication output of the two departments during the evaluation period (1975 – 1984) is given in Table 2.

Multi-authored publications were counted proportionally. Where a publications was written by members of a group and "foreigners" a proportion of the publication is given to the group. Trend-analysis of the publication output is presented in Fig. 1.

Table 2
Publication output of the two groups

Department	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Total	Average
Ioannina	6	17	13.5	20.5	23.5	31.3	29.3	35.5	35.5	28.5	240.4	24
Patra	16.3	6.5	12.3	9	13	11.5	4.8	6.3	11.5	9.2	100.4	10

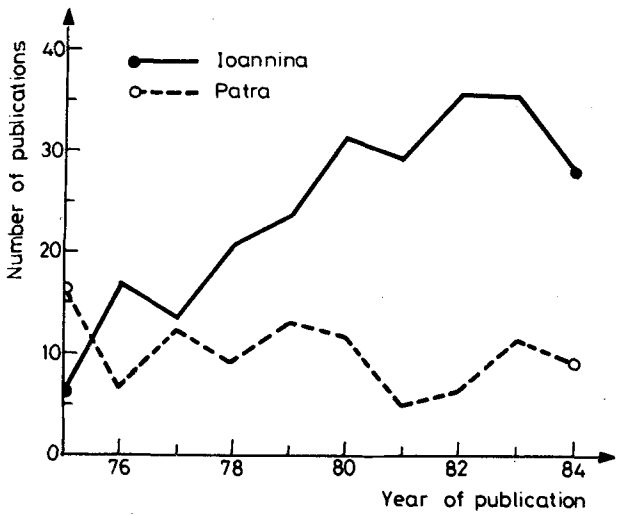

Fig. 1. Trend-analysis of publication output

From Figure 1 we see that the level of research output of the Ioannina group was increasing fairly steadily during the decade, receiving maximum values in 1982 and 1983. Patras' group graph shows a more haphazard behaviour of research publication with a fall in 1981. A separate study with the participation of the scientists under evaluation would reveal the reasons for increase of decrease in publication output. Discovering of these reasons would improve research policy decisions.

Absolute number of publications cannot be used for evaluation purposes if not linked with other factors which affect them. In order to have an estimate of the scientific productivity of each research group the number of publications produced each year was divided by the number of researchers. The results are shown in Table 3.

Table 3
Publications/Scientists (publication productivity)

Department	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Average
Ioannina	0.24	0.55	0.35	0.6	0.57	0.76	0.66	0.82	0.84	0.81	0.62
Patra	0.81	0.26	0.47	0.3	0.46	0.38	0.15	0.21	0.38	0.32	0.37

From Table 3 we see that publication productivity in Ioannina group is higher than Patras' group. With an exception in 1975 they were more productive during the evaluate period. On average they were 68% more productive than Patras' group.

Trend-analysis of publication per scientist ratio of the two groups is shown in Fig. 2.

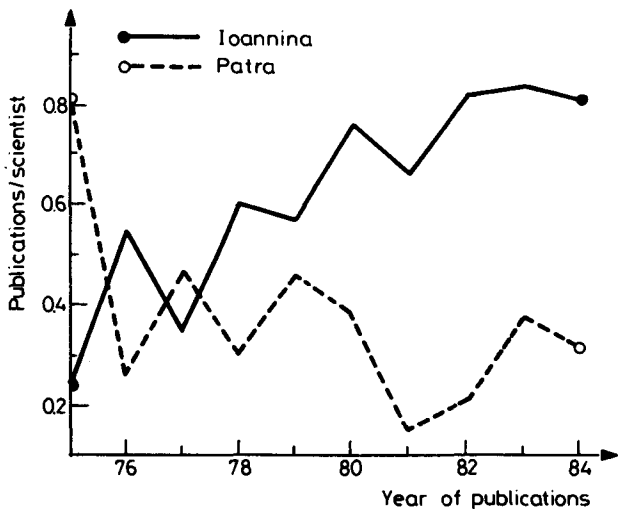

Fig. 2. Trend-analysis of Publications/scientist ratio

Figure 2 shows that in Ioannina group we have a fairly steady increase in productivity while in Patra's we have a decrease with two large falls in 1976 and 1981.

A separate study of these figures may reveal reasons which affect publication productivity and could be used for research policy decisions.

Citation indicators

In order to measure impact produced by the publication output of each group and to estimate the visibility of their research in the international research community a number of citation indicators were constructed. Citation data obtained from the *Science Citation Index*.

Using the names of the scientists, citations received by all their publications appearing in the international mathematical literature until the end of the evaluation period (1984) were collected. In cases where a scientist had left his department during the evaluation period, citations were collected only for publication published until his last year with that department. Citations received by a publication are accumulated some years after its appearance in the literature. For this reason and in order to allow a minimum number of years for receiving citations the last year for citation collection was 1987. Self-and in-house citations were counted separately.

The assumption is that counting all citations we may measure impact and visibility created by publications produced previous to and during the evaluation period. It is assumed that based upon these data comparisons of research performance previous to and during the evaluation period can be done. Citations received during the period 1975 – 1984 by all publication production of the two groups are shown in Table 4.

Trend-analysis of all citations received by the two groups are shown in Fig. 3. A similar analysis only for foreign citations is shown in Fig. 4.

Table 4
Citations received during the period 1975 – 1984 by all previous publication output

Year	Ioannina				Patra			
	"Foreign" cit.	Self-cit.	In-house cit.	Total	Foreign cit.	Self-cit.	In-house cit.	Total
1975	21	13	1	35	40	16	3	59
1976	20	44	5	69	26	7	3	36
1977	69	22	8	99	29	17	6	52
1978	14	7	9	30	16	9	2	27
1979	18	11	15	44	39	24	3	66
1980	40.5	15.5	5	61	34	11	-	45
1981	33.5	30.5	7	71	25	10	-	35
1982	23.5	18.5	12.5	54.5	26	14.8	-	40.8
1983	22	30.5	7.5	60	40.5	7.5	-	48
1984	70.8	42.3	22	135.1	32	19.5	1	52.5
1985	79.5	7.8	5	92.3	34	4	2	40
1986	27.3	8.3	1.5	37.1	25	14	-	39
1987	41	7	6	54	33	11	2	46
Total	480.1	257.4	104.5	842	399.5	164.8	22	586.3
%ages	57%	30.5%	12.5%	$\bar{c}=64$	68%	28%	4%	$\bar{c}=45.1$

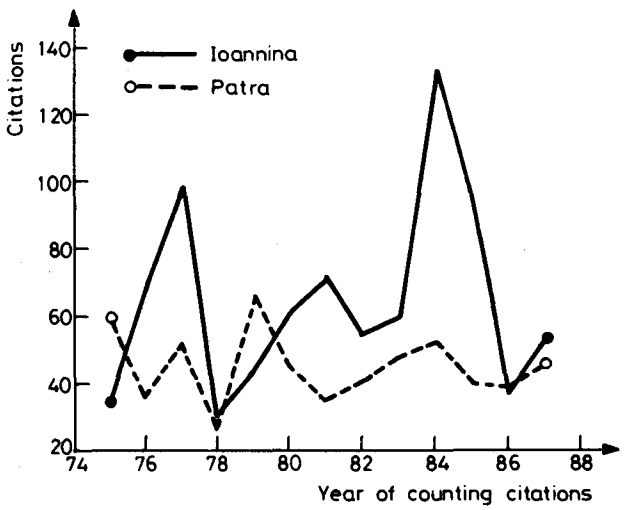

Fig. 3. Trend-analysis of all citations received

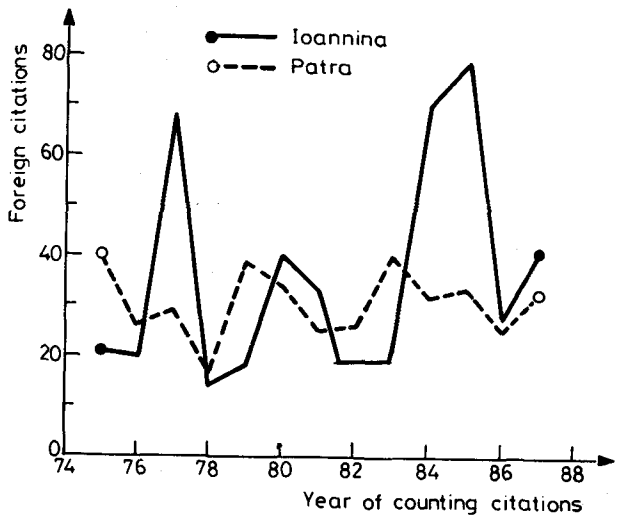

Fig. 4. Trend-analysis of foreign citations received

From Table 4 and Figs 3 and 4 it can be seen that:

1. Patras group has a higher percentage of foreign citations (citations given by scientists outside Patras group) than Ioannina group (68% and 57% respectively). This is an indication that impact and visibility produced by Patras research output are more international than Ioannina's.

2. The low percentage of in-house citation in Patras group (4%) supports the evidence shown in the analysis of collaboration that in Patras group, members work more isolated than Ioannina's group.

3. Patras group shows a more steady level of impact while in Ioannina there are large differences during the evaluation period.

In order to measure impact and visibility produced by publications written during the evaluation period (1975 – 1984) a separate counting of citations was done.

Table 5 shows annual citation counts received by 1975 – 1984 publications.

Table 5
Annual counts of citations received by 1975 – 1984 publications

	Ioannina			Patra		
Counting year	Foreign citations	Self- and in-house citations	Total	Foreign citations	Self- and in-house citations	Total
1975	2	4	6	10	4	14
1976	4	1	5	3	2	5
1977	28	7	35	5	3	8
1978	0	12	12	11	2	13
1979	8	12.5	20.5	10	8	18
1980	28	17.5	45.5	6	3	9
1981	25	18	43	9	5	14
1982	16	27.5	43.5	8.5	2.5	11
1983	21	30.5	51.5	15	4.5	19.5
1984	60.5	38.5	99	28	12	40
1985	50	9.3	59.3	16	0	16
1986	24	9.3	33.3	18	13	31
1987	41	8	49	5	3	8
Total	307.5	195.1	502.6	144.5	62	206.5
Percentages	61%	39%		70%	30%	

Table 5 shows that:

1. Percentages of self- and in-house citations of Ioannina group are higher than Patras group (39% and 30% respectively).

2. Citations received by publications produced during the evaluation period as percentages of citations given to all previous publications are 35% for Patra's group and 60% for Ioannina group. These figures show that Patra's group impact was decreased rapidly during the evaluation period. If we take into consideration the obsolescence of the literature with time the situation seems more important.

3. It is of note that a number of "old" publication in Patra's group continue to accumulate citations many years after their appearance. An in-depth examination of these figures found that one publication published in 1972 by a member of Patra's group received almost 30% of all foreign citations received during the evaluation period by all group. Even in 1987 this publication received seven foreign citations. For mathematical literature these figures are remarkable. The fact that one scientist had produced a so highly influential work shows that impact produced by the rest of

the publication output of Patra's group was very modest. There is nothing comparable to this in the Ioannina group.

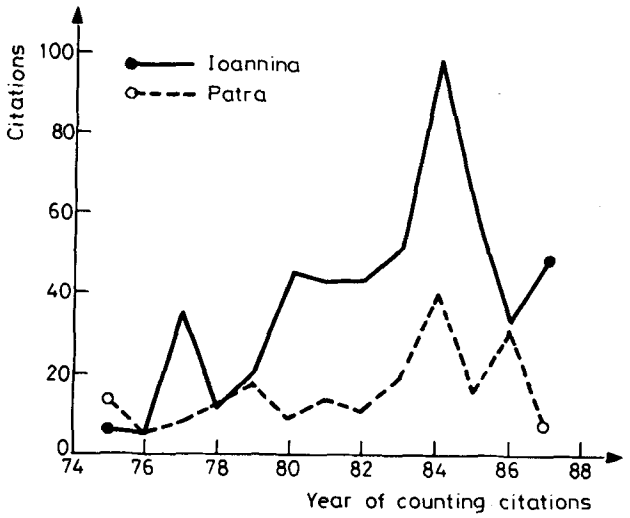

Fig. 5. Trend-analysis of citation given to 1975-1984 publications (All citations)

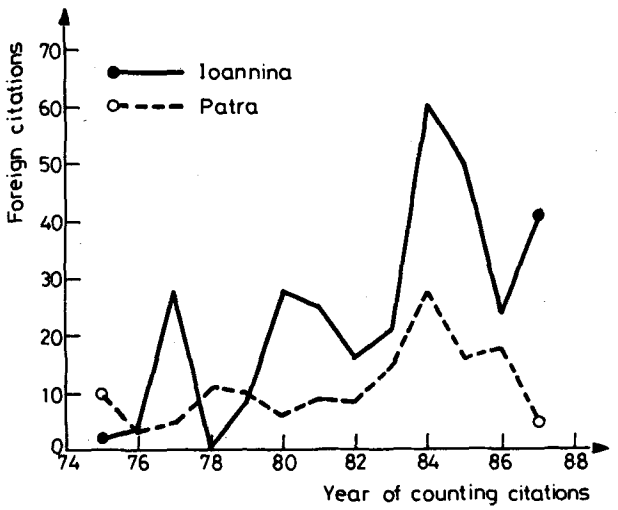

Fig. 6. Trend-analysis of citations given to 1975-1984 publications (Foreign citations)

In cases where citation rates of a publication are very high a separate intellectual examination is needed, in order to discover the reasons for this. Trend analysis of

citations received by 1975-1984 publications is shown in Figs 5 and 6. Figure 5 shows trends of all citations received by 1975 – 1984 publications while Fig. 6 shows trends for foreign citations only.

From Figures 5 and 6 we see that numbers of citations given to Ioannina and Patra publication output are increasing almost steadily during the evaluation period receiving their maximum value in 1984. In foreign citations Patra's group shows a better increasing tendency than Ioannina's group which in 1978 did not receive foreign citations.

In order to measure impact produced by each year's publication output a separate counting of citations was done. In this citations given to 1975 – 1984 publications were allocated to the publication output of each year. Results of this counting are shown in Table 6.

Table 6
Citations received by publications produced in the corresponding year

	Ioannina			Patra		
Publication year	Foreign citations	Self- and in-house citations	Total	Foreign citations	Self- and in-house citations	Total
1975	38	13	51	39.5	12	51.5
1976	23	17	40	2	3	5
1977	16	17.5	33.5	33	8	41
1978	62	34.5	96.5	9	8	17
1979	47	33	80	26	5.5	31.5
1980	39.5	31	70.5	17	11	28
1981	28	16	44	-	4.5	4.5
1982	25	14.5	39.5	9	2	11
1983	17	10.6	27.6	6	2	8
1984	12	8	20	3	6	9
Total	307.5	195.1	502.6	144.5	62	206.5

Trend analyses of Table 6 data (all and foreign citations) are shown in Figs 7 and 8.

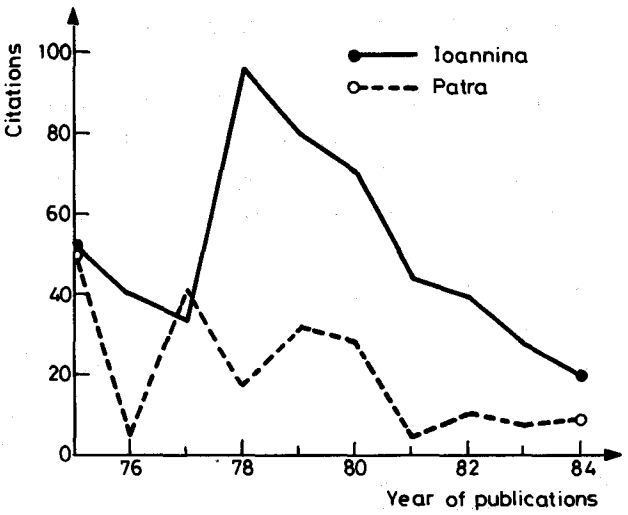

Fig. 7. Trend-analysis of citations given to publication output of the corresponding year

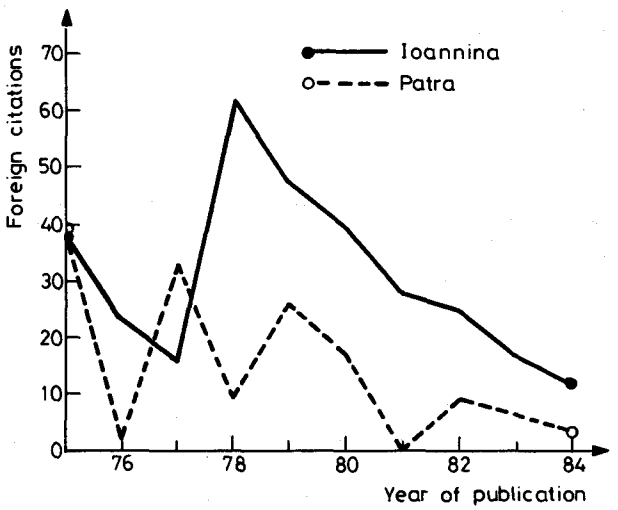

Fig. 8. Trend-analysis of foreign citations given to publication output of the corresponding year

From Table 6 and Figs 7 and 8 we see that Ioannina's publication output produced in 1978 received the largest numbers of citations and Patra's in 1975 and 1977. This is an indication that publications produced during these years were more influential than that of other years. It is of note that Figs 8 and 9 are almost identical.

This may show a normal distribution of citation data during the evaluation period and that only one graph may reveal trends in impact produced. Research on this could show that for trend-analysis of impact separate counting of self- and in-house citations is not necessary.

Conclusions based on absolute numbers of citations only are meaningful or misleading if they are not related to the numbers of scientists or publications which received these citations. In Table 7 annual achievements of citations given to all previous research, to the number of scientists are shown.

Table 7
(Citations received by all previous publications)/scientists.

Department	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Average
Ioannina	1.4	2.2	2.6	0.9	1	1.5	1.6	1.27	1.42	3.86	1.77
Patra	2.95	1.44	2	0.93	2.35	1.5	1.13	1.36	1.6	1.8	1.7

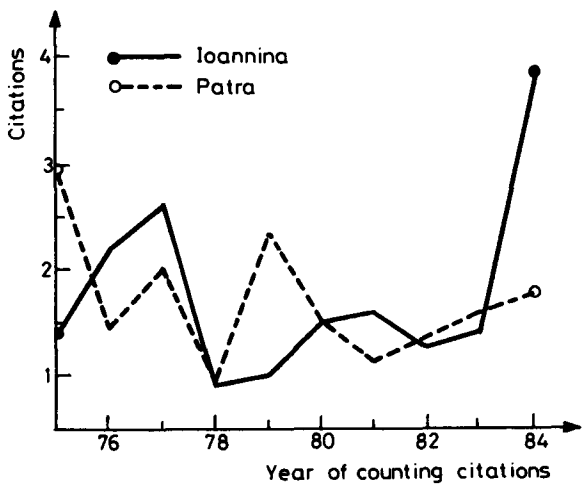

Fig. 9. Trend-analysis of citations/scientist (All previous publications)

Figure 9 shows trends of this indicator during the ten years evaluation period. From Table 7 we see that "citation productivity" are on average equal for the two groups. However for 1984 Ionnina's group show a remarkable increase.

As shown in Table 8 and Fig. 10 the data are different when we calculate the ratio of citations received by publications written during the evaluation period, to the number of scientists.

Table 8
(Citations received by 1975 - 1984 publications)/scientist (All citations)

Department	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Average
Ioannina	0.24	0.16	0.92	0.35	0.5	1.1	0.98	1	1.18	2.8	0.9
Patra	0.7	0.2	0.3	0.45	0.64	0.27	0.39	0.33	0.58	1.35	0.5

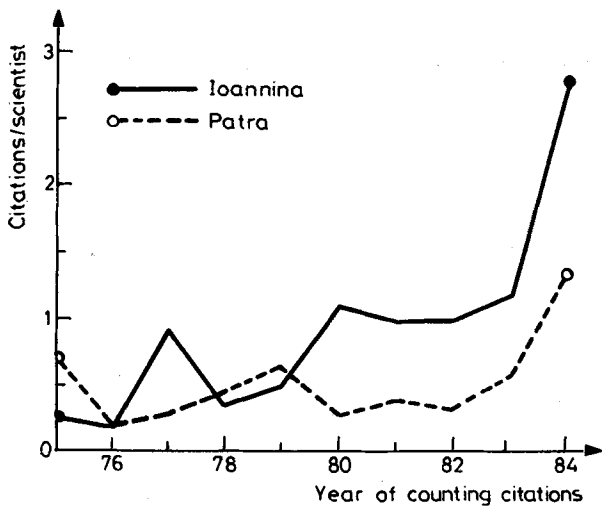

Fig. 10. Trend-analysis of citations/scientist (Citations given to 1975-1984 publications)

Table 8 shows that publications written during the evaluation period by Ioannina's scientists received on average 80% more citations than Patra's group. In these citation figures self- and in-house citations were included. Figures for foreign citations only are shown in Table 9 and Fig. 11.

Table 9
(Citations received by 1975 – 1984 publications)/scientists (Foreign citations)

Department	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Average
Ioannina	0.02	0.13	0.74	-	0.2	0.7	0.57	0.4	0.5	1.7	0.5
Patra	0.5	0.12	0.2	0.4	0.36	0.2	0.3	0.3	0.5	1	0.4

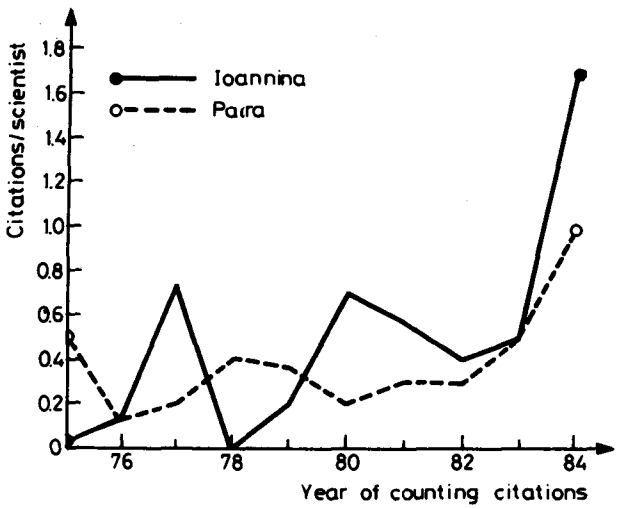

Fig. 11. Trend-analysis of citations/scientist (Foreign citations given to 1975-1984 publications)

From Table 9 we see that scientists from Ioannina's group received on average more foreign citations per scientist (0.5) than Patra's group (0.4). However, Fig. 11 shows that Patra's group produces a "standard" level of impact while Ioannina has years with high and low impact.

Tables 10 and 11 show impact allocated to annual publication output of each department.

From Tables 10 and 11 we see that in 1975 the two groups received high rations of citations per publication. This is something expected as these publications were the "oldest" collected and accumulated citations for more years than others.

Table 10
Citations/Annual publication output (All citations)

Department	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Average
Ioannina	8.5	2.35	2.5	4.7	3.4	2.25	1.5	1.11	0.78	0.7	2.8
Patra	3.16	0.77	3.3	1.9	2.4	2.43	0.93	0.3	0.7	0.98	1.7

Table 11
Citations/Annual publication Output (Foreign citations)

Department	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Average
Ioannina	6.3	1.13	1.18	3	2	1.26	0.95	0.7	0.48	0.42	1.74
Patra	2.4	0.3	2.7	1	2	1.48	-	1.43	0.52	0.32	1.2

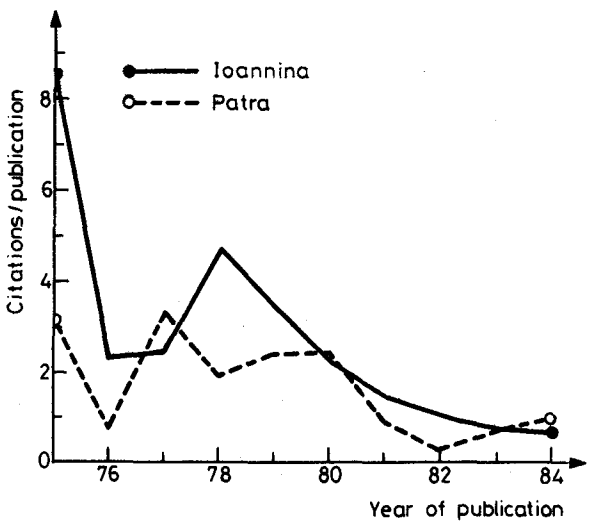

Fig. 12. Trend-analysis of citations/publication (All citations given to annual publication output)

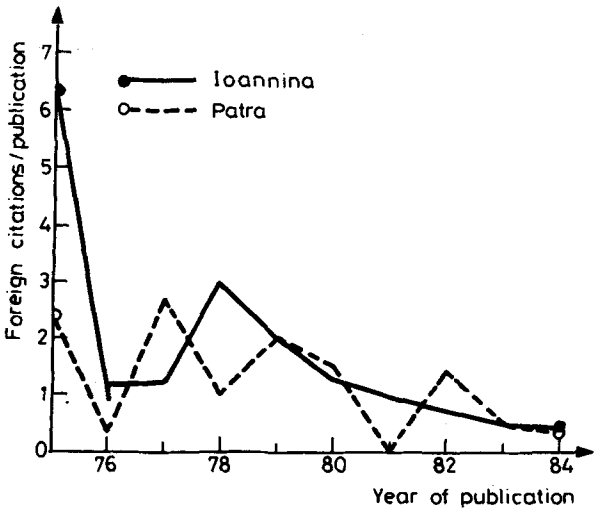

Fig. 13. Trend-analysis of foreign citations/publication (Foreign citations given to annual publication output)

However the fact that there is large differences from the ratio of the next year (1976) shows that inherent "quality" of 1975 publication output played an importance role. Publications produced by Ioannina's group had greater impact than Patra's (on average 64% – greater if we count all citations). When we measure impact using only foreign citations we see that Ioannina's publications produced on average 45% greater impact. Trend-analysis of citations/publications is shown in Figs 12 and 13.

From Figures 12 and 13 we see that for Ioannina's group the most influential publications produced in 1975 and 1977 while for Patra's group in 1975 and 1977.

If we want to discover the position of a research group in the international research community we must compare it with all similar groups working in the same research field. It is evident that this is impossible because of lack of data and the many factors which affect research performance. For this reason only an approximate procedure can be used. The only existed methodology which aims to find the international position of a research group is the procedure of comparing "expected" and "actual" impact of the Leiden methodology.

Expected impact is calculated using the formula:

$$\overline{JCS}_x = \sum_{i=1}^{n} n_i J_i \; / \; \sum_{i=1}^{n} n_i$$

n_i – number of articles appeared in journal i,
J_i – impact factor of the journal i,
n – number of journals in which the group published during the year x.

Actual impact is found using the formula:

$$Al_x = \sum_{i=1}^{n} C_i \ / n$$

C_i – citations received by articles appeared in journal i in the third year of their existence e.g. If a publication appeared in 1978 we count citations received by it in 1980,

n – number of articles appeared in the set of journals used for the estimation of the "expected impact" of the year x.

Science Citation Index (*SCI*) gives impact factors only for some of the journals in which the two groups published during the evaluation period. As a result only these journals were used for calculations of "expected" and "actual" impact. This fact together with the theoretical problems we face whenever we use impact factors call for careful use of results found using this methodology.

For the two groups values of expected impact are shown in Table 12.

Table 12
Ecpected impact produced by the publication output of the two groups

Department	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Ioannina	0.4	0.41	0.26	0.4	0.3	0.34	0.38	0.33	0.32	0.5
Patra	0.3	0.7	0.2	0.32	0.3	0.5	0.33	0.43	0.37	0.47

"Actual impact" produced by the publication output of the two groups is shown in Table 13.

Table 13
Actual impact produced by the publication output of the two groups

Department	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Average
Ioannina	2.7	0	0.27	0.8	0.9	0.17	0.33	0.9	0.35	0.1	0.652
Patra	1.09	0	0	0	0	0	0.3	1	0.2	0.75	0.334

Using data from Tables 12 and 13 trend-analysis of "expected" and "actual" impact for each group may be done. This is shown in Figs 14 and 15.

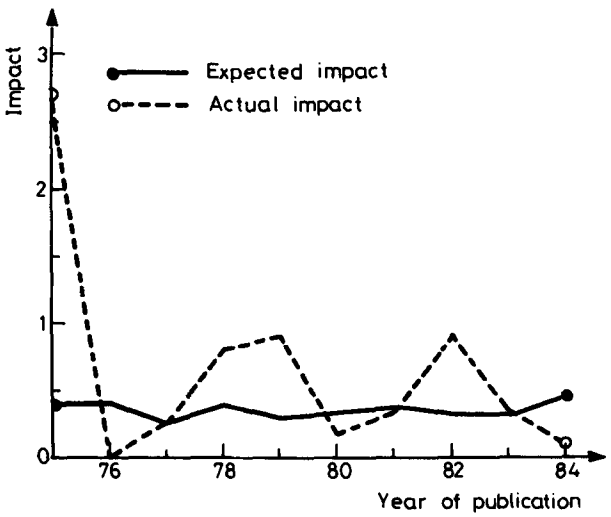

Fig. 14. Trend-analysis of actual and expected impact produced by Ioannina group publication output

Figure 14 shows that the "actual impact" of Ioannina's group publication output was higher than the "expected" in four years (1975, 1978, 1979 and 1982), equal in three years (1977, 1981, 1983) and lower in two years (1976, 1980). On average, during the evaluation period, "actual impact" produced by the publication output of Ioannina's group was 1.3 times higher than the expected. Having in mind all limitations inherent in an analysis like this we may conclude that the publication output of Ioannina's group achieved high impact during the evaluation period.

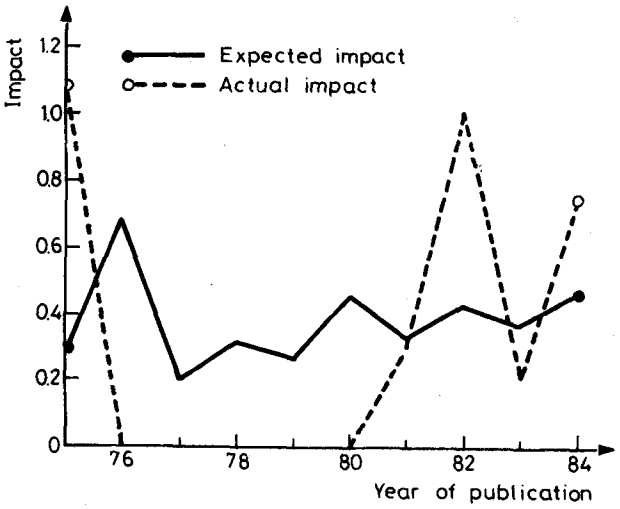

Fig. 15. Trend-analysis of actual and expected impact produced by Patra group publication output

From Figure 16 we see that Patra's group publication output achieved impact higher than the "expected" in three years (1975, 1982, 1984), equal in one (1981) and lower in six (1976, 1977, 1978, 1980, 1981, 1983). On average "actual impact" of Patra's group was lower than the "expected".

Research collaboration

Bibliometric data reveal interesting information on the nature research performed by a research group. Today's big science is characterized by a large degree of collaboration amongst scientists. Study of these collaborations may show the local or international character of connections between scientists and the degree of "openness" or "closeness" of their research. It is assumed that groups with a large number of publications written by members of a group and "foreign" scientists are more open than groups with low collaborative scores. Results of a study of the collaborations in the two groups concerned are shown in Tables 14 and 15.

Table 14
Collaborations in publication output

Department	Two-authored publications	Three-authored publications	Six-authored publications	Total	Percentage of publication output
Ioannina	90	34	1	125	52%
Patra	39	10	-	49	48.8%

Table 15
Analysis of collaborations

Department	"Foreign"	"In-house"
Ioannina	43 (34.4%)	82 (65.6%)
Patra	39 (79.5%)	10 (20.5%)

From Table 14 we see that collaborative publications form a large percentage of the total publication output of the two groups. These percentage are 52% for Ioannina and 48.8% for Patra's group. If we treat these publication counts as random samples of mathematical literature we may conclude that today almost half of mathematical research is the results of collaborations or two or more scientist. This fact justifies the need for proportional allocation of publications or citations to each co-author. Another interesting situation is revealed from Table 15. The Ioannina researchers tend to collaborate "locally" (65.6% of all collaborations) while the group at Patra collaborated more "internationally" (79.5% of all collaborations). It is believed that further investigation of the level and nature of these collaborations may reveal interesting aspects of the communication practices in these two groups.

Conclusions

From the bibliometric indicators used in this study we may conclude that:

1. The higher number of scientists involved in research in Ioannina's group together with higher number of publications produced shows that scientific activity is greater in Ioannina.

2. Publication productivity, namely number of publications produced per scientists is higher in Ioannina's group.

3. Impact and visibility produced by all publication output of Patra's group are more international than Ioannina's.

4. Members of Patra's group do not make research in similar fields of mathematics. In contrast in Ioannina's group many scientists follow research findings of other members of their group.

5. Impact produced by all publication output of Patra's group was more steady during the evaluation period.

6. Publications produced during the evaluation period (1975 – 1984) by Patra's group created less impact than publications produced previous to the evaluation period.

7. Publications written by members of Patra's group created very high impact and visibility.

8. Publications produced in 1978 by the Ioannina and in 1975 and 1977 by Patra's group were the more influential during the evaluation period.

9. Citation productivity, namely citations per scientist are almost equal for the two groups when citations received by all previous research are used.

10. Citation productivity based on citations given to 1975 – 1984 publications is greater for Ioannina's group.

11. For both groups publications written in 1975 created the greatest impact and visibility.

12. Foreign impact, namely impact shown in foreign citations, produced by 1975 – 1987 publications is greater in the Ioannina group.

13. Impact produced by each publication produced during the evaluation period of the Ioannina group was greater than Patra's.

14. Scientists in the Ioannina group collaborate locally (with members of their department) while members of Patra's group were more international (with scientists outside their department).

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