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Publication Pattern of scientists of Physical Research Laboratory (PRL), Ahmedabad, India

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Publication Pattern of scientists of Physical Research

Laboratory (PRL), Ahmedabad, India

1. Introduction

The knowledge and processing of research results regarding any scientific area are a basic input to the evaluation of the research activities. Derek de Sola Price (1963) was the first one to discern a pattern in publications and elaborated it in his most influential work 'Little Science Big Science'. This book describes the exponential growth of the scholarly literature and scientific manpower. It covers various aspects of the productivity of scientists like authorship pattern, collaboration pattern, preference of a journal for publishing their results, etc.

Seventies and eighties saw the rise in quantitative methods being devised and used to supplement the standard approach of peer review to evaluate research. One such method is bibliometrics. Roots of bibliometrics can be traced back to 1917 wherein Cole & Eales analyzed publications in comparative anatomy published between 1543 and 1860 by simply counting number of titles, both books and journal articles and grouping them by country. In 1923 Hulme published an analysis of the international catalogue of scientific literature for the year 1901 through 1913. Bibliometrics took a quantum jump through the works of Eugene Garfield (1955) and Price (1963). However, it was not until 1969 that the term bibliometrics first appeared in print (Pritchard, 1969). He defined bibliometrics as “the application of mathematics and statistical method to books and other media of communication”. Bibliometrics is thus a measuring technique by which inter-connected aspects of written communication can be quantified. In the same year Robert A Fairthorne published a classic article “Empirical hyperbolic distributions (Bradford-Zipf-Mandelbrot) for bibliometric description and prediction” in which he used the term 'bibliometric' and also acknowledged that Pritchard was the donor of this term.

2. Review of Literature

Chu Keong Lee (2003) carried out a bibliometric study of Institute of Molecular and Cellular Biology (IMCB) as lot of funds had gone into building up this institute. It was set up in 1987 at the National University of Singapore (NUS). In its first 10 years, the IMCB produced 395 research papers, 33 book chapters, 24 conference papers and 4 monographs. The research papers were published in journals of increasing impact factor, resulting in increased visibility for the IMCB. The articles received 25 to 35 citations per article. Four of its articles received more than 200 citations. IMCB contributed 46 PhDs and 14 MScs to the research force in Singapore.

Many such bibliometric and scientometric studies have been carried out in India too. These studies have helped in identifying India's publications growth rate which has been

relatively much faster in recent years. Gupta & Dhavan (2006) found that publication output in S & T, as compared to 2.51% annually during 1985-2005, has almost doubled to 5.4% annually during 1995-2005. India's publications as indexed in Web of Science (WoS) have grown from 14,405 papers in 1990 to 28,603 papers in 2005. The institutional participation in research has broadened from 1,734 institutions in 1985-86 to 3,443 in 2001-02. However, there were only 24 institutions which published 300 or more papers during 1985-86 or 2001-02.

In one other study, using the Science Citation Index, Virk (2004) has surveyed the scientific research in India vis-à-vis global trends. This study reveals that during the 1980s, India occupied the 8th position among top 20 nations of the world, in scientific research and during the 1990s, India came down in rank to the 12th position, after Italy, Holland, Spain and Australia with only one tenth of the scientific manpower available to them compared to that in India. It clearly shows that our per capita productivity is much lower compared with that of Europeans, not to mention that of Americans and Japanese who are far ahead. With continuing decline in scientific research, India is now out of top 20 nations. Compared to India, scientific productivity of China and South Korea has increased immensely.

The above studies clearly suggest that bibliometrics is increasingly being used as a tool for a critical assessment of research output of countries, specific subject disciplines as well as single institutes. All significant compilations of research indicators depend heavily on publication and citation statistics.

3. Statement of the Problem

The quantifying methods employed in a bibliometric study yield a fairly good idea about an institute's contribution in the national scientific output. Therefore, universities and institutes where a lot of funds are being allocated to the research activities are expected to assess the research output of their scientists. Physical Research Laboratory (henceforth mentioned as PRL) is one such institute of national repute and is being funded by Department of Space (Government of India). However, a bibliometric study measuring its research output has not been carried out yet.

The present study is a step in that direction and it tries to find the publication pattern of PRL scientists. PRL, established by Dr Vikram Sarabhai way back in 1947, is the cradle of Space Sciences in India. As a unit of the Department of Space, it carries out fundamental research in Astronomy & Astrophysics, Geosciences, Planetary Sciences, Solar Physics, Space and Atmospheric Sciences and Theoretical Physics. For the present study, the record of papers - published in journals and conference proceedings - and invited talks delivered have been used to study the publication pattern. The source for this data is the Annual Reports of the institute for the period of 1997-2006.

The findings of the study will help in identifying the future direction of research. It will be useful and relevant to the S & T policy makers in general and PRL Management in particular. The improved understanding will help in consolidating lines of research, exploring new approaches or beginning collaboration on a national or international scale.

4. Objectives of the study

Several investigators have conducted bibliometric analysis of research productivity of different countries in the world. Comparisons between research outputs in different subject fields are limited because of the different methodologies used and the impact of geographic and population characteristics on the research output. A few studies have also been carried out to assess the productivity and impact of a single institute. As no bibliometric study on PRL has been done before, the researcher thought it appropriate to carry out the study for her doctoral research with the following objectives:

1. To study the publication pattern of PRL research publications
2. To study the productivity of scientists in PRL
3. To determine whether it conforms to the Lotka's Law

5. Research Method used and Scope of the study

To arrive at an appropriate method for the present study, the researcher made a detailed study of the research methods/strategies commonly used.

Robson (2002) has divided the type of research studies by research purpose as well as by methods used. a) Research type by research purpose – Exploratory, Descriptive and Explanatory b) Research type by research method used – Historical, Comparative, Experimental, Case study, Survey and Archival.

Each of the research methods can be used for exploratory, descriptive or explanatory research. It should be remembered that these methods are not mutually exclusive. For example, it is quite possible to use the survey method as a part of a case study.

The present study is a bibliometric study of one organization. According to Lancaster (1991) the tools used in bibliometric studies are : i) citation and reference analysis ii) document and content analysis iii) user studies and iv) circulation statistics. The present study uses the publication data of articles published in journals, conference proceedings and invited talks delivered by the PRL scientists during the period 1997-2006.

6. Data Collection

Data for the study (papers published in journals and conference proceedings and invited talks delivered) was collected from the Annual Reports of PRL from 1997-98 to 2006-07. For papers in journals, the record consisted of names of the authors, name of the division, and name of the journal, whether it is national or international, whether it has single author, double author or multi authors, whether the collaboration is international, national or domestic and the year of publication. For conference proceedings, data consisted of names of authors, name of the division, whether it has single author, double author or multi author, whether the conference was national or international, whether the collaboration was international, national or domestic and year of the conference. For Invited talks, the record consisted of name of the speaker, location of the talk – India or abroad and the year. Thus, such record was made for all the three components of the research output for all the years. This data was used to find the publication pattern of PRL scientists.

Excel software was used to enter the records of each year. Each record consisted of the name of the author/s of the article published, name of the journal, double/multi/single author (D/M/S), international/national journal (JI/JN), international/national/local collaboration (CI/CN/P), division of the author and year of publication. Each category of this data was counted and sorted in descending order of number of times it appears in each year. Each year's data was then combined and computed in similar manner. The authorship pattern (D/M/S), collaboration pattern (CI/CN/CP), pattern of papers in international/national journals (JI/JN), international/national conference proceedings (CPI/CPN) and invited talks delivered (TI/TN) were identified by carrying out similar computation.

7. Research output of PRL

The present study was undertaken to identify the publication pattern of one institute – PRL. The period of study is 10 years. The publication data has been gathered for the years 1997 through 2006. The research output in this period measured in terms of papers published and invited talks delivered consists of 2,518 records out of which 1,318 papers have been published in journals, 436 are published in conference proceedings and 764 are invited talks. This macro data is presented in Table 1.

Table 1 : Research output of PRL during 1997-2006

Year	Papers in Jnls	Papers in Conf. Pr.	Invited Talks	Total
1997	121	40	73	234
1998	140	60	65	265
1999	158	37	74	269
2000	142	30	76	248
2001	114	25	64	203
2002	142	84	58	284
2003	132	45	72	249
2004	122	34	107	263
2005	113	50	78	241
2006	134	31	97	262
Total	1318	436	764	2518

The above macro data is further analysed at micro level to give an idea about the **publication pattern** in terms of indicators such as authorship and collaboration in papers published in journals and conference proceedings, papers published as chapter of a book or in national / international journal, papers contributed in conferences held in India or abroad and invited talks delivered in India or abroad. For ease of understanding, the total number of publications for each indicator is represented first and then the pattern over 10 years is shown.

Tables 2-5 cover the authorship in journals and conference proceedings, Tables 1.6-1.9 cover the collaboration in journals and conference proceedings, Tables 1.10-1.15 cover the publication in national / international journals, national / international conference proceedings and national / international invited talks respectively. Last table gives the list of most preferred journals for publication of PRL scientists.

7.1 Authorship Pattern

Table 2 gives the overall picture of authorship during 1997-2006 for the research papers published in journals. It indicates that number of multiple and double authored papers far outweigh the single authored papers. This result is cognizant with the world pattern and confirms many earlier studies. Out of 1318 papers published in journals, 741 (56.22%) papers are multi-authored (M) and 404 (30.65%) are double authored (D) papers and 173 (13.13%) are single authored (S) papers. It can be inferred from this result that team effort in research has become integral part of PRL research.

Table 2: Authorship Pattern in Journals during 1997-2006

Authorship	Papers	%
Double authors	404	30.65
Multi authors	741	56.22
Single author	173	13.13
Total	1318	100.00

Table 3 shows the pattern of double authored (D), multi-authored (M) and single authored (S) papers in conference proceedings. Here again, similar scenario emerges, with multi-authored papers far out numbering the double and single authored papers.

Table 3 : Authorship Pattern in Conference Proceedings during 1997-2006

Authorship	Papers	%
Double authors	117	26.83
Multi authors	197	45.18
Single author	122	27.98
Total	436	100.00

Comparing the data of papers in journals and conference proceedings, overall proportion of multi-authored and double authored papers are more in journals than in conference proceedings, while single authored papers are more in conference proceedings. High percentage of multi-authored and double authored papers in journals is in accordance with the world pattern and can be attributed to the fact that double and multi-authored papers are generally cited more than single authored papers (Lancaster, 1991).

Table 4 gives the year wise authorship pattern of papers published in journals through the years 1997 to 2006. Double authored and multi authored papers have increased during the years 1997-2006, on the other hand single authored papers have decreased over the years. Years 2000 and 2006 saw maximum number of multi-authored papers. A sharp decrease is seen in number of single authored papers from 2000 onwards. The reason for this could be that internet and email made it very easy for scientists to share and communicate and make changes in the manuscripts. Geographical location was not a hindrance anymore and hence more number of papers were generated which were either double authored or multi-authored.

Table 4 : Year wise Authorship Pattern in Journals from 1997-2006

Year	D	M	S	Total
1997	29	68	24	121
1998	53	67	20	140
1999	51	77	30	158
2000	34	89	19	142
2001	28	69	17	114
2002	56	71	15	142
2003	50	72	10	132
2004	32	76	14	122
2005	37	65	11	113
2006	34	87	13	134
Total	404	741	173	1318

Table 5 shows the authorship pattern in papers published in conference proceedings from 1997 through 2006. Out of 436 papers, 197 papers are multi-authored papers followed by double authored and single authored papers. The year 2002 saw maximum number of papers in all three categories of papers.

Table 5 : Year wise Authorship Pattern in Conference Proceedings from 1997-2006

Year	D	M	S	Total
1997	4	20	16	40
1998	13	26	21	60
1999	11	18	8	37
2000	7	11	12	30
2001	4	13	8	25
2002	25	41	18	84
2003	14	21	10	45
2004	18	9	7	34
2005	14	24	12	50
2006	7	14	10	31
Total	117	197	122	436

7.2 Collaboration Pattern

Table 6 below gives a graphical representation of the collaborative papers published in journals at PRL during 1997-2006. As seen from the table there are 596 (45.22%) papers

with collaboration within PRL (CP) i.e. all the authors of a paper are affiliated to PRL, 411 (31.18%) papers with international collaboration (CI) and 311 (23.60%) papers with national collaboration (CN). The result shows that there is healthy culture of collaboration within PRL.

Table 6 : Types of Collaborative Papers in Journals during 1997-2006

Collaboration	Papers	%
CI	411	31.18
CN	311	23.60
CP	596	45.22
Total	1318	100

Table 7 below gives an indication of collaborative papers published in conference proceedings. In this case, national collaborative papers (CN) are more than international collaborative (CI) papers. The reason could be that funding is available for national conferences but it is more difficult for international conferences. The domestic collaborative papers (CP) are in much higher proportion (69%) than national or international collaborative papers.

Table 7 : Types of Collaborative Papers in Conference Proceedings during 1997-2006

Collaboration	Papers	%
CI	45	10.32
CN	93	21.33
CP	298	68.35
Total	436	100.00

Comparing the data of collaborative papers in journals and conference proceedings, it is seen that international collaboration is higher in journals (31%) than in conference proceedings (10%), national collaboration is almost the same in journals and conference proceedings. Domestic collaboration (CP) is higher in conference proceedings (69%) than in journals (45%).

Table 8 gives year wise pattern of collaboration in papers published in journals from 1997 through 2006. There has been a general increase in international collaborative papers. National collaboration has increased slightly and domestic collaboration (CP) has decreased slightly over the years. Highest number of international collaborative papers (53) published in journals were in the year 2000. National collaboration was highest (37) in 2006.

Table 8 : Year wise Collaboration Pattern in Journals from 1997-2006

Year	CI	CN	CP	Total
1997	29	33	59	121
1998	35	36	69	140
1999	46	23	89	158
2000	53	34	55	142
2001	37	30	47	114
2002	38	26	78	142
2003	48	33	51	132
2004	44	31	47	122
2005	39	28	46	113
2006	42	37	55	134
Total	411	311	596	1318

Table 9 below shows the pattern of collaborative papers in conference proceedings during the years 1997-2006. The year 1997 saw highest number of international collaborative papers (12), while national collaborative papers (19) and PRL collaborative papers (58) were highest in 2002.

Table 9 : Year wise Collaboration Pattern in Conference Proceedings from 1997-2006

Year	CI	CN	CP	Total
1997	12	7	21	40
1998	4	16	40	60
1999	4	3	30	37
2000	4	6	20	30
2001	2	3	20	25
2002	7	19	58	84
2003	5	6	34	45
2004	2	8	24	34
2005	0	17	33	50
2006	5	8	18	31
Total	45	93	298	436

Also, there has been a decrease in the international collaborative papers over the years i.e. there were 12 papers with international collaboration in 1997 and only five papers with international collaboration in 2006. National collaboration has remained at the same level.

In this category too, domestic collaboration has decreased slightly over the years from 21 in 1997 to 18 in 2006.

7.3 Publication Mode

Table 10 gives an overview of publication mode preference of researchers with articles published in national and international journals and as chapter of a book. Almost 80% of the papers are published in international journals. It may be noted that researchers at PRL do not seem to prefer to contribute chapters in books.

Table 10 : Publication Mode Preference during 1997 - 2006

Publication Mode	Papers	%
CB	27	2.05
JI	1051	79.74
JN	240	18.21
Total	1318	100.00

Jacobs (2001) states that most of the scientists in the developed countries are not aware of the research carried out in third world countries. Probably because of the fact that scientists from some of the third world countries fail to publish the results of their research in reputed international journals. However, the result of the present study is contrary to this, as out of 1318 articles published by PRL scientists, 1051 are in international journals (JI) and only 240 are in national journals (JN) and 27 are chapters of a book (CB). Thus, most preferred mode of publication of PRL scientists is international journal.

7.4 Papers in Conference Proceedings – National / International

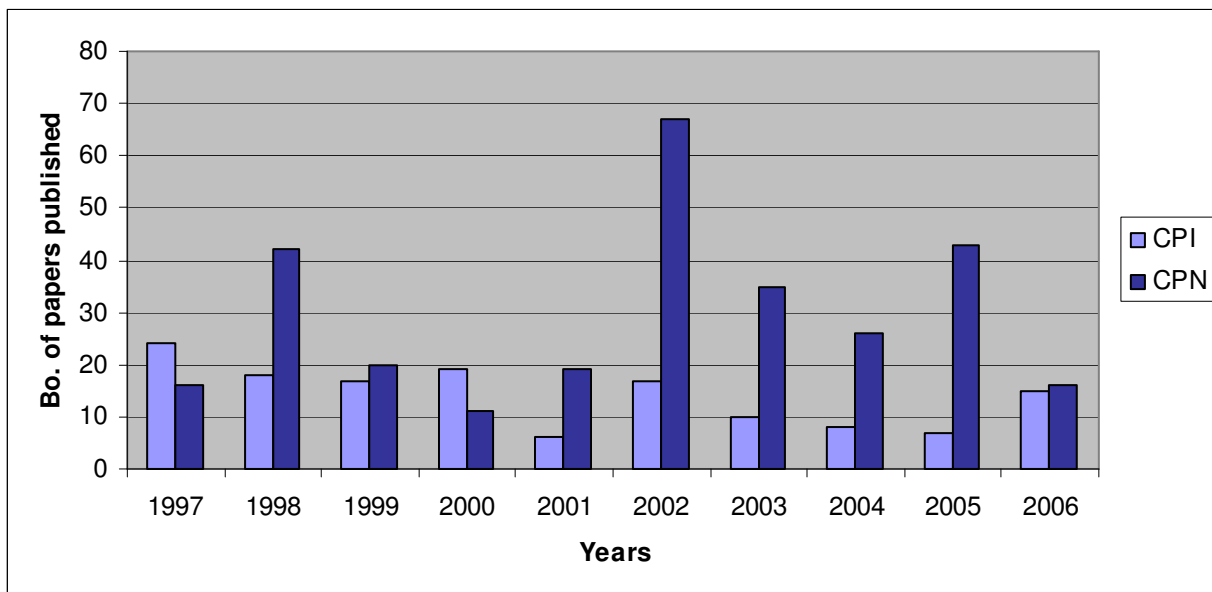
Table 11 give the proportion of papers published in conference proceedings of international and national conferences. Out of a total of 436 papers published in this period, 295 (67.66%) are in the proceedings of conferences held in India and 141 (32.34%) papers were published in the proceedings of conferences held abroad. Less proportion of papers published in international conference proceeding could be attributed to less number of scientists and students attending the international conferences than the national conferences.

Table 11: Papers in Conference Proceedings - National/International during 1997 - 2006

Conference Proceeding	Papers	%
CPI	141	32.34
CPN	295	67.66
Total	436	100.00

Figure below shows the year wise pattern of papers published in conference proceedings by researchers of PRL at international and national level.

Fig 1 : Year wise Pattern of Papers in Conference Proceedings during 1997 - 2006



The above table and figure show that there has been a decrease in number of papers in international conferences' proceedings (CPI) over the years 1997-2006 from 24 in 1997 to 15 in 2006 while almost no change is seen in number of papers in national conference proceedings (CPN).

7.5 Invited Talks delivered – National / International

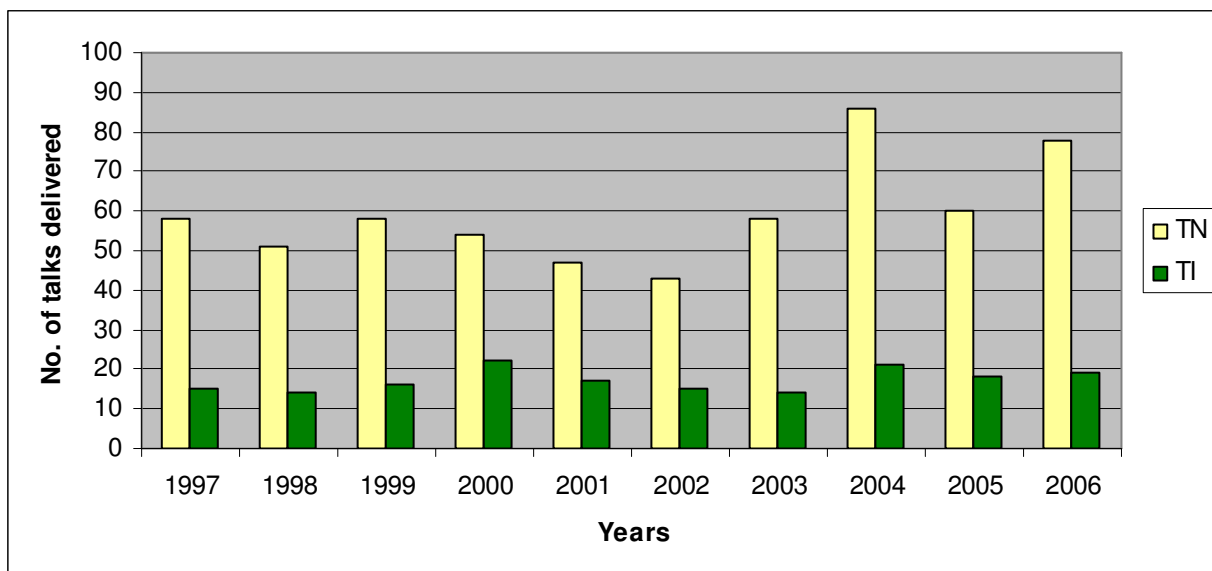
Table 12 and Figure 3 below give the number of invited talks delivered by PRL scientists in India and abroad. Out of 764 invited talks, 593 (77.62 %) were delivered in India (TN) and 171 (22.38%) were delivered abroad (TI).

Table 12 : Invited Talks delivered – National / International during 1997-2006

Invited Talks	No. of Talks	%
TN	593	77.62
TI	171	22.38
Total	764	100.00

Figure 2 gives year wise pattern of invited talks delivered at national and international level during 1997-2006. It is evident from the table that there is an increase in the number of invited talks delivered at national level, particularly since 2002.

Fig 2: Year wise Pattern of Invited Talks – National/International from 1997 to 2006



Note : TN – Invited Talk in India, TI –Invited Talk outside India

The figure above indicates that peer recognition of PRL scientists seems to be on rise in India. However, there is only a marginal increase in number of invited talks delivered abroad during the years 1997-2006.

7.6 Journal Preference for Publication

According to Lancaster (1982) many scientists in developing countries prefer to publish in foreign journals rather than in their native journals for the sake of prestige and recognition. Half of the papers of Indian scientists are published in American journals. It is a matter of pride, if one's paper is accepted in high impact foreign journals like 'Nature' or 'Science'. This is confirmed by the result of the present study. Table 1.16 tells us about the journal preference of PRL scientists. It lists the journal titles which have 20 or more papers published during the 10 year study period. **Physical Review A** tops the list with 83 articles followed by **Current Science** with 68 articles and **Physical Review D** with 50 articles published during 1997-2006 by PRL scientists. Out of the 17 most preferred journals, 4 are Indian – Current Science, Journals of Earth System Science, Pramana, and Bulletin of Astronomical Society of India. All others are international journals of high impact as is seen from the high impact factors. Thus there is clear preference to publish in international journals because it brings recognition.

Table 13 : Most preferred journals for publication during 1997-2006

Journal Name	No of Papers
Physical Review A	83
Current Science	68
Physical Review D	50
Journal of Geophysical Research (ALL)	47
Physics Letters B	41
Astronomy and Astrophysics	37
Solar Physics	37
Journal of Earth System Science	34
Physical Review E	33
Advances in Space Research	30
Geophysical Research Letters	25
Meteoritics and Planetary Science	23
Physical Review Letters	22
Pramana	22
Astrophysical Journal	21
Bulletin of Astronomical Society of India	20
Physics of Plasmas	20

8. Productivity of Scientists

Research output of scientists is affected by many factors such as age, education, status, the subject field and funds available for research. Stephan & Levin (1993) showed that there is evidence that, generally scientists produce less output as they age. They also concluded that age – publishing profiles differ across the subject fields. In physical sciences, peak output is generally produced by the young scientists. The result obtained in one of the studies carried out by Jacobs (2001) showed that there is a significant difference between the numbers of papers published by the scientists with doctorates as compared to those without PhDs. There is also a relationship between the importance of the scientist and the number of papers he/she has published during his/her life. According to Price (1986)

prestige seems to be one of the driving forces that encourages scientists to publish profusely. That is why promotion remains the driving force behind faculty research and publication, as this upgrades the faculty members in status and pay. Pelz & Andrews (1966) showed that teaching and administrative positions taken up as advancement in career facilitate publishing.

Table 14 : Twenty most prolific researchers - for papers published in journals

Division	Author	No. of papers
THE-PH	Agarwal G S.	137
GSDN	Singhvi A. K.	61
THE-PH	Sarkar U	54
GSDN	Ramesh R.	50
GSDN	Bhandari N	46
GSDN	Bhattacharya S. K.	42
THE-PH	Kota V. K. B.	42
SPA-SC	Chandra H.	33
THE-PH	Panigrahi P. K.	33
AAD	Ashok N. M.	31
THE-PH	Rao N. N.	31
THE-PH	Rindani S. D.	31
THE-PH	Joshiyura A. S.	30
SPA-SC	Lal S.	30
GSDN	Sarin M. M.	30
SPA-SC	Jayaraman A.	29
GSDN	Gupta S. K.	27
PSDN	Murty S. V. S.	27
THE-PH	Mohanty S.	26
GSDN	Somayajulu B. L. K.	26

Table 14 above gives the list of top 20 researchers who have published more than 25 papers in journals during the years 1996-2007. Prof. G. S. Agarwal, tops this list with 137 papers, followed by Prof. A. K. Singhvi with 61 papers and Prof Utpal Sarkar with 54 papers published in journals.

It is interesting to note that in addition to being such prolific researchers, many of the scientists listed held administrative positions too. Prof. G. S. Agarwal was the Director of PRL from 1996-2005, Prof S K Bhattacharya was the Dean during 2004-07 and Prof A K Singhvi was the dean during 2007-10. Besides these, most of the other scientists also held the position of chairman of their respective division during different years of the study period.

9. Lotka's Law of Scientific Productivity

Having collected the data of research output of PRL scientists, the researcher thought it worth while to check out whether productivity of PRL scientists conforms to the Lotka's Law of Scientific Productivity.

Alfred J Lotka (1926) studied author productivity patterns and developed one of the main laws in bibliometrics. He observed that in a given area of science there are a lot of authors who publish only once, while a small group of prolific authors contribute a large number of publications. This premise is the basis of Lotka's Law also commonly known as the 'inverse square law' for author productivity. This law uses the number of authors contributing one paper as the base number and goes on to predict the number of authors contributing 2, 3, 4, 5, papers and so on using the formula

$$y_x = c * 1/x^2$$

Where y_x is the number of authors contributing x papers and c is the number of authors contributing one paper.

One condition to arrive at a list of prolific authors is to take a time frame such that authors have opportunity to publish more than once. Generally a ten year period is considered to be reasonable. As the period of the present study is also 10 years, the researcher thought it appropriate to look into this aspect of a bibliometric study too. The sample of 1318 articles published in journals was used to see whether the sample follows the Lotka's Law. These 1318 articles have been contributed by 622 authors out of which 333 authors have contributed a single paper in journals during 1997-2006. Using the Lotka's law of productivity, authors contributing two papers would be

$$Y_2 = 333 * 1/2^2$$

$$= 333/4$$

$$= 83$$

In the present study sample there are 75 authors contributing two papers during the 10 year period of study. Similarly, according to Lotka's law there would be 37 authors contributing 3 papers. Actually there are 28 authors contributing 3 papers. Till this point, the present study can be considered to conform to the Lotka's Law. However, for authors contributing 4 papers the actual figure and those derived from the law are too far apart – according to the Lotka's law there should be 21 authors contributing 4 papers while actually there are 40 authors contributing 4 papers. But 5 paper data (15) nearly matches with the Lotka figure of 13 authors contributing 5 papers, number of authors contributing 6 papers is 9 according to Lotka's Law, while actually in the study sample it is 19 authors contributing 6 papers.

Table 15 : Non-conformation of Lotka's Law

No. of papers	Authors (actual)	Authors (Lotka)
1	333	333
2	75	83
3	28	37
4	40	21
5	15	13
6	19	9
7	20	7
8	9	5
9	7	4
10	5	3

The data in the above table indicates that the present study conforms to the Lotka's Law of scientific productivity only partially (up to 3 papers). This could be due to the fact that in the present study, each collaborative author gets the count of one paper instead of giving credit to only the first author or giving proportionate credit according to the number of collaborative authors. A few earlier studies (Gupta, 1987) and (Nwagwu, 2006) also found that Lotka's Law did not hold true in their studies.

10. Major Findings

1. With the advent of Big Science has come research collaboration and collaborative authorship. The foregoing pages indicate that multiple authored and double authored papers are on the rise in PRL, especially from 2000 onwards probably due to ease of contact through emails and ease of writing and editing using the computers and the Internet. In 1961 Price had predicted the disappearance of single authored papers. Fifty years hence, this trend is more than obvious as scholarship becomes interdisciplinary, leading to greater cooperation among individuals and institutions.
2. The research output of PRL in terms of publication record and invited talks summing upto 2518 units gives an average of about 250 research output units per year. Out of these, 1318 papers in journals give an average of about 130 papers published in journals per year. The average number of academic faculty being 60, gives the output of 2.17 papers per academic faculty per year. Comparing the data of collaborative papers in journals and conference proceedings, international collaboration is higher in journals than in conference proceedings. For conference proceedings, national collaborative papers are more than double of international collaborative papers. This indicates that international collaboration needs to be developed. This could be achieved by more scientists attending and presenting their research results in international conferences which would lead to more collaboration. Increased international collaboration would increase the citation rate of PRL papers.
3. The journals most preferred by PRL scientists for publication are **Physical Review A** (83 articles) followed by **Current Science** with 68 articles and **Physical Review D** with 50 articles during 1997-2006 by PRL scientists. Out of the 20 most preferred journals, 4 are Indian – Current Science, Journals of Earth System Science, Pramana, and Bulletin of Astronomical Society of India. All others are international journals of high impact. Thus there is clear preference to publish in international journals because it brings recognition.
4. It is interesting to note that many of the prolific researchers held senior administrative positions too. This confirms the earlier studies carried out by Pelz and Andrews (1976) and Price (1986) that motivation to publish comes from recognition and prestige.
5. The sample of this study does not completely follow the Lotka's Law of scientific productivity probably because of increasing number of papers with double or multiple authors

11 Conclusion

The aim of the present bibliometric study was to discover a better understanding of what is actually taking place in research at PRL. It has fulfilled its objectives of discerning the publication pattern of PRL. The results of the study will help those charged with making difficult choices about allocating the resources. It will also help in taking human resource

decisions as regards the induction of faculty members in different divisions. The researcher is sure that this information will be useful to the institute's decision makers for future research planning. Also, such a study on quantification of research will act as a pointer to other similar R & D institutes when they decide to undertake a study to assess their research output.

12. Areas of Future Research

Going through the various studies during the literature survey, the researcher found that very few bibliometric studies have been carried out in the field of Geosciences and Space Sciences. These would be interesting subject fields to study for the future research. Also, citation analysis of the papers published by the scientists of PRL would help in determining CFY of PRL. PFY (papers per faculty per year) and CFY (citations per faculty per year) are considered to be more objective indicators to assess the impact of any research institute as compared to the total number of papers and total number citations. Comparative study may be undertaken of research institutes in similar research domain.

13. Acknowledgments

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