EVALUATION OF RECENT SCIENTIFIC RESEARCH OUTPUT BY BIBLIOMETRIC METHOD

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ABSTRACT

This paper describes a new method of evaluation of scientific output by laboratories engaged in diverse fields of research. The method used is aiming at evaluating those outputs which are quiet recent and not amenable to citation analysis. For the purpose of analysis, impact factor of journals in which papers are published are considered. A method for normalisation of impact factor of journals has been described and, normalised impact factors have also been used It is found that normalised impact factor tends to show better results compared to simple impact factor. The analysis helps us to generate numerous performance indicators such as average impact factor and normalised impact factor for each laboratory and the research complex such as the Council of Scientific and Industrial Research (CSIR) as a whole; average impact factor and normalised impact factor for each scientist of a laboratory and the research complex; spectral distribution of papers falling within various ranges of impact factors and normalised impact factors. By comparing the performances over several years the trend of research activity of each laboratory can also be obtained.

RESUME

Cet article décrit une nouvelle méthode d'évaluation de la production scientifique de laboratoires actifs dans des domaines de recherche variés. La méthode utilisée a pour but d'évaluer les produits scientifiques récents pour lesquels les analyses de citation se révèleraient inappropriées. Il s'agit d'utiliser le 'facteur d'impact' des revues dans lesquelles les travaux sont publiés. Des facteurs d'impact normalisés ont été mis au point et utilisés. Ces derniers permettent d'obtenir de meilleurs résultats que le facteur d'impact simple. Ce travail a permis de générer de nombreux indicateurs de performance tels que le facteur d'impact moyen et le facteur d'impact normalisé pour chaque laboratoire et pour l'ensemble du Conseil National de la Recherche Scientifique et Industrielle (CSIR); un facteur d'impact moyen et normalisé pour chaque chercheur; une distribution spectrale d'articles scientifiques en fonction de leurs facteurs d'impact simple et normalisé. En comparant les performances sur une période de plusieurs années, la tendance de l'activité scientifique de chaque laboratoire peut également être obtenue.

INTRODUCTION

With the appearance of Science Citation Index (SCI) in 1963, it became possible to judge by the citation scenario, the impact a paper has made in the world. The number of citations received by a paper was more or less clearly depicting its impact. In addition the total impact of the contribution of a scientist was also becoming available from the aforesaid publication purely through the citation count of his papers. It is at this time, 1968 to be precise, when SCI was in its formative stage. Dr. Eugene Garfield, the originator of the publication, drew out a list of 50 most cited scientists of the world (Table 1) using SCI database of 1967 from among about a million scientists and predicted that many a scientist appearing in the list would be crowned with Nobel Prize in future [1].

It is rather amazing that in the year 1969 itself Dr. Garfield's prediction came true through the winning of Nobel Prize by M Gell-Mann in Physics and DHR Barton in Chemistry. From 1969 to 1989, as many as 8 scientists figuring in the list won the Nobel Prize. Several scientists like L Pauling (54 Chem), R S Mullikan (66 Chem),F Jacob (65 Med), L D Landau (62 Phys), and S C Eccles (63 Med) figuring in the list won the Nobel Prize before the prediction, and maybe a few more from the list will be winning the award in future.

As can be guessed from the foregoing paragraph and Table 1, the citations received by a paper not only show its impact, but also its quality. An original contribution attracts more scientists and generates more contributions, whereby the original contribution receives more citations. .Review papers, methods papers and sometimes controversial papers also give rise to copious citations..But these papers are generally identifiable, and can be separated out, if need be.

It is now more or less proven that the quality of a paper can be judged on the basis of citations it has received. Of course, there are certain limitations which are as follows:

i) The method of citation counting does not normally apply in judging the quality of a recent paper.

ii) The method is also not very helpful in determining the quality of a paper belonging to engineering sciences.

iii) Review papers normally receive more citations than research papers, and this phenomenon does not mean that review papers are better in quality than research papers. Review papers and research papers belong to two different categories, and they need not be mixed together while judging the quality of the contributions by a scientist.

BIBLIOMETRIC ANALYSIS OF RECENT PAPERS

There is practically no bibliometric method whereby the quality of recent papers can be judged. In 1987 we encountered this problem when we were asked to bibliometrically analyse the research output of 1986 of CSIR (Council of

Scientific and Industrial Research, India) laboratories numbering about 40 to generate indicators which might be useful for decision making and other purposes.

After considering various probables, it was decided that impact factors of periodicals in which CSIR papers have been published can be used in place of citations for our analysis, since impact factor shows the standing of a periodical in the world which is available from the Journal Citation Report (JCR), an associate publication of SCI database [2]. The impact factor is a measure of the frequency with which the 'average article' in a journal has been cited in a particular year. The JCR impact factor is basically a ratio between citations and citable items published. Thus, the 1986 impact factor of journal X would be calculated by dividing the number of all the SCI, SSCI and A&HCI source journals' 1986 citations of articles journal X published in 1984 and 1985 by the total number of source items it published in 1984 and 1985. For example, Nature published 1,192 and 1,176 citable items in 1984 and 1985 respectively and these items were cited 20,173 and 15,943 times respectively in 1986. Therefore the 1986 impact factor (2) of Nature is given by :

$$\text{If} = \frac{20{,}173 + 15{,}943}{1{,}192 + 1{,}176} = 15{,}525$$

Our basic premise was that the higher the impact factor of a journal the better will be its quality. Of course, this premise may not hold good where the impact factors of journals are very close to one another. As a corollary to our premise it was assumed that a paper published in a high-impact-factor journal will be better in quality than the one published in a low-impact- factor journal. This premise again may not be always true as some good papers at times may get published in low-impact-factor journals. This type of phenomenon is rather uncommon, and as we were taking a comparatively large sample, about 2000 papers, so we thought that one or two such exceptions would not distort our results very much and our premise would work. From our premise it follows that a laboratory which publishes its papers in high- impact-factor journals, is doing good work, since the journals having high impact factors are in most cases rigorously refereed journals, and getting a paper published in those journals is creditworthy. Taking this as the basis of our work, we proceeded in the following way.

Methodology

First, all CSIR laboratories were requested to send a list of their publications of the year, i.e. 1986. Only research papers, short communications, and the like, published in journals were considered for analysis. The papers presented in conferences, seminars, etc. as well as popular and informative papers were all

excluded. Papers published in monographs, patents, research reports were also not considered.

Once we have finally selected the articles for our analysis, we started assigning each paper its impact factor, i.e. the impact factor of the joural in which the paper has been published. It is to be noted that Journal Citation Report is a yearly publication, and it provides impact factors of some 4000 journals selected from all fields of science and technology.

While assigning impact factors to papers, we encountered a formidable problem. Around 50% papers published by CSIR scientists were in such journals as were not covered by JCR. Hence, their impact factors were not available. It was neither possible to ignore the huge number of papers nor any method was known to us whereby we could determine the impact factors of those periodicals. Finding no other alternative, we assigned impact factor to such a periodical arbitrarily keeping in view several factors of the journal like its age, yearly productivity, coverage by abstracting and indexing services and the impact factor of such a journal, which could act as a standard for Indian journals. For example, while assigning the impact factors of general Indian medical periodocals, we always kept in view the impact factor of Indian Journal of Medical Research, which being a SCI covered journal, acted as our standard. We compared other general Indian medical journals with it, and accordingly assigned impact factors taking, of course, other factors also into account as described earlier. Following this method, we assigned the impact factors to all journals not covered by SCI (i.e. non-SCI Journal). This method has since been mostly discarded as we have succeeded to develop a method whereby impact factor of a non-SCI journal can be accurately determined [3]. The impact factor determined by the method is consistent with JCR impact factor.

As can be seen from above, a periodical can have impact factor only when it has completed three years of its age. So, for our analysis, whenever we encountered a periodical aging below three years, 0 (zero) impact factor was assigned to the periodical.

Once assigning of impact factor to each paper was over, the score of a laboratory was determined by totalling the impact factors of all the papers. The exercise helped us to generate the following indicators.

1) Total impact factor of each laboratory (Fig.1)
2) Average impact factor of a paper of each laboratory (Fig.2)
3) Average impact factor of a scientist of each laboratory (Fig.3)
4) Total impact factor of all the laboratories i.e. CSIR impact factor.
5) Average impact factor of a paper of CSIR.

Normalised Impact Factor (NIf)

When we plotted the graph with Total Impact Factor (TIf) of each laboratory (Fig.1) it was found that the TIf of engineering laboratories was coming far

below the TIf of biomedical laboratories. Two factors were found to be responsible for this: first, the engineering laboratories published less number of papers, compared to biomedical and other laboratories, and second, engineering science periodicals, by and large were having very low impact factors, compared to those of the biomedical periodicals. For example, the top research journal on aerospace engineering called AIAA Journal was having If of .520 in 1986, when the top journal on general medicine called New England Journal of Medicine was having If of 17.752. In order to resolve this anomaly we had to think of normalised impact factor (NIf).

In JCR, categorywise list of journals ranked by impact factor is available. The ranked list of journals under each category includes both review and research journals. The If of review periodicals are generally high, sometimes very high, compared to research periodicals. For example, in the subject category Biochemistry and Molecular Biology, the 1988 If of Annual Review of Biochemistry (a review journal) is 48.313, whereas the topmost research journal in the subject category is Cell, whose If 24.212 is almost half of Annual Review of Biochemistry! This particular phenomenon makes the normalisation of impact factor of research periodicals unworkable as the impact factor of the topmost periodical under each subject category is normalised to 10 using a suitable multiplier. In a subject category where there is no review periodical, the normalised impact factor of the topmost periodical is 10, but in majority of the fields where a subject category list contains review periodicals, the normalised impact factor of the topmost research periodical falls below 10, sometimes as below as 5. To avoid this type of situation, normalisation of impact factor is done only with research periodicals. Review periodicals are generally left out.

Procedure of normalisation

For determining the normalised impact factor of a periodical, the following procedure is employed.

NIf (J) = If (J) .X where

NIf (J) is the normalised impact factor of the periodical J
If (J) is the impact factor of the periodical J, and
X is the multiplier

Now, the value of X is determined by putting the value of NIf (J) as 10 as the NIf of the topmost research journal in a subject category is always considered as 10 and the value of the impact factor of the aforesaid journal.

Let us take a concrete example to determine the NIf of a periodical. The If of Indian Journal of Medical Research (IJMR) for the year 1988 is 0.204. IJMR belongs to the subject category Medicine, General and Internal, where New England Journal of Medicine (NEJM) is the topmost research journal having the If 21.148.

So, the value of X for this subject category is

$$X = \frac{10}{\text{If (NEJM)}} = \frac{10}{21.148} = 0.473$$

Hence, the NIf (IJMR) = If (IJMR) . X = 0.204 x 0.473 = 0.10

Indicators with NIf

Assigning NIf to all the papers, we get the following indicators as we got with If.

1) Total normalised impact factor of each laboratory (Fig. 4).
2) Average normalised impact factor of a paper of each laboratory (Fig. 5).
3) Average normalised impact factor of a scientist of each laboratory (Fig.6).
4) Total normalised impact factor of all the laboratories, i.e. CSIR normalised impact factor.
5) Average normalised impact factor of a paper of CSIR.

Average Impact Factor & Average Normalised Impact Factor of a Paper

The number of scientists engaged in research differs from laboratory to laboratory, and the difference at times is very significant. For example, in the Institute of Microbiological Technology, there are only a few scientists, whereas in Central Drug Research Institute, the number goes far beyond 100. The more the number of scientists, the more will be the number of research papers. Hence, with total impact factor or normalised impact factor, comparison of the performance of the laboratories is not possible. But, the same is possible with the average impact factor and average normalised impact factor. The performance of the laboratories in terms of average If and average NIf can be seen from Fig. 7. It can easily be noticed that average NIf of several laboratories have shot up, and of some others come down. On the whole, the graph of average NIf of laboratories have considerably reduced the disparity in the performances of the laboratories. It seems that normalised impact factor helps to generate better indicators when the comparison of performances of laboratories conducting research in very large number of diverse areas of science and technology is done.

Total Impact Factor (TIf) and Total Normalised Impact Factor (TNIf)

The total impact factors and total normalised impact factors of laboratories help in generating such indicators as average If and average NIf of each laboratory, as well as in determining the trend as to the performance of laboratories over the years.

Average Impact Factor and Average Normalised Impact Factor of a Scientist

This helps to generate indicators as to the productivity per scientist of a laboratory or a group of laboratories pertaining to a broad discipline like Chemical Sciences or Life Sciences, or a big research complex like CSIR.

Total Impact Factor of all laboratories and their average Impact Factor

These help us to study the trend as to the performance of the laboratories taken together over a period of years. It may be pointed out that the average impact factor and normalised impact factor of CSIR laboratories as a whole remained more or less constant at 0.6 and 2 for three years since 1986 .

Papers above CSIR average

Laboratorywise distribution of papers above CSIR average impact factor and normalised impact factor (Fig.8 & 9) provides a good deal of indicators about the papers published in good quality journals. From the graph, one can also have some idea as to the standard of work being done in various laboratories.

Spectral Distribution

Spectral distribution shows the concentration of papers at various impact factor and normalised impact factor ranges (Fig.10 & 11).

CONCLUSION

The CSIR Research Output is being analysed since 1987 following the method described above. This method of analysis has attracted the attention of many scientists of the country, including those in the top brackets, and has earned a great deal of appreciation even from scientists like the Director General of CSIR, and many directors of CSIR laboratories. However, it has attracted criticism as well mainly from the group of engineering laboratories, in as much as engineering periodicals are very sparingly covered by SCI. For some branches like highway engineering and leather science, the coverage of SCI is practically zero. This is for the first time that the method is being placed before a global audience for its proper evaluation.

Acknowledgement

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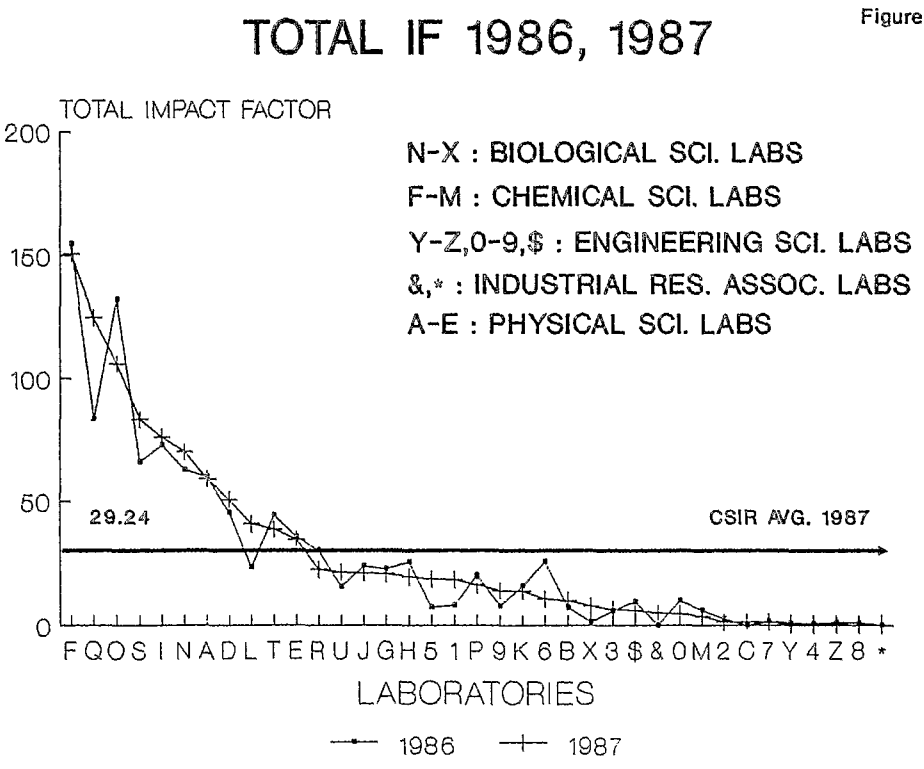
4. Council of Scientific and Industrial Research (CSIR), New Delhi: Research Output 1987: Bibliometric analysis of research papers. New Delhi: the author, 1988.

5. Council of Scientific and Industrial Research (CSIR), Research Output 1988 - a Bibliometric analysis. New Delhi: the author, 1989.

Annex

Figure-1



AVERAGE IF/SCIENTIST 1986, 1987

Figure-3

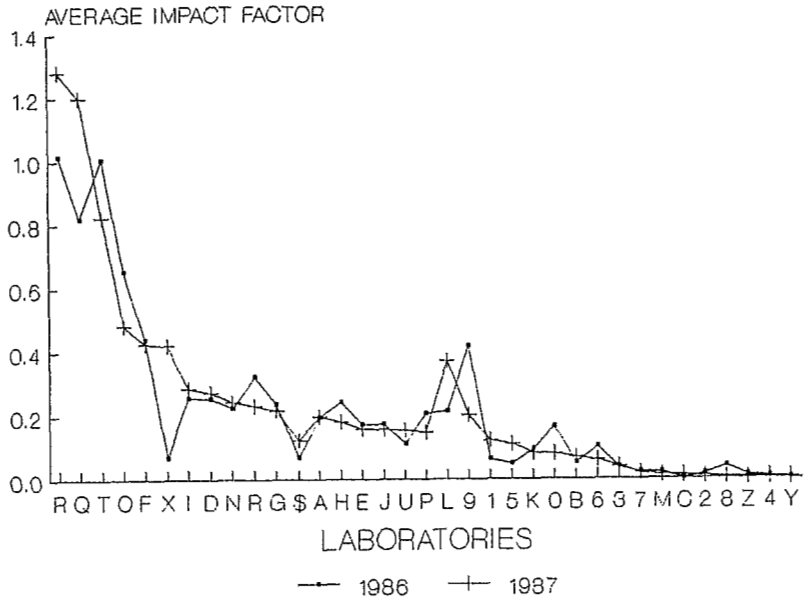


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Figure-2

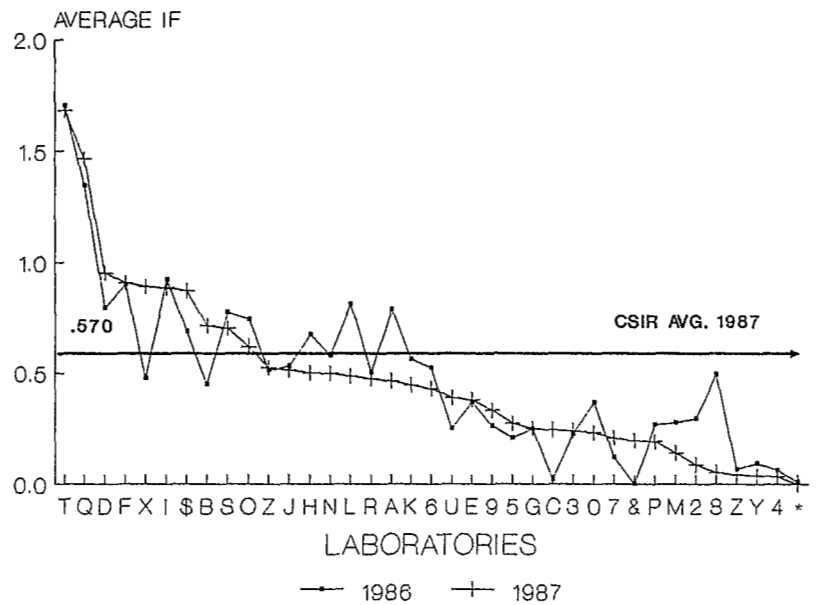


Figure-4

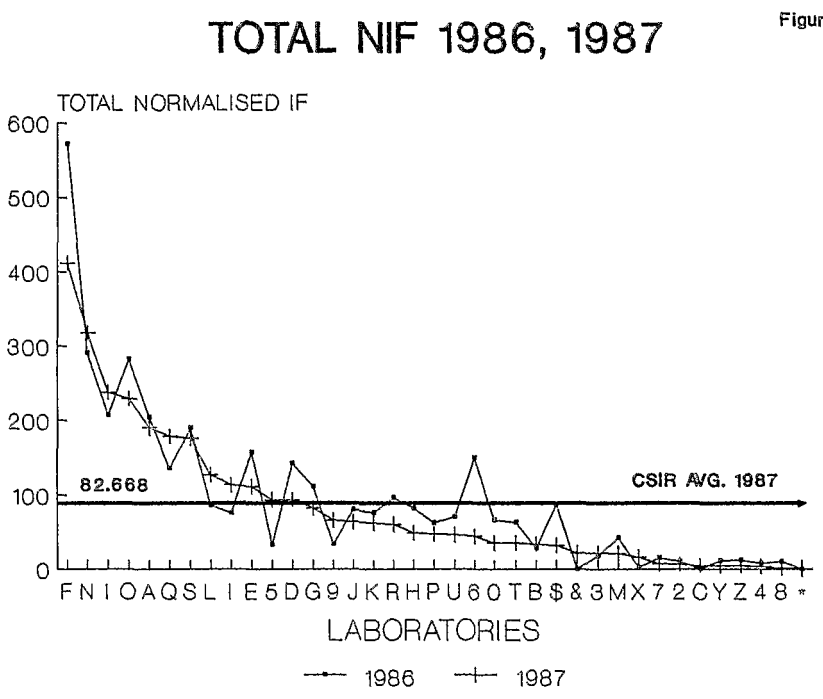
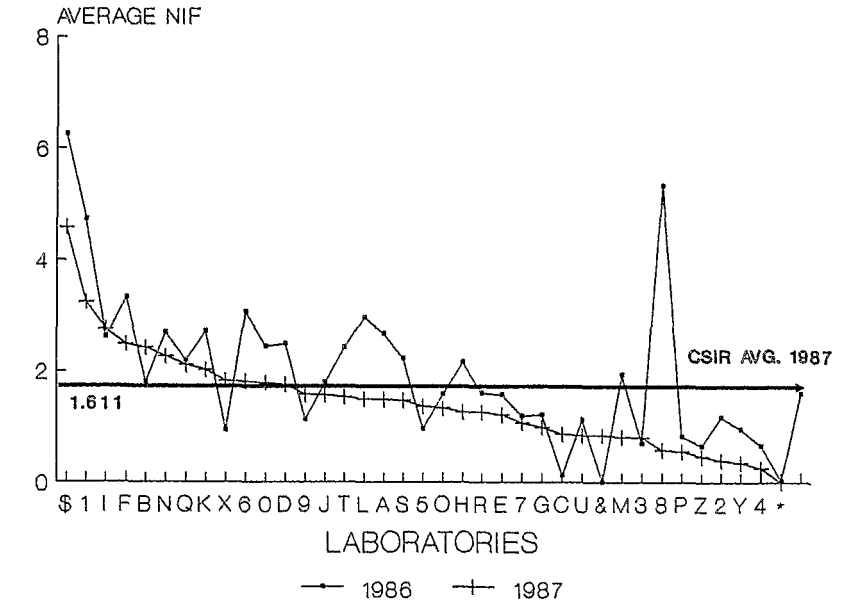


Figure-5



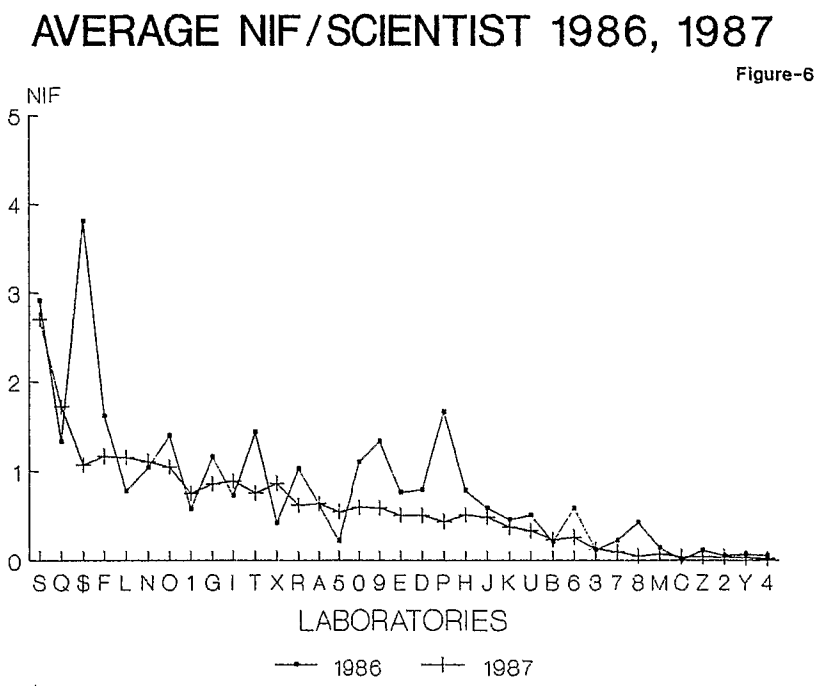


Figure-6

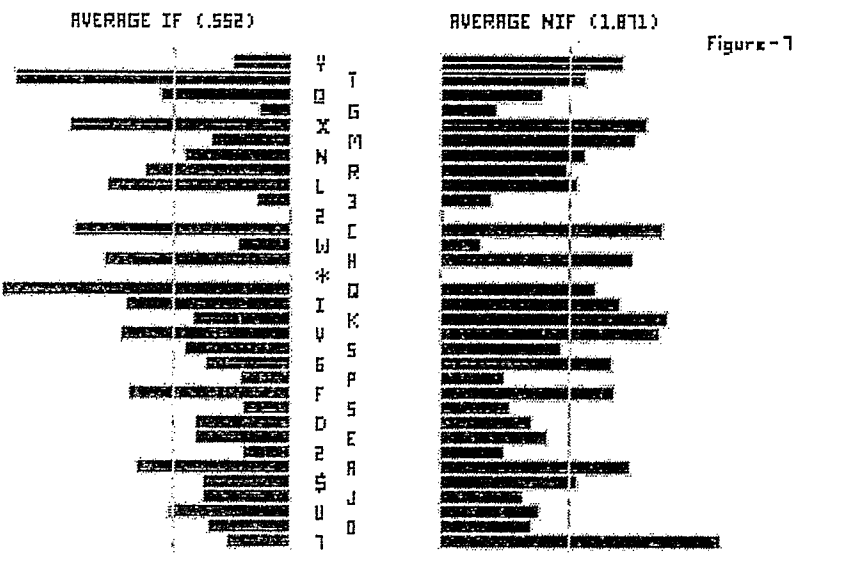


Figure-7

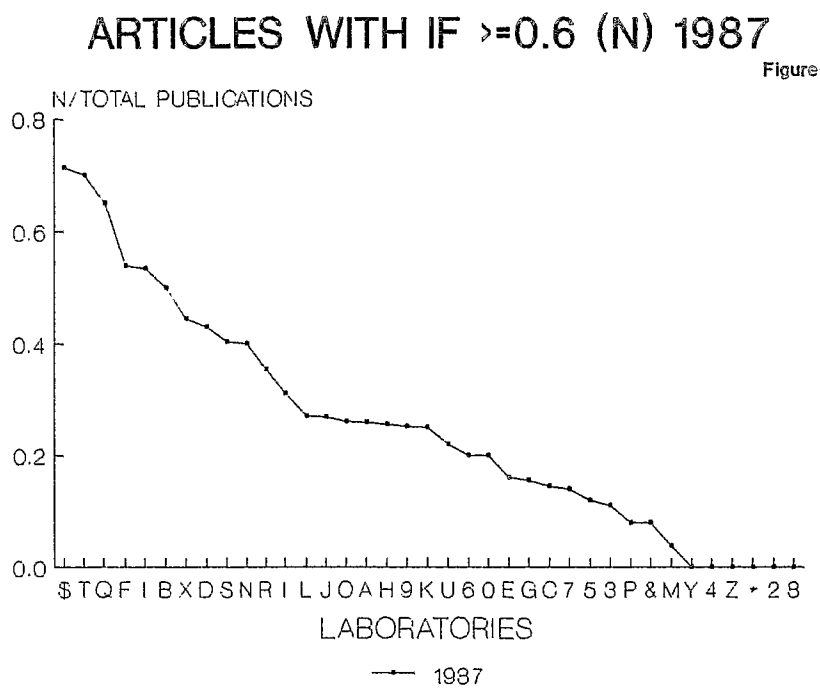


Figure-8

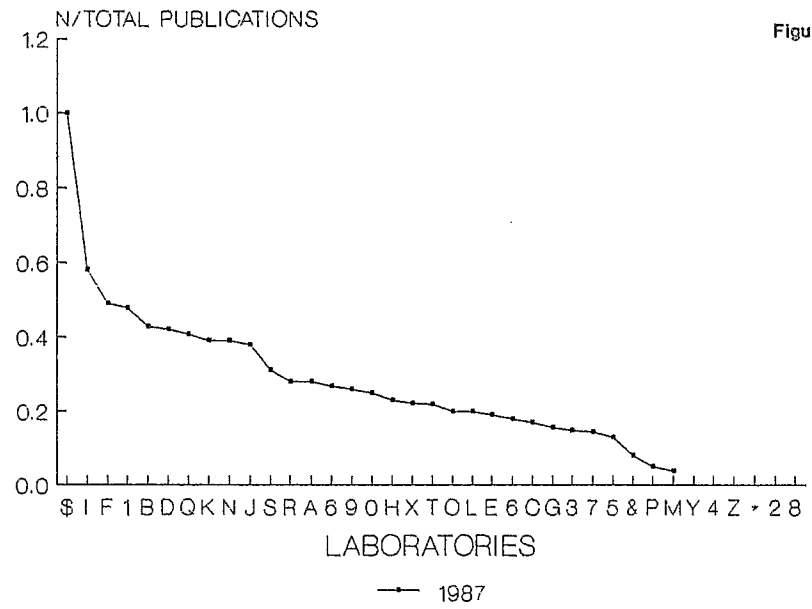
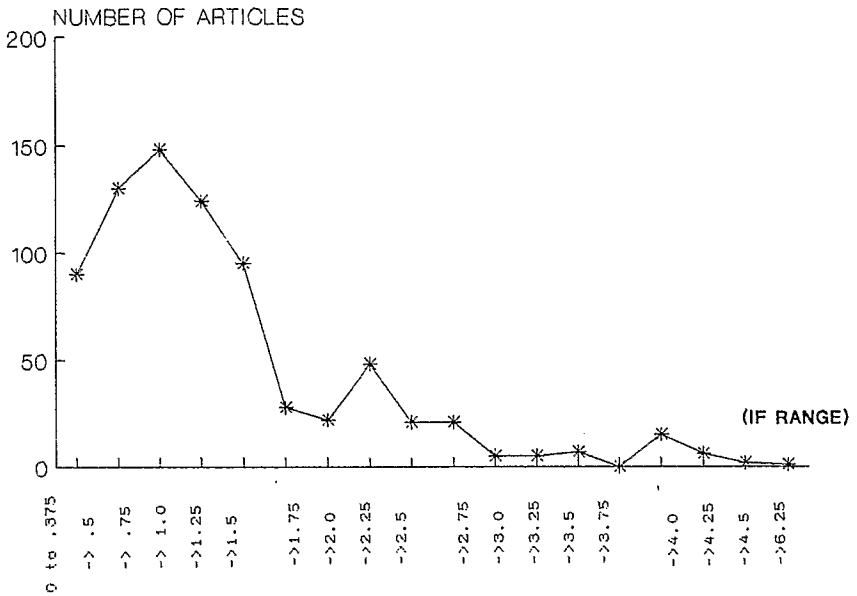


Figure-9

SPECTRAL DISTRIBUTION OF ARTICLES - 1987 (IF RANGE)

Figure-10



SPECTRAL DISTRIBUTION OF ARTICLES - 1987 (NIF RANGE)

Figure-11