What Factors Determine Astronomical Productivity?

Helmut A. Abt
Kitt Peak National Observatory, Box 26732, Tucson, Arizona 85726-6732
e-mail: abt@noao.edu

Received 9 December 2000; accepted 26 December 2002
[S0002-7537(93)01903-1]

In view of the large increase during the past 30 years in the number of astronomical spacecraft launched, large ground-based telescopes built, increased sensitivity of detectors, and increased computing power of computers, we wonder which factors contributed most to the substantial increase in number of astronomical papers worldwide. We found that the number of papers per astronomer in four countries or regions has remained constant within 9% in the last 30 years and has shown no jumps as the result of initiated technical improvements. We conclude that the number of papers published depends only upon the number of astronomers doing research and not upon the technical improvements made, although the average content of the papers has improved. Thus the only way to increase the number of papers is to employ more research astronomers.

1. INTRODUCTION

Astronomical publication has been growing rapidly in recent decades, and that should not be a surprise in view of the many astronomical spacecraft launched, new large ground-based telescopes built, increased sensitivity of the solid-state detectors over photographic plates, and the tremendous increase of computing power of computers. We wonder which of these factors, or others, have caused the expansion in publication.

We first document the number of journal papers published, both in the U.S. and abroad. For the latter we selected the ESO countries, United Kingdom, and Japan. By a process of elimination we can identify the key factors in the publication expansion.

2. NUMBER OF PAPERS PER ASTRONOMER

Abt (1995) documented for the *Astrophysical Journal* (*ApJ*) the increase in the number of pages (normalized to 1000-word contents) published annually during the 20th century. The numbers were static during the first three decades and then in the early 1930s abruptly changed to a logarithmic increase of 8.8% per year. In contrast, the sum of papers published in the *Astronomical Journal* (*AJ*), *ApJ*, and the *Publications of the Astronomical Society of the Pacific* (*PASP*) showed a linear increase of 71 more papers each year. Do such numbers apply to papers in other countries?

In Table 1 we collected the number of papers published at five-year intervals in, for fairness, the one major journal in each country or region. For the U.S. it was the ApJ, for ESO countries it was *Astronomy & Astrophysics* (*A&A*), for the United Kingdom the *Monthly Notices of the Royal Astronomical Society* (*MNRAS*), and for Japan the *Publications of the Astronomical Society of Japan* (*PASJ*). We started with 1970 because *A&A* started publication in 1969. We did not include errata, announcements, abstracts (only), or obituaries, but we did include Letters and Supplements. Most of them showed an increase of 300–400% in 30 years; those percentages are given in the last line of the table. The weighted average is 333%.

Of course authors in those countries published in other journals (e.g. Americans published in *AJ* and *MNRAS*, and Europeans in *ApJ*). Also authors in other countries (e.g. non-ESO countries) published in those journals, and most authors publish in other journals (e.g. *Astronomical Journal*, *Publications of the Astronomical Society of the Pacific*, *Icarus*, *Solar Physics*, *Nature*, *Science*). Most journals are becoming increasingly international. Thus the data for these journals in Table 1 are representative samples of publication numbers; they both include papers from authors outside their countries and miss papers by authors in those countries that are published in other journals.

We wish to compare the paper numbers with some measure of the number of astronomers in the countries sampled. Suitable lists of total astronomers are in the list of members of the International Astronomical Union (IAU). Those numbers are given in the Proceedings of the IAU General Assemblies that occur every three years; we will start with 1970. Each volume includes a ''List of Adhering Organizations'' that conveniently gives the national total memberships. For the ESO countries we included only those countries that were members of ESO at each of the three-year intervals. Accordingly, membership numbers at three-year intervals were plotted for each country or region, fitted to quadratic curves, and interpolated to give numbers at five-year intervals.

In Table 2 we show the number of papers per year per IAU member, e.g. the number of papers in A&A per ESO IAU Member. The penultimate row gives the means for

TABLE 1. Numbers of Papers per Year in Various Journals

Year	USA ApJ	ESO A&A	UK MNRAS	Japan PASJ	Total
1970	644	387	165	47	1243
1975	1064	616	298	52	2030
1980	1256	964	391	49	2660
1985	1278	933	465	56	2732
1990	1699	1141	525	67	3432
1995	2191	1570	746	88	4595
2000	2528	1843	880	135	5386
Inc. (%)	290	380	430	190	333

TABLE 2. Papers in National Journals per Year per IAU Member

Countries Journals	USA ApJ	ESO A&A	UK MNRAS	Japan PASJ	Total Combined
1970	0.86	0.87	0.72	0.44	0.81
1975	1.02	0.87	0.90	0.32	0.91
1980	0.91	0.94	0.95	0.23	0.88
1985	0.75	0.68	0.98	0.20	0.71
1990	0.85	0.67	1.00	0.20	0.75
1995	0.99	0.77	1.35	0.22	0.90
2000	1.10	0.90	1.56	0.29	1.00
Mean	0.93	0.81	1.07	0.27	0.85
SYMBOL	$\pm$0.12	$\pm$0.11	$\pm$0.29	$\pm$0.09	$\pm$0.10

1970–2000 and the final row gives the dispersions about the means. The last column gives the means for all those countries combined, computed from the sum of all the papers divided by the sum of all the IAU members in those countries. What is significant here is not that there are different means for the different countries, e.g. 0.27 for Japan and 1.07 for the UK. Those differences partly reflect that authors in some countries may publish in a larger or smaller variety of journals, or that authors in other countries published in those journals, e.g. Australians publishing in MNRAS. Furthermore not all IAU members may be active in research in the years selected; some were preoccupied with administration or instrumentation and some were retired from research. Therefore both the numerator (papers per year in a given national journal) and denominator (IAU members) are approximate.

What is significant, though, is that in each country or region the number of papers per IAU members has been constant to within 13–33%, compared with roughly 300% increases in number of papers. The total set as described in the last column is shown in Figure 1. Those numbers are constant to within $\pm$0.10/0.85=9%. In other words, authors in those countries publish, on the average, a relatively constant one paper per year (or two 2-author papers or three 3-author papers, etc. or various combinations of those) during each of the past 30 years. This confirms earlier data (Abt 2000a) for American papers only.

3. OTHER FACTORS

We mentioned in the first paragraph the various factors that should have influenced the numbers of papers published. For instance, the conversion from photographic plates before the mid-1970s to nearly universal use of CCDs and other solid state detectors by 1990 have yielded gains of about two orders of magnitude. That should affect the 22% of all published papers that are based on optical and near infrared observations (Abt 2003). We would therefore expect a 22% jump in papers during 1975–1990 if increased detector speeds led to a comparable increase in paper numbers. However, the scatter of only 9% in Figure 1 does not allow for a 22% jump in 1975–1990. Therefore we learn that when astronomers have faster detectors, they work on fainter objects or write papers containing more data, but they do not write more papers.

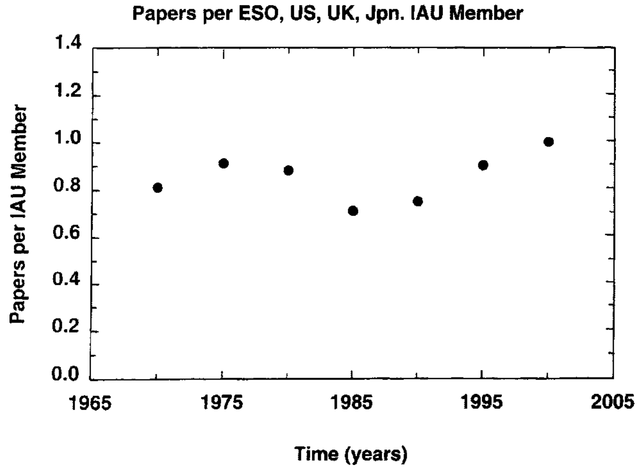

FIG. 1. The total annual number of papers published in A&A, ApJ, MNRAS, and PASJ is divided by the number of IAU members in the ESO, US, UK, and Japanese countries, respectively, for the years from 1970 to 2000. The error due to the finite number of papers and astronomers counted is $\pm$0.02–0.03 in each ordinate.

Similarly, since 1980 the number of optical ground-based telescopes with apertures greater than 4 meters has grown from two to 10, or a 400% increase. That should have affected many of the 22% of all papers in the general journals that are based on optical and near infrared observations as astronomers move from moderate to large telescopes. One might think that the use of larger telescopes would have produced more papers per person by their users, but not so. Apparently when astronomers have access to larger telescopes, they shift their research to fainter objects or do more thorough studies, but they do not write more papers.

One can discuss similar huge increases in numbers of spacecraft, or the computing power that has increased by about five orders of magnitude since 1970 for similar cost computers. Those affect both theoretical and observational work. However those increases do not cause astronomers in the U.S., Europe, or Japan (as examples) to publish more papers per astronomer. It appears that the number of research astronomers provides a bottleneck that determines how many papers are published.

In view of the evidence that only the number of astronomers determines the number of astronomical papers published, we must conclude that if we wish to increase substantially the number of papers, we should employ more astronomers. Without employing more astronomers, technical improvements will undoubtedly improve the resulting research papers, but they will not increase the number of research papers.

Abt, H. A. 1995, ApJ, 455, 407
Abt, H. A. 2000a, PASP, 112, 1417
Abt, H. A. 2000b, Scientometrics, 48, 65