Introduction

From the first model of the modern journal, *Le Journal des Scavans*, published in France in 1665, followed by *Philosophical Transactions*, published by the Royal Society in London later that year, the number of active scholarly journal titles has increased steadily. In 2006 there were roughly 23,750 titles. There are direct correlations between the numbers of researchers, journals, and articles. Björk et al. have argued that changes in the dynamics of literature-based research, provoked by the communications revolution, have made the article itself relevant today as the basic molecular unit of research communication.

The correlations are revealed by studies in the past decade on global research output that have reported the growth rate and annual figures for researchers, journals, and articles. Researchers retire, but more new researchers emerge. Journals fold, but a higher number are launched. Changes over time in the number of active researchers and journals describe the dynamics of both publishing and research, and the increase in absolute size of active production. However, the article has a static nature that makes it unique as a metric. Articles, once created and published, are rarely destroyed. They can always be reactivated, and through citation each article occupies a position in the architecture that researchers can continue to build upon. The article is born essentially through the efforts of journals and their publishers, but articles survive the death of journal titles. Although disciplines develop distinct fields of inquiry, there are ultimately no fixed boundaries in scholarship – this is a single system of documented written knowledge.

Therefore a metric that describes the quantitative whole of this system – the global total of all modern scholarly journal...
Inquiry into the scope of production of scholarly articles has never been precise. How-

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In 1963, Derek de Solla Price plotted the growth of journal titles from 1665 to 2000 and predicted that an astronomical 1 million journal titles would exist by 2000. Price also identified key relationships between research investment, the numbers of researchers, and the numbers of journal titles, abstracts, and articles. These relationships have been carried forward in more recent research. Estimates of the numbers of journal titles worldwide were made by King et al. in 1977 at 57,400 and in 1995 by Meadows and Singleton at 70,000–80,000. More recent research reports figures that are far more modest than these earlier estimates and predictions. Mabe and Amin explained in the introduction to their 2001 paper that improvements to Ulrich’s system of classification allow for more realistic estimates, and Mabe followed up in an 2003 article with an argument for a novel approach based upon this. Earlier estimates are considered high because researchers were unable to differentiate peer-reviewed jour-

The authors were then able to make the first estimate of global annual output of articles. In order to do this, they distinguished ISI-indexed titles, which as a rule produce more articles than non-ISI titles, and then determined the average number of articles per title for each category (by an indirect method for ISI described in the study, and by statistical sample of non-ISI titles). Calculating the sum of titles multiplied by the average number of articles per title for each category gives an estimate of 1,346,000 (rounded) articles for 2006. Incidentally,
though ISI titles represent 36% of the total number of active journals, ISI articles represent 70% of the total number of articles.  
At the time of revising this article, a lively discussion occurred on the American Scientist Open Access forum regarding the wide variance in estimates, demonstrating the ongoing difficulty in getting precise numbers. Morris discusses the limitations of relying on Ulrich's database, stating:

[T]he directory's publishers are entirely reliant on the information supplied by the publishers of the journals listed therein. New journals are often not listed immediately. There can therefore be no hard-and-fast guarantees as to the completeness, currency, or accuracy of that information.

(p. 299)

Concern was expressed on the AMSCI forum that a greater number of smaller journals, particularly those published in languages other than English and those published in developing countries, would be more likely to be excluded, leading to both a skewed view of the universe of academic publishing and an underestimation of its size. This issue was discussed further by Tenopir and King in their recent book The Future of Academic Publishing. However, aside from embarking on a manual method of counting titles, Ulrich's remains the most comprehensive database for determining worldwide totals and the most sensitive to filtering for key distinctions such as active, refereed and scholarly titles. Moreover, results from Ulrich's have been consistent with what we understand about the relationships between the numbers of researchers, titles, and articles as well as the growth rates. Included in this study is a replication of the basic method of searching Ulrich's to determine the number of active journal titles in 2009. From this figure, we can produce an estimate for global annual article output assuming no great change in the average number of articles per title for ISI and non-ISI titles since 2006.

**Methods**

The estimate is based on the measurement of global output of scholarly output in 2006 reported by Björk et al., and rests on the assumption that Mabe, Ware, Mabe and Amin, and Tenopir and King are correct in reporting a steady increase in the number of researchers, journals, and articles over three centuries. While the average rate of increase in the number of journals is reported by these authors to be 3.26%, Ware reports a growth in article output of roughly 3% per year. This produces a doubling time of just under 24 years.

We chose 1726 as the initial year for our calculations, because it corresponds to the beginning of the line of steady growth of journals shown in Figure 1 (reproduced from Ulrich's Periodicals Directory 2001 in Mabe).

![Figure 1. Number of journals launched per year](source: Ulrich's International Periodicals Directory, reproduced with permission from Mabe.)
The literature reports steady growth for over two to three centuries. The earliest period of publishing, from 1665 to the middle of the 18th century, shows less predictable growth. Ulrich’s does not produce results for the number of journals as far back as 1726 so this method cannot be applied to determine the start figure. It appears reasonable to start 1726 with a number greater than zero but negligible to the global quantity today. Additionally, the number of articles can be set to a figure that produces closely matched results to estimates for global annual output in the past decade when the 3% growth curve is applied, a form of backward mapping.

When the number of articles for 1726 is set to 344, the curve corresponds closely to Tenopir and King’s estimates of annual output at the turn of the millennium as well as to the estimate by Björk et al. for the number of articles in 2006. This was done using an Excel spreadsheet. The estimated annual output for each year from 1726, and the cumulative total is given in the online Appendix. Mabe reports that journal growth experienced its largest year-to-year increase during the Big Science period from 1946 to 1976, with lower-than-average rates before the Second World War and after 1976. The author used the same multipliers for the changes in the journal growth rate to adjust the article growth rate and calculated a sum taking into account this variability. Since the results for both calculations were almost identical, the more straightforward calculation based on the average growth rate is reported here.

Results
This method yielded an estimate of nearly 50 million articles by the end of 2008, with the figure expected to pass 50 million in 2009. In actual fact, the year that the sum of all scholarly articles passes 50 million cannot be determined precisely, but we can report that this result is the first estimate to follow from the current evidence for the grand total of all scholarly articles that exist at the time of writing in 2009 and publishing in 2010. In good humour, the author can make the claim that this article could itself be the 50 millionth to be published in history!

- Estimated total at 31 December 2008 = 49,234,626
- Estimated total at 31 December 2009 = 50,712,009

Replicating Björk et al. and using the search terms ‘Academic/Scholarly’, ‘Refereed’, and ‘Active’ in Ulrich’s, the total number of active journal titles for the year 2009 is 26,406.

Assuming little change in the proportion of ISI titles (36%) and using the averages given by Björk et al. for articles per title in ISI and non-ISI journals, the total number of published articles estimated for 2009 by relation of journal titles to articles is calculated by estimating the number of ISI titles and subtracting that from the total number of titles for 2009, then multiplying each category by its respective average number of articles. The average number of articles per title reported by Björk et al. for ISI titles is 111.7; for non-ISI, the average number of articles is 26.2.

To determine the number of ISI titles, we multiply the total number of titles by 35%.

- 26,406 × 0.36 = 9,506 (i.e. the estimated number of ISI titles).

To determine the number of ISI articles, we multiply the number of titles by the number of articles per title for ISI journals.

- 9,506 × 111.7 = 1,061,820 (i.e. the estimated number of ISI titles).

To determine the number of non-ISI titles, we subtract the number of ISI titles from the total number of titles.

- 26,406 – 9,506 = 16,900 (i.e. the estimated number of non-ISI titles).

To determine the number of non-ISI articles, we multiply the number of non-ISI titles by the number of articles per title for non-ISI journals.

- 16,900 × 26.2 = 442,780.

To determine the annual global output of articles for 2009, we sum the number of ISI and non-ISI articles.
1,061,820 + 442,780 = 1,504,600.

Summing these, the global output of articles in 2009 is 1,504,600. This data is shown in Figure 2.

The total number articles estimated for 2009 using the 3% growth curve and produced in the Excel table is 1,477,382. The difference between the estimate by the method employed by Björk et al. and that produced by the growth curve is less than 2%.

Discussion and conclusion

The estimate of the global total of scholarly articles that exist is clearly a ballpark figure, rather than a precise number. However, the study of the size, growth, and composition of a global body of scholarship has moved forward in this decade. We can better determine a global annual output of scholarly articles through our understanding of (i) the relationship between numbers of researchers, journals, and articles; (ii) the year-to-year growth rates for the number of active titles and the number of published articles; (iii) the relationships between ISI and non-ISI journal titles; and (iv) the improvements to Ulrich’s classification system. However, further investigation is needed to test the robustness of each of the relationships and indeed the comprehensiveness of Ulrich’s database.

50 million peer-reviewed journal articles is an impressive heritage, and a powerful resource for humanity. In order to manage such a resource in a way that is equitable, useful and sustainable, we would do well to take ongoing interest in where we stand in terms of the access, digitization, search and indexation, and preservation of this global library of knowledge.

Appendix

The calculated data for annual and cumulative article totals are available online: http://dx.doi.org/10.1087/20100309

Acknowledgements

The author would like to acknowledge the assistance of Azim Jinha with the calculations, and the advice and editorial help of Robin Beecroft (Searchlighter) and Moustapha Diack.

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