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Scientific Wealth of Mongolia on a Global Scale

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Abstract

This article attempts to objectively evaluate the scientific wealth of Mongolia as a nation, by analyzing journal publications by Mongolian scientists recorded in the ISI database. Publications by Mongolian authors for the period of 1979-2002 were included for analyses. Although the total number of publications has increased for the given period, there was no significant increase in the relative citation impact or RCI. Changes of publication quality as measured by RCI showed different trends for various scientific fields. Publications in clinical medicine and biology show most positive trend, whereas publications in mathematics and physics declined in quality. All the fields are well below the world's total publication quality for a comparable period. Additionally, percentage of papers by Mongolian senior authors has declined (though the trend is not significant). This is a rather disturbing trend given the fact that the number of researchers with a doctor's degree in the country has greatly increased during the same period of time. Quality of publications by Mongolian first authors and only Mongolian authors were significantly lower than collaborative ones. As far as we are aware, this is the first evaluation of scientific wealth of Mongolia as a whole and it is hoped that it would be helpful to policy-making and scientific communities in prioritizing and determining the direction of support and finance.

Key words: scientific wealth, ISI, publication quality, citation impact, Mongolia

Introduction

In the comparatively short history that modern science has been practiced, Mongolian scientists have accomplished a tremendous amount of work. However, arguably in almost all fields of scientific research, Mongolian scientists are far behind their international peers. Perhaps that is why from time to time in the media people hear a researcher saying that his/her research "has reached the international level." Thus, questions arise naturally: What is the "international level" of scientific research and how does the "Mongolian level" compare with it? What is the scientific wealth of Mongolia and how have we been doing in different fields of study? What disciplines are we better at and what should we be doing to improve science? In this article, we objectively evaluate scientific wealth of Mongolia on the global scale. It is conventional to estimate scientific activity of a certain nation by the number and quality of scientific publications because publication is the main output of scientific research and is therefore the best indicator of scientific wealth. Scientific activity is usually indicated by the number of publications in peer-reviewed journals. Commonly the total number of publications standardized by total population of a nation is taken as scientific wealth of that nation (Perez-Iratxeta and Andrade 2002). In this paper we offer an evaluation of scientific research output of Mongolia between 1979 and 2002. We also give comparisons of outputs and trends in quality of different scientific disciplines as practiced in Mongolia during the same period of time.

The study was based on the database of The Institute of Scientific Information (ISI) which offers the largest compiled information on scientific journal publications from all over the world. ISI maintains the following databases: Science Citation Index (SCI), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (AHCI). We used all three of them for searching publications authored by Mongolian researchers. The SCI is a multidisciplinary index to the journal literature of the sciences. It fully indexes 5,900 major journals across 150 scientific disciplines. The SCI includes all cited references captured from indexed articles providing access to retrospective data from 1945

to the current interactive information. Each week an average of 19,000 new records and approximately 423,000 new cited references are added to the SCI database. The SSCI is a multidisciplinary index to the journal literature of the social sciences. It fully indexes more than 1,725 journals across 50 social sciences disciplines and individually selected, relevant items from over 3,300 of the world's leading scientific and technical journals. The SSCI provides access to information from 1956 till today. Each week an average of 2,900 new records and approximately 60,000 new cited references are added to the SSCI database. The AHCI is a multidisciplinary index covering the journal literature of the arts and humanities. It contains a total of over 2.5 million records and fully covers 1,144 of the world's leading arts and humanities journals. It indexes individually selected, relevant items from over 6,800 major science and social science journals. It provides access to information from 1975 until today. Each week an average of 2,300 new records and approximately 15,250 new cited references are added to the AHCI database. Collectively these databases constitute the largest and most widely used information source for scientific publication. Although they have many biases and shortcomings (see May 1997b), their worldwide coverage of almost all of the peer-reviewed scientific publications makes the ISI the best information source possible.

Material and methods

We queried the ISI databases for publications by Mongolian scientists in the period of 24 years from 1979 to 2002. The search took place in February 2004. We could classify the hits by authors, fields of research, number of times each paper was cited etc. The reason for not including beyond 2002 is because it takes time for the scientific community to react to publications and therefore the quality of papers published after 2002 cannot be fairly judged by the number of times they were cited by other authors. All collaborative papers that had at least one Mongolian author were included in the analysis. Furthermore, we know this does not constitute the complete list of all publications by Mongolian scientists because the data do not include most of the publications by many Mongolian researchers published while affiliated with foreign institutions. Additionally, many, except for a few, of the journals from the former socialist countries have not been included in the ISI databases. However, not being read and cited by scientific communities in most of the world means that these publications had effectively no impact on the advancement of science.

Moreover, we calculated relative citation impact (RCI) which is the most widely used measure of quality of an average paper. We will describe here how to calculate the RCI as used by May (1997b). For country *i*, let total papers be P_i and citations C_i. The share of the world's papers is then $p_i = P_i/P$, where $P = \sum P_i$ is the world's total number of papers. Similarly, citation share is $c_i = C_i/C$, with $C = \sum C_i$. Therefore, $\mathrm{RCI}_i = c_i/p_i = (C_i/P_i)\times(P/C)$. That is, for country *i*, the average number of citations per paper, C_i/P_i, is RCI_i multiplied by the ratio of all papers to all citations, which is $1/8.53$ for a comparable period of time in another study (May 1997a, b).

To look at the trend, we divided the data into two, 12-year periods and compared them by fields of research. As stated above, the ISI database contains hundreds of research fields, but it was impossible to classify them into the same research fields as in the database in the case of Mongolia. This was due to (*a*) a small number of publications and (*b*) a few disciplines that are practiced in Mongolia. Therefore, we classified the publications into the following broad research fields: *Agri-* all agricultural fields including veterinary medicine; *Biol-* all biological fields except for biochemistry; *Chem-* chemistry and biochemistry (as most publications here represent biochemistry and pharmacology); *Geo-* all fields of earth and atmospheric sciences; *Materials-* materials science; *Math-* Mathematics; *Med-* clinical medicine; *Phys-* all fields of physics; and *Social-* all fields of social sciences. Citation patterns vary among fields (for example citation rates are higher in molecular biology and genetics than in materials science; May 1997b). Because it was impossible to get worldwide scientific publication data that can suit our broad classification of research fields above, we used the same ratio ($P/C = 1/8.53$) when we estimated the RCI for these fields of research practiced by Mongolian scientists. Although we do not believe that this will change the pattern greatly, one should be cautious

about interpreting the results.

Results

Publications and citations

Exhaustive search from ISI citation indices (SCI, SSCI and AHCI) yielded 635 publications by Mongolian scientists for the period of 1979-2002. The total number of publications in all fields per year has been increasing and the positive trend is significant (Fig. 1, quadratic regression, R^2=0.71, p<0.0001). The similar trend could be seen for the total number of citations. However, there was a slight decrease in the percentage of journal publications whose first authors were Mongolian scientists, although the trend is not statistically significant (Fig. 2, linear regression, R^2=0.037, b=-0.38, p=0.37). About one third of all publications (n=217) were not cited at all. Furthermore, comparisons of quality of publications by Mongolian first authors and by only Mongolian authors to the collaborative papers show that the quality of those publications as expressed by the number of total citations were significantly lower in both cases than the collaborative papers (one-way ANOVAs, Table 1). The RCI of all publications was 0.63, which was much lower than RCI's for many countries for a comparable period (Table 2, for more see May 1997b who studied the worldwide publication activities for the period of 1981-1994). Self-citation accounts at least 10% of total citations

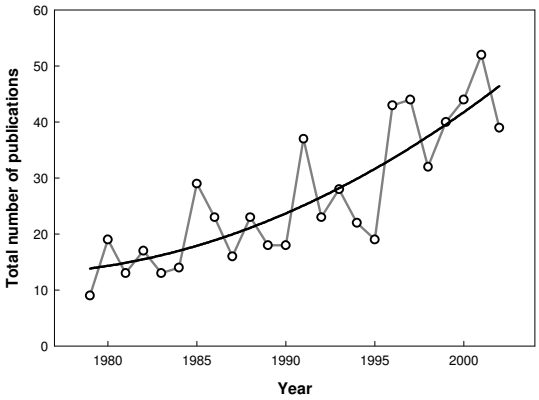

Fig. 1. Total number of publications by Mongolian scientists in all fields of science (line is for quadratic regression, R^2=0.71, p<0.0001).

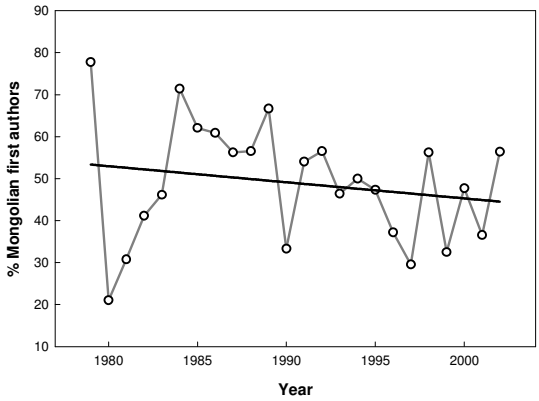

Fig. 2. Percentage of papers by Mongolian senior authors. Although not significant, the trend is negative (linear regression, R^2=0.037, b=-0.38, p=0.37).

Table 1. Comparison of quality of publications by Mongolian first authors and only Mongolian authors as expressed by number of total citations to the collaborative publications (one-way ANOVA tables). Total number of citations for those publications by Mongolian first authors and only Mongolian authors were significantly lower than the rest of the publications.

Source of variation	*DF*	*SS*	*MS*	*F*-ratio	*p*-value
Mongolian first authors					
Mongol first authors	1	5178.5	5178.459	27.39	<0.0001
Error	633	119688.2	189.081		
Total	634	124866.7			
Only Mongolian authors					
Only Mongol authors	1	3561.9	3561.884	18.59	<0.0001
Error	633	121304.8	191.635		
Total	634	124866.7			

Table 2. Comparison of the RCI of publications of Mongolia to scientific powerhouses on the world. Although the RCI for Mongolia may not look very low, it should be remembered that it could have been escalated by factors such as self-citation and "insularity effect" (see text for more). Note that the study was based on only the ISI databases. The table was modified from May's study (1997b) which was based on a comparable time period.

Country	RCI (rank)
United States	1.42 (1)
Switzerland	1.37 (2)
Sweden	1.24 (3)
Denmark	1.16 (4)
United Kingdom	1.14 (5)
Netherlands	1.10 (6)
Canada	1.00 (7)
Australia	0.97 (8)
…	…
Mongolia	0.63 (?)

of worldwide publications (May 1997), but this appears to be higher for Mongolian publications (although this was not quantified).

Scientific activities in different research fields varied greatly for the period of 1979-2002 (Fig. 3). Chemistry, geology and physics were highest in the total number of publications (Fig. 3A) whereas geology, biology and clinical medicine enjoyed the highest number of citations (Fig. 3B). Most of the chemistry research concentrated on biochemistry and pharmacological characteristics of natural compounds, mostly from wild plants from Mongolia. The geology (or earth science) research is dominated by publications in paleontology as Mongolia is the third country in the world in the number of fossil findings; whereas physics was dominated by theoretical quantum physics. Significant percentages of biological research were published in the fields of molecular biology and genetics. Four highly cited papers with >100 citations were in the fields of medicine and biology (2 in medicine and 2 in biology). In fact, 10 of the highly cited publications include 6 in biology, 3 in medicine and 1 in geological and earth sciences.

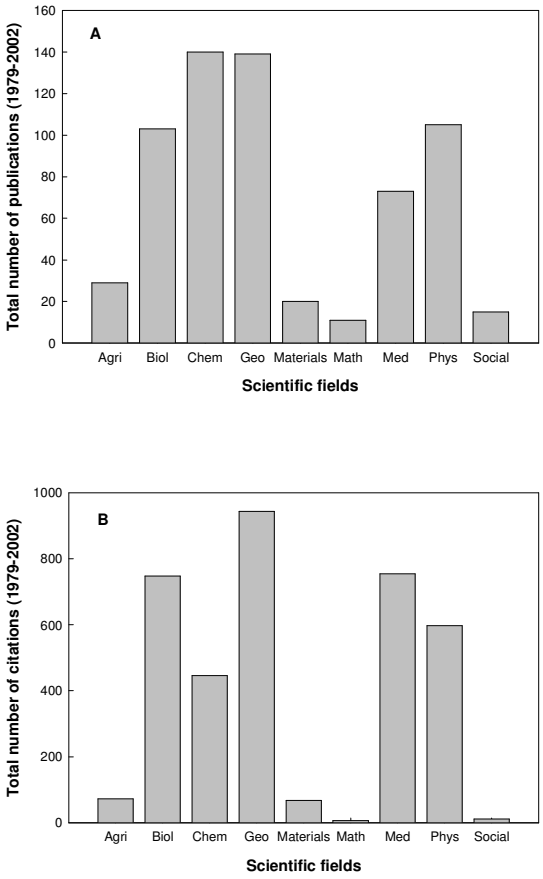

Figure 3. Scientific activity by Mongolian scientists in different research fields. (A) Total number of publications and (B) total number of citations by research fields between 1979 and 2002. For abbreviations, see the text.

Patterns of change

As discussed above, total number of publications and citations has increased over time (Fig. 1). Unfortunately, percentage of papers authored by senior Mongolian authors has shown no increase (Fig. 2). In all the fields of research, publications by Mongolian scientists were lower than the worldwide publication in quality as expressed by RCI (Fig. 4). Trend of changes was also different for the disciplines and in some cases the trend was negative for some fields in what is called the "hard sciences." For example, publications in physics were highest in quality to begin with. But, the quality seems to have decayed over time as indicated by the negative percentage change (Fig. 4). Research in the fields of clinical medicine and biology was very low at the beginning, but the trend is promisingly positive shown by large percentage increase in RCI (Fig. 4). But, publications in these fields are still nowhere near the average level of RCI for the worldwide publication during a comparable period (as in May 1997b). Researchers specializing in new fields are starting to emerge, such as materials science and different fields of social sciences.

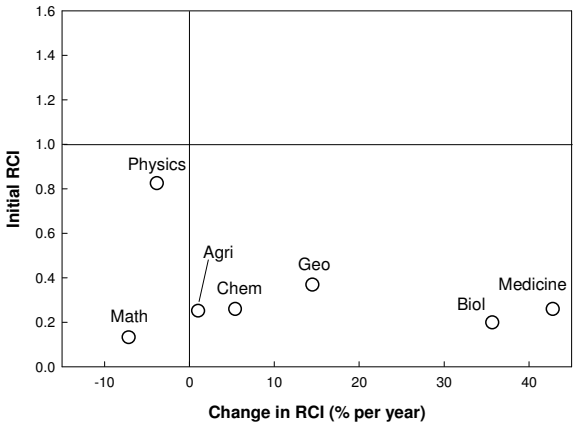

Figure 4. Change in the quality of scientific publications in different disciplines by Mongolian researchers, measured as average percentage change in RCI versus the initial RCI (average 1979-1990). For abbreviations, see the text. Materials and social sciences were not included in the graph because they have only emerged since the 1990s.

Discussion

The quality of scientific research is ultimately measured by its main output, which is the number of scientific publications and their impact on scientific thinking as measured by RCI. However, data compiled on the worldwide scientific publishing activity indicate that the number of publications (per million people) by Mongolian researchers was one of the fewest in the period of 1996-2001, and the trend of change was negative compared to the period of 1989-1995 (Perez-Iratxeta and Andrade 2002). We believe that the results of our analyses are in agreement with their findings. First of all, the total number of publications is surprisingly small for the 24-year period. And one-third of all publications (n=217) did not receive any citations. It should be remembered that the publications with at least one Mongolian author were included in the analyses. Although the total number of publications by Mongolian scientists and citations hase increased over time, detailed analyses tell different stories. This is rather disturbing because the trend shown in Figure 1 can easily be discounted by several factors. First, a higher rate of self-citations seems to occur in publications of Mongolian scientists. Second, higher rates of citations of publications of Mongolian authors can result from what we will call the "insularity effect of publications," following assertion by May (1997b) (i.e., a few papers are published but they receive lots of citations because there is no other source of information; the insularity may also be due to a lack of familiarity with outside source of information and inability to purchase international journals). For example, publications in paleontology had to do with interesting fossil findings discovered only in Mongolia and therefore enjoyed higher number of citations. Third, it is hard to separate out good publications with large number of citations from the bad ones that happened to have high citations because occasionally incredibly wrong papers attract much criticism. Lastly, there was a significant increase in the number of researchers who earned their doctorate during the same period of time, especially since 1990s. We call this period the PhD-boom due to the higher rate of graduations with doctorates during the period of time. Given all these factors, the small increase in the total number of publications of Mongolia does not look promising. It reminds me of the tradeoff between offspring quality and quantity in life history theory. According to this theory, offspring quality decreases as the number of offspring increases because finite amounts of resources have to be allocated over more offspring. An analogous thing can be said about the tradeoff between quality and quantity of doctorates in Mongolia and their publications.

No increase in percentage of papers by Mongolian senior authors as shown in Figure 2 may be excused by increased international collaborations or perhaps by tightened budgets for scientific research. On the other hand, it may suggest that our scientists are no longer taking a charge in research projects, especially given the significant increase in the number of scientist with a doctorate. The fact that the citation impact of publications by Mongolian scientists who were the sole authors or who were the senior authors was statistically significantly lower than the collaborative publications suggests that we need to improve scientific activity and creativity in all fields. Some scientific fields exhibit more promising trends in quality as well as quantity than others and these fields should be supported more than others. However, one should interpret these trends with caution because citations accumulate with time.

The last point we want to make is that scientists have moral responsibilities to publish their results. In any given country, without exception, most of the financial resources to support scientific research

is provided by tax money. That means scientists make their living and hopefully their names by spending people's money on research. For this reason, scientific results, which are the main product of that investment, must be reported in publications. Without publication, results are not seen by public and policy-makers and it has negative consequences on research-funding. Moreover, science becomes stagnant without publications. Science cannot advance itself and serve society without publications. In this regard, only a few hundred papers by Mongolian scientists in the 24-year period of funding is quite insufficient.

In this paper, we show that the scientific wealth of Mongolia is poorer than many think or would like to give credit for, compared on a global scale. It is not only demonstrated by the low RCI of Mongolian publications, but by the poor quality of publications where Mongolians are the sole or the first authors and by negative trends in some hard science fields. It therefore seems as if our scientific activity has not reached "the international level" in many regards. We are not denying some promising trends by this paper. Our point is that we must take a critical look at what we have accomplished so far, what the trend is showing in different disciplines, how we should go about making our marks and contributing to society by producing new knowledge and technology and what should be our priorities or how we should allocate our policy or resources into different scientific fields. To our knowledge, this is the first attempt at seriously questioning scientific activity in Mongolia, supported by quantitative data and analyses.

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Монголын шинжлэх ухааны баялаг дэлхийн түвшинд

Энэ өгүүллээр Монголын судлаачдаас гадаадын сэтгүүлүүдэд хэвлэн нийтлүүлж, Шинжлэх Ухааны Мэдээллийн Хүрээлэнгийн өгөгдлийн санд (ISI database) бүртгэгдсэн эрдэм шинжилгээний өгүүллүүдэд дүн шинжилгээ хийх замаар Монгол улсын шинжлэх ухааны ажлын түвшинг бодитойгоор үнэлэхийг зорилоо. 1979 оноос 2002 хүртэлх хугацаанд Монголын судлаачдын нийтлүүлсэн өгүүллүүдэд дүн шинжилгээ хийсэн. Энэ хугацаанд жил тутам нийтлүүлсэн өгүүллийн нийт тоо өссөөр ирсэн (R^2=0.71, p<0.0001) боловч иш татагдсан байдлын харьцангуй түвшинд (relative citation impact, RCI) бодитой өсөлт ажиглагдсангүй. Эрдэм шинжилгээний өгүүллийн чанарыг иш татагдсан байдлын харьцангуй түвшингээр (RCI) хэмждэг олон улсын практикийг баримтлан үзэхэд манай улсын хувьд шинжлэх ухааны салбарууд хоорондоо ялгаатай хандлага үзүүлэв. Анагаах ухаан, биологийн салбаруудад хамгийн эерэг хандлага ажиглагдаж байхад математик, физикийн салбаруудын хувьд эрдэм шинжилгээний өгүүллийн чанар харьцангуй буурсан нь харагдаж байв. Адил хугацаанд хэвлэгдсэн Дэлхийн бүх өгүүллүүдийн чанартай харьцуулахад Монголын бүх эрдэм шинжилгээний өгүүллийн дундаж чанар нэлээд доогуур байлаа. Түүнчлэн дурдсан хугацаанд Монгол судлаач нэгдүгээр зохиогч нь болон хэвлэгдсэн бүтээлийн тоо буурах байдал ажиглагдаж байна (гэхдээ энэ хандлага статистикын хувьд бодитой бус, R^2=0.037, b=-0.38, p=0.37). Тухайн хугацаанд докторын зэрэгтэй судлаачдын тоо манай улсад үлэмж өссөн баримтыг харгалзан үзвэл энэ хандлагыг бараг уналтын байдалтай гэж тодорхойлж болохоор байна. Түүнчлэн Монгол судлаач нэгдүгээр зохиогч нь болон хэвлэгдсэн болон зөвхөн Монгол судлаачдын нийтлүүлсэн өгүүллийн чанар

гадаадын судлаачидтай хамтарсан бүтээлийн чанараас бага байна (p<0.0001). Зохиогчдын мэдэж байгаагаар энэ өгүүлэл нь Монголын шинжлэх ухааны түвшинг бүхэлд нь бодитой дүгнэж үзсэн анхны оролдлого бөгөөд эрдэм шинжилгээний ажлын бодлого боловсруулах, аль салбарт санхүүгийн болон бусад дэмжлэг үзүүлэх байдлаар тэргүүлэх чиглэлээ тодорхойлох зэрэгт тус нэмэр болох буй заа хэмээн найдсан болно.

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