Are Chinese nanoscience citation curves converging towards their American counterparts?

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ABSTRACT

We investigate if the shape of citation curves of Chinese publications in the field of nanoscience and nanotechnology converge to those of America and find that they, indeed, do. The used approach is size independent and, hence, can be used to compare not only large countries but also countries of intermediate size.

Keywords: Nanoscience and nanotechnology; Citation curves; Convergence; China; USA

INTRODUCTION

Nanoscience is the study of the control of matter on an atomic and molecular scale, while the term nanotechnology refers to a range of technologies operating at the nano scale. Recall that a nanometer (nm) is equal to 1 x 10^{-9} meter. Hence nanotechnology deals with structures of which at least one dimension is of the size of 100 nanometers or smaller, and involves developing materials or devices within that size.

At this scale some materials exhibit behaviour not seen on a macroscopic scale. Rather than working with materials as a whole, nanoscientists work with individual atoms and molecules. When placed together in well-defined ways materials obtain new and technologically interesting characteristics. Bhattacharya and Shilpa (2011) point out that nanoscience and nanotechnology find applications in materials, manufacturing (coating), information and communication technology (ICT), electronics, pharmacology and health (maybe drugs that cannot be used on a macro scale can at the nano scale), food and food safety (Hewett 2006; Zhang, Guo and Cui 2009). Wang and Guan (2012) make a distinction between four types of nano-products: nano-materials, nano-intermediates, nano-enabled market-ready products and nano-tools. Nano-materials are minimally processed raw materials such as: carbon nanotubes and nanoparticles. In a second stage these nano-materials are incorporated or assembled into nano-intermediates such as coatings, superconducting wires, and optical materials improved with nanomaterials. Finally, these nano-intermediates are assembled or incorporated in another product leading to nano-enabled market-ready products for use in airplanes, cell phones and medical diagnostics tools. During these three stages special equipment, nano-tools are necessary. This equipment is necessary to visualize, manipulate and model nano-products in the three stages. Wang and Guan (2012) provide an extensive list of these four types of products (their Table 1, p.5).

Because of these characteristics nanoscience and nanotechnology are highly interdisciplinary fields. Porter and Youtie (2009) provide a base map of science overlaid by the field of nanoscience and nanotechnology, illustrating, among other things, the interdisciplinary nature of this field. They also show how other fields have influenced nanoscience, as shown by citations to these fields in nano publications.

Emerging countries such as China and India see this field as a way to compete with developed countries, because developed countries too must still develop expertise (Bhattacharya and Shilpa 2011). In a study about the situation of nanoscience in India Bhattacharya and Shilpa (2011) conclude that China provides a lesson for India, namely that if a country has a strong strategic focus it is possible to become a leading country at a new frontier area of research.

Indeed, following the United States and Europe, China, Japan and South Korea have adopted nanotechnology as a research and development (R&D) policy priority. The Chinese Government declared nanotechnology a critical R&D priority in its Guidance for National Development (Ministry of Science and Technology of the People's Republic of China 2001). This declaration can be placed within China's research policies to develop fundamental research and technologies that are considered to be critical to its social and economic development (Benner, Liu and Schwaag Serger, 2012). Among these priority fields nanoscience and technology has received the most attention (Bai 2005).

Leydesdorff and Wagner (2007) wrote that by 2005 China had become the second largest nation in both numbers of publications and total number of citations received, a fact confirmed by Kostoff, Koytcheff and Lau (2007). Using a specially designed query Kostoff (2012) found that during the period 2008-2009 China has indeed overtaken the USA in terms of nano-related publications.

Focusing on core journals only, i.e. those assigned by Thomson Reuters to the category Nanoscience & Nanotechnology, we note that at this moment (December 2012) China has not yet overtaken the United States (Table 1), but clearly this is soon to happen.

Table 1: Number of publications resulting from the query WC=Nanoscience & Nanotechnology (December 24, 2012)

Publication Year	USA	China	ratio
2007	6532	3841	1.70
2008	6551	3971	1.65
2009	6506	4907	1.33
2010	7254	5231	1.39
2011	7238	6648	1.09
2012 (part.)	6290	6072	1.04

In 2008 Kostoff, Barth and Lau published an article studying trends in quality of nanotechnology and nanoscience papers produced by authors from China, using the ratio of highly cited articles (defined as the top 1% of all nanotechnology publications) as metric. Although starting from a low level, in 2003 China had increased its number of highly cited articles to 20% of that of the USA. Using the same metric Bhattacharya and Shilpa (2011) observed that China ranked 6th in 2000; 3rd in 2005 and 2nd in 2009. In that year China had 132 articles among the top 1% most-cited while the USA had 257 such articles. Clearly also the quality, as measured by citations, of China's publications is increasing.

Yet, the field of nanoscience and nanotechnology in China has its own characteristics as described by Liu and Zhang (2007). According to these colleagues Chinese nanotechnology research is characterized by the following four aspects:

1) Growing fast in quantity and improving gradually in quality;
2) Besides an internationally oriented research community it has also an independent domestic nanotechnology research community that communicates in Chinese and publishes in domestic journals, a fact also observed by Lin and Zhang (2007);
3) Conducting multidisciplinary research across boundaries of chemistry, physics and material sciences;
4) Dominated by universities and public research institutes (such as CAS) with little industrial contributions.

Pei, Porter and Gao (2010) observed that China is strong in 'traditional' nanoscience but lags behind in the recently developing field of bionanoscience. This field can, in general terms, be described as a multi-disciplinary area situated at the interface between engineering and the biological and physical sciences, and this within the global area of nanoscience and technology. It is exactly the field of bionanoscience that was chosen by Rafols and Meyer (2007; 2010) to study the nature of interdisciplinarity, using a two-dimensional approach. One of the aims of the second Rafols-Meyer's article (Rafols and Meyer 2010) is to inform policy makers on the dynamics of emerging fields such as bionanoscience by providing measures that capture the intensity of interdisciplinarity in the wider sense of knowledge integration.

Shapira and Wang (2010) studied which countries had the most funded papers in nanotechnology (during the period August 2008 – July 2009) and found that China was leading before the United States, followed at a considerable distance by the European Union, Germany and Japan. Remarkably many papers were funded by two or more countries, especially by the United States and China, showing the high level of collaboration taking place in this field.

In the field of nanoscience and technology patents play an important role, probably even more important than publications. Consequently patents have been the source of many investigations. Wang and Guan (2012), for instance, showed that in China there is a huge gap between patenting activity and market demands leading to a low rate of technology transfer. Some other recent examples of studies related to patenting activities in China and elsewhere are: (Guan and Shi 2012) and (Guan and Zhao 2013). In this contribution, however, we do not consider patents and focus on papers only.

RESEARCH PROBLEM

As mentioned above, studies on nanoscience in relation with China often compare the absolute numbers of publications with other countries or regions, especially with the USA. Some studies (Bhattacharya and Shilpa 2011; Kostoff, Koytcheff and Lau 2007; Kostoff, Barth and Lau 2008; Leydesdorff and Wagner 2007; Porter and Youtie 2009) also considered citations and citations per publication. Studying absolute numbers of publications and citations is a "big is beautiful" approach. It is part of human nature to find out who is the biggest/largest/tallest but such an approach is not really scientific or fair. In such lists China will always come before Belgium (referring to the authors' home countries). Relative studies are able to bring forward other aspects than pure magnitude. Yet, relative studies need a baseline and as such are more subjective. If one would consider publications/population it would take many years (if ever) before China would top such lists.

In this investigation we present a relative approach able to compare any two entities (countries, regions, institutes) whatever their (publication) size. Concretely we compare the curves of the received citation distributions over a given period. The term distribution is used here in a statistical sense. This means that the sum of all values is equal to one (discrete data) or the area under the curve is one (continuous data).

The research question studied here is: Is the received citation distribution in nanoscience and nanotechnology of China approaching the one of the United States? Note that we implicitly assume that they are different.

METHOD

In this section we describe how we dealt with the following method-related questions.

a) Which set of articles are used to describe the field of nanoscience and nanotechnology in China and the USA?
b) How are citation curves compared?

Earlier investigations used an elaborate search string aiming at finding a complete collection of nano-related publications within the WoS (Glänzel et al. 2003; Lin and Zhang 2007; Kostoff, Koytcheff and Lau 2007; Zhao and Guan 2011). A related approach is to determine the leading journals in the field (Leydesdorff 2008; Leydesdorff and Zhou 2007).

Since 2005 Thomson Reuters' Journal Citations Reports (JCR) has added a category *Nanoscience & Nanotechnology*. Records of articles published in journals included in this category and published before 2005 were retrospectively assigned to the category *Nanoscience & Nanotechnology*. As we do not aim at a full or detailed description of this field we just use this category to represent the field. All publication types are included.

The next problem is to determine which publications are considered American ones and which Chinese. For our investigation US-publications are defined as publications of which at least one author has an American address and none of the authors has a Chinese address. Similarly, Chinese publications are publications of which at least one author has a Chinese address and none has a US address. This leads to two non-overlapping sets of publications.

Data were collected from the Web of Science (WoS) in November 2012, considering publications in the period [1995; 2003] and retrieving for each publication year citations received during the first ten years (including the year of publication). This leads to nine distributions of received citations for US publications and similarly for Chinese publications.

In order to compare these distribution curves we determined the maximum absolute difference, denoted as D, between the cumulative relative citation curves over a ten year period. As an example, we explain how we determined the D-value for the year 2000, see

Table 2. In this year the United States had 1175 publications in the WoS category *Nanoscience & Nanotechnology*, while China had 295 publications. The columns with headings USA and China show the yearly number of citations received by these publications. The next column shows the cumulative number of received citations, and the columns headed r(USA) and r(China) show the relative cumulative number of citations (values in the previous column divided by the total number of received citations). The difference between these two columns is shown in the last column. The maximum value of these differences is the D-value, here 0.029. We note that these data are also used when performing a Kolmogorov-Smirnov test (Egghe and Rousseau 1990), but we do not do such a test as we have another objective.

Table 2: Data for the year 2000 (source: WoS)

	USA	1175 publ.	r(USA)		China	295 publ.	r(China)	Difference
2000	334	334	0.012		24	24	0.005	0.007
2001	1920	2254	0.079		308	332	0.063	0.016
2002	2841	5095	0.179		509	841	0.160	0.019
2003	3225	8320	0.292		587	1428	0.272	0.020
2004	3506	11826	0.416		601	2029	0.386	0.029
2005	3388	15214	0.535		682	2711	0.516	0.018
2006	3378	18592	0.653		614	3325	0.633	0.020
2007	3364	21956	0.772		612	3937	0.750	0.022
2008	3356	25312	0.890		678	4615	0.879	0.011
2009	3141	28453	1.000		636	5251	1.000	0.000
							D =	0.029

The research question of finding out if these citation curves converge is then operationalized as: does the time series of D-values have a decreasing trend?

RESULTS

Table 3 and Figure 1 show the final result. The trend line (y = - 0.006 x + 0.069; R = 0.806) clearly has a decreasing trend. Hence we conclude that the relative citation curves of nanoscience publications of the USA and China converge. It is well-known that citation curves can be influenced to a large extent by one or a few highly-cited publications. In this sense we were lucky and the trend line shown in Fig.1 though not a perfect straight line, is still quite acceptable (Pearson R > 0.8).

Table 3: D-values

Year	D-values
1995	0.0624
1996	0.0780
1997	0.0487
1998	0.0285
1999	0.0266
2000	0.0285
2001	0.0249
2002	0.0387
2003	0.0115

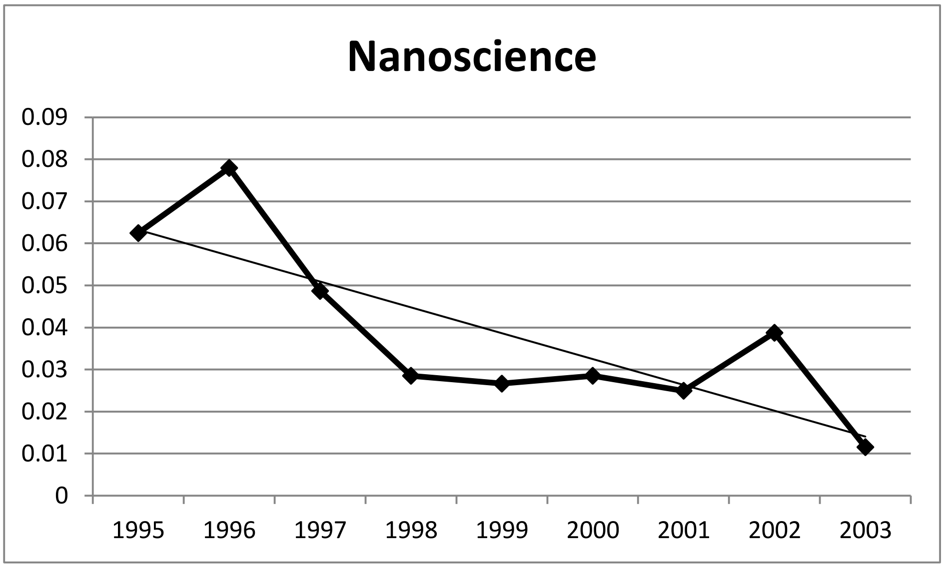

Figure 1: D-values and trend line

DISCUSSION AND CONCLUSION

The fields of scientometrics and informetrics develop and apply mathematical and statistical methods to study all aspects of scientific information. As such these fields play a crucial role in the management of science and, if necessary, in adapting existing science policies. In a climate where innovation is considered one of the driving forces leading to new technologies nanotechnology has become an R&D policy priority in many countries and regions. Under these circumstances it is of utmost importance to monitor the position of a country within this field.

In this article we took a new look at the relation between China and the United States in the field of nanoscience and nanotechnology. We found that, although during the period under study China's citations were considerably smaller than the United States', their statistical citation distributions seem to converge. This observation points to the fact that the response to China's publications in this field becomes similar to that of the United States.

Because of its size independence our approach can be used in quantitative studies of relative country performance in general. Concretely, large countries and intermediate size countries can now be compared.

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