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Research note

China/USA nanotechnology research output comparison—2011 update

Ronald N. Kostoff *

Research Affiliate/Georgia Institute of Technology/School of Public Policy, 13500 Tallyrand Way, Gainesville, VA, 20155, USA

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ABSTRACT

This Research Note updates our 2006 and 2009 China/USA nanotechnology and nanoscience (NN) research output comparisons.

A 2009 comparison of China/USA research publication outputs showed that China is about to overtake the USA in NN research output. As predicted by the extrapolated 2009 curve, China has passed USA in NN research publication output. This transition occurred in the 2008/2009 time frame, and if the 2011 results (taken at mid-2011) hold for the full year, will become quite pronounced (~20%).

When specific sub-disciplines are examined, the differences between China and USA become more pronounced. For example, the 2009 paper presented the time trend for China/USA publications in nanocomposites, an important sub-discipline of NN. The updated nanocomposites curve has increased about twice the rate of the overall NN curve, and shows no sign of abating.

The USA papers lead in the numbers of citations by all metrics considered, but the Chinese papers are showing significant improvement with time. Overall, the Chinese papers are cited very modestly, but there is a core of 'heavy hitters' that appears to be increasing substantially with time, and is increasingly making its presence known in the higher Impact Factor journals.

1. Background

In 2004–2005, the Office of Naval Research conducted a scientometric assessment of the global NN literature. A modest-sized NN query was developed, and applied mainly to the 2003 Science Citation Index/Social Science Citation Index (SCI/SSCI) database. Conclusions relative to East Asia trends were as follows [1–4]:

- The Far Eastern countries have expanded nanotechnology publication output dramatically in the past decade.
- The People's Republic of China ranks second to the USA (2004 results) in nanotechnology papers published in the SCI, and has increased its nanotechnology publication output by a factor of 21 in a decade.

Based on the wide interest shown in this study, an expanded analysis of the global NN literature was conducted in 2006 by the Office of Naval Research. The query used for the 2004–2005 study was expanded to over 300 terms, and included not only topical components, but journal and address information as well. It was the most comprehensive NN query in use at the time. Many unique features were added to the study, a comprehensive report was published [5], and spinoff papers were generated to make the results available more widely [6–18].

Two of the unique features in the comprehensive report and the encyclopedia chapters related to sharpened display of the autocorrelation maps (social networks) and generation/cross-plotting of unique variable sets. One of the problems with display/interpretation of autocorrelation maps and associated social networks is the data density tends to make many of these network maps unintelligible. We found that choosing a mid-region of the text frequency spectrum (neither the highest nor lowest frequency phrases) transformed the network displays from 'spaghetti' diagrams to crystal-clear easily interpretable diagrams.

* Tel.: +1 571 248 2661.
E-mail addresses: ronald.kostoff@pubpolicy.gatech.edu, rkostoff@gmail.com.

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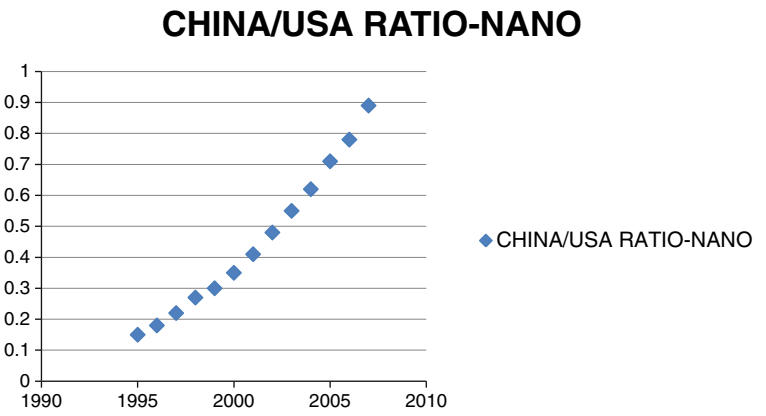

Fig. 1. Ratio of China/USA nanotech publications.

The unique variable sets were obtained by generating desired categories beforehand (major nanotechnology instruments, materials, properties, phenomena, nanostructures, etc.) that could not be obtained from document clustering or factor analysis of the raw data, and assigning the specific technical phrases that belonged to each category by visual inspection. While this approach was highly labor intensive, it produced categories of interest unmatched by any other study at the time.

In 2009, under the auspices of the MITRE Corp., this query was used to compare China/USA NN research output dating back over a decade. The results were published as part of a larger China/USA research output comparison [19]. It used three main assessment metrics: 'right job' (investment strategy/research merit), 'job right' (research quality), and progress/productivity. There are four metrics commonly used for the progress/productivity category: input, output, impact, and outcome. While 'outcome' is the desired goal, it tends to occur far downstream of the research performance/publication in time, and has limited use in a management sense. Therefore, the proxy metrics of output and impact tend to be used in the majority of research publication assessment studies, and that was the case in the 2009 study. The relative investment thrusts for the USA and China tended to be highly polarized, with China showing strong relative emphasis in the physical and engineering sciences and the USA showing strong relative emphasis in the biological, social, and psychological sciences. It was concluded that "China's investment strategy is providing a solid technology-based foundation for future military and commercial competitiveness."

One of the proxy output metrics from the 2009 studies was as follows. Fig. 1 (reproduced from Ref. [19]) compares China/USA NN research outputs (based on numbers of NN records in the Science Citation Index, and using only records classified as Articles and Reviews). There are two points of note about this graph. It is remarkably smooth, and shows China about to overtake the USA in NN research output.

In mid-August 2011, the 2006 NN query was re-run on the new Web of Science database, to update the China/USA NN research output comparison. A summary of the results follows.

2. Results

Fig. 2 contains an updated version of Fig. 1. Except for an anomaly in 2010, the curve is again remarkably smooth. As predicted by the 2009 curve (if extrapolated), China has passed the USA in NN research output, as defined by the metric in this study. This transition occurred in the 2008/2009 time frame, and if the 2011 results hold for the full year, will become quite pronounced (~20%).

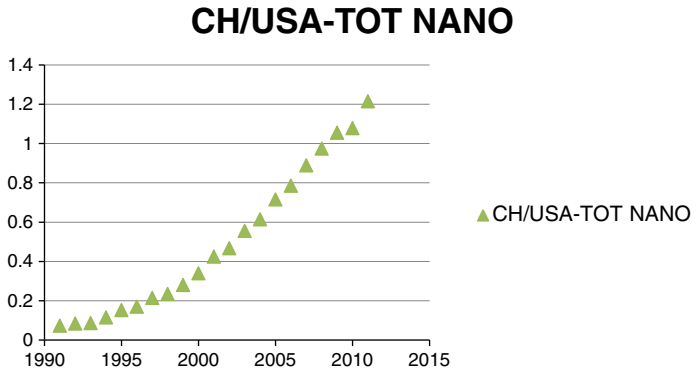

Fig. 2. Ratio of China/USA nanotech publications.

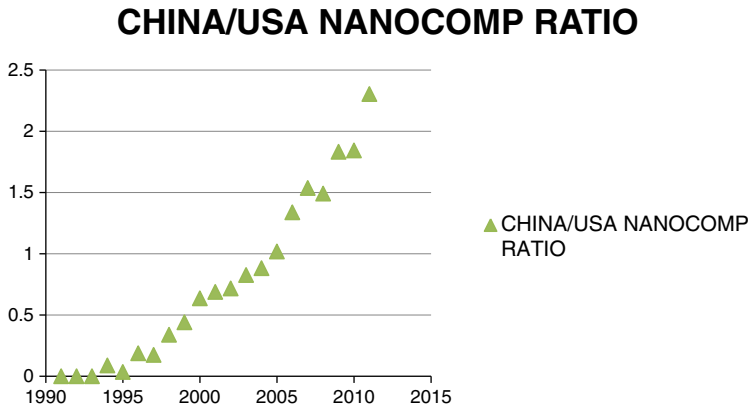

Fig. 3. Ratio of China/USA nanocomp publications.

These results apply to the broad discipline of NN. When specific sub-disciplines are examined, the differences between China and USA become more pronounced. For example, the 2009 paper presented the time trend for China/USA publications in nanocomposites, an important sub-discipline of NN. Fig. 3 presents the updated trend comparison for nanocomposites. The curve has increased about twice the rate of the overall NN curve, and shows no sign of abating. There are undoubtedly other NN sub-disciplines where the trend rates are even higher than for nanocomposites. At this level of detail, the analyst can examine specific investment spikes, such as nanocomposites, and start to connect the dots to identify the investment strategy priorities on an integrated basis.

The above results apply to quantity published in a sub-set of the total literature. What about the quality of these published results? One measure of quality is citations received. Fig. 4 uses two simple citation metrics for comparison. One is the median number of citations of the ten NN papers cited most highly ('heavy hitters'), and the other is the median number of citations of all the NN papers published in the year of interest.

The USA papers lead in the number of citations by both metrics. However, especially in the top ten metric, the Chinese papers are showing significant improvement with time. Thus, overall, the Chinese papers are cited very modestly, but there is a core of 'heavy hitters' that appears to be increasing substantially with time. This result coincides with the findings of our 2005/2007 assessments of China's R&D outputs [8,20–25], which showed that much of their increase in publication quantity was in relatively low Impact Factor journals, but there was a small and growing core that was increasingly making its presence known in the higher Impact Factor journals.

As examples of the latter, Figs. 5 and 6 compare China/USA publications in the journals Applied Physics Letters (APL—Impact Factor almost 3.9) and Journal of Applied Physics (JAP—Impact Factor greater than 2), the two most highly cited journals in applied physics according to the American Institute of Physics. For APL, China started from an almost zero ratio in the early 1990s to its present ratio of about half of USA publications, where it has remained since mid-decade. For JAP, China started from a small ratio in the early 1990s, grew steadily but slowly, and has increased dramatically since mid-decade. China is presently at about 70% of USA publications in JAP, with no signs of abating its dramatic growth. It almost appears that Chinese researchers shifted their publication strategy growth from APL to JAP, but that may also be coincidental. A more detailed analysis would be required to clarify this issue.

	USA		CHINA	
YEAR	MEDIAN TOP 10	MEDIAN ALL	MEDIAN TOP 10	MEDIAN ALL
1992	1499	18	91	5
1997	1933	18	207	5
2002	1668	18	497	6
2007	677	9	232	5

Fig. 4. China/USA nanotech citation comparisons.

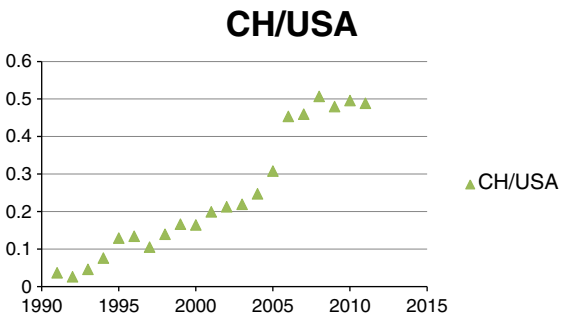

Fig. 5. Ratio of China/USA nanotech publications in APL.

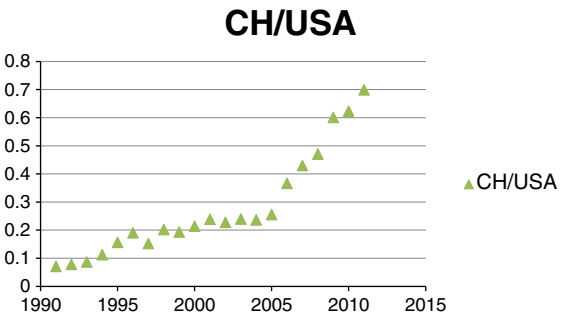

Fig. 6. Ratio of China/USA nanotech publications in JAP.

3. Conclusions

China's rapid growth in NN research publications in the SCI continues unabated. The number of 'heavy hitters', as evidenced by increasing citation counts and increasing publications in higher Impact Factor journals, continues to grow.

It should be noted that the number of publications in SCI-indexed journals is only one measure of research performance, albeit an important measure. Many other factors (well beyond publications and citations) need to be considered for a comprehensive research assessment. Nevertheless, China's NN research publication performance based on the few and simple metrics used for this analysis is quite impressive.

The numbers for China also have to be viewed in a larger context. For technology and engineering development, it is very important to have a trained cadre of researchers available to address the research issues that inevitably arise in the course of development. It is not necessary for these researchers to all be highly cited authors in order for them to have substantial value for supporting and accelerating technology and engineering development. If researchers are of the caliber to publish in the high quality journals typically accessed by the Science Citation Index, they can offer expert assessment of what is being produced globally, and can exploit this cutting edge research in the development process.

Thus, if China is increasing the numbers of nanotechnology researchers rapidly, and if their participation in highly cited papers is increasing at the same time, this rapid and increasing quality growth translates into a powerful foundation for accelerated growth in the industrial capability of their national development in the future. They are building a strong foundation not only for enhanced research quantity and quality capability, but for the more commercially and militarily important industrial capability as well.

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FURTHER READING

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Ronald Neil Kostoff received a Ph. D. in Aerospace and Mechanical Sciences from Princeton University in 1967. He conducted research at Bell Labs and MITRE Corp, and managed programs at the Department of Energy and Office of Naval Research. He is presently a Research Affiliate with the School of Public Policy, GA Tech, where he focuses on textual data mining. He is listed in Who's Who in America, Who's Who in Science and Engineering, and 2000 Outstanding Intellectuals of the 21st Century.