Mapping knowledge production and scholarly communication in China
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Chapter 12
Conclusions, Discussion, and Perspectives

1. Conclusions
This chapter will answer the questions raised in Chapter 1. Since the studies are based on data sources including the WoS and the CSPTCD which have coverage limitations, the conclusions ONLY reflect the dynamics of knowledge production and scholarly communication in peer-reviewed journals covered by the WoS or the CSPTCD.

1.1 China has become a major producer of scientific publications

China’s exponential growth (Figs. 1 and 2 in Chapter 4) in scientific publications is unique in the world. Along with the exponential increase of scientific publications, the citation rates of Chinese publications are increasing exponentially as well (Figure 3 in Chapter 4). Other indicators measuring the impact of publications, such as the percentage of world share of citations and the number of most highly cited publications, also demonstrate the increased status of Chinese publications (Figs. 4 and 5 in Chapter 4). Nonetheless, the overall citation impact of Chinese publications is still low because of not being well cited by international authors. The progress of citation impact of Chinese publications is much slower than that of publications. In the international scientific community, citation relations mostly happened between Chinese publications since Chinese journals have not integrated into the citation environment of international journals.

In addition to raising its holistic level in publishing scientific literature, China has put enormous energy in developing critical fields, one of which is nano-science and technology. Although China started research in this field later than other major countries like the USA, France, Germany, and Japan, its world share of publications in this field has increased rapidly. China took the second position in 2004 just behind the USA and has potential in further expanding research in this field. Such expectation is based on China’s higher world share of publications in nano-relevant fields compared with its world share of publications over the entire data set of the SCIE. The USA and the EU are the major players in this field, while China, Japan, and South Korea account for most of the remaining share (Figures 11 and 12 in Chapter 4).

The Chinese government pays unprecedented attention to the development of knowledge production and the transition to a knowledge-based economy. More than any other country in the world, funding for R&D is growing not only absolutely, but also relative to the spectacular growth in the gross domestic product (Figures 14 and 15 in Chapter 4). It is noteworthy that business investment in R&D is increasing even faster than government expenditure. This increased investment has been reflected in the output and thus one may assume an efficient coupling between input and output in scientific research. Among the countries studied, Japan has the highest GERD/GDP ratio, and its trend shows linear growth, but like most countries it spends more to maintain approximately the same share (Cozzens et al., 1990). The EU countries grow slowly in terms of this indicator, but they are still more than one percent below the...
target of 3% (GERD/GDP) set by the “Lisbon” agreement. The USA’s investment is higher than that of the EU countries, but with less output in scientific publications.

China has huge human resources in science and technology. With exponentially increased funding and proper guidance of scientific policies, China’s increased momentum in knowledge production is expected to be sustainable. Our most recent study (Zhou & Leydesdorff, 2008) based on the SCIE 2007 has proved such expectation. Nowadays, the problem for China is not the production of scientific publications, but the dissemination and visibility of scientific publications in the international communication system of science.

1.2 Regional contributions are highly skewed

A few Chinese regions are very productive while the most regions are not. Regions with the most human resources usually have high national share of both publications and citations. Beijing, Shanghai, Hong Kong, and Jiangsu take the lead and Qinghai, Hainan, Macao, Ningxia, and Tibet are almost invisible in either publications or citations. Regions in the Mainland are apparently active in publishing in traditional disciplines including physics, chemistry, and mathematics. Some regions are also active in geosciences and space sciences but are not strong enough to raise China above the world average in this subject category. For historical reason, Hong Kong has its own activity pattern of being extremely active in engineering and mathematics. Compared to regions in the Mainland, Hong Kong’s publication activities in other fields are relatively balanced.

Regional Citation impact in terms of national share of citations basically corresponds to regional productivity: the leading prolific regions are also leading contributors to national citations. Relative citation impact of leading regions from the Mainland is lower than the world average. The performance of Hong Kong is best. No matter the indicators are based on production scale or on average quality, Hong Kong is always among the top.

The decline of Hong Kong in national share of publications may imply that Hong Kong has reached its potential in publishing international papers. But the situation in Chinese Mainland regions is different: they have huge reservoir of human resources and a large population of the manpower has not published internationally yet. For historical and language reasons, Chinese Mainland researchers mainly publish in domestic journals. With China’s effort of integrating into the outside world, more and more Mainland researchers will shift from publishing domestically to internationally. This trend has already been seen in China’s amazing growth in international publications, and there is no sign showing this growth trend will slow down or stop (Zhou and Leydesdorff, 2008).

Regarding to the relation between R&D and scientific publications, high R&D expenditure does not necessarily bring high output since scientific publications are only one form of R&D output. In the case of Chinese regions, high investment in R&D does have some relevance to knowledge production in publications: prolific regions usually invest more in R&D, although productivity does not well-corrrespond to R&D investment.
1.3 International collaboration plays an important but decreasing role

While establishing collaboration relations with more countries in science, China has strong relations with countries including the USA, Japan, the UK, Germany and Canada. Collaborations with Australia and Singapore have also been enhanced. Chinese internationally co-authored publications keep growing, but the contribution to Chinese total productivity is decreasing. This is not the case in most scientific players like the USA, the UK, Germany, Japan, etc. The fact that the growing momentum of Chinese total publications is faster than that of international ones may explain the Chinese phenomenon.

International collaboration compensates China’s disciplinary deficiency: China’s disciplinary publication activities are skewed with extreme activity in Chemistry, Physics, and Mathematics. But its activity in international collaboration is the opposite. International collaboration increases China’s citation impact in almost all scientific disciplines except that of mathematics. But the raising effect of international collaboration in many subject categories has reduced remarkably. The subjects in which China is extremely inactive, namely, clinical and experimental medicine and neuroscience and behavior, still increasingly benefit from international collaboration.

In terms of regional activeness in international collaboration, prolific regions like Beijing, Hong Kong, Shanghai, and Jiangsu are also the most active in international collaboration.

International collaboration in the social sciences has also been increased in China. The USA and Singapore are two major countries collaborating with China. Other important Chinese partners include the EU-15, Australia, Canada, and the UK. Collaboration ties with Singapore, South Korea, the USA, and the EU-15 have increased, but the collaboration relation with Japan has decreased.

1.4 China progresses slowly in the internationalization of social sciences

The world share of Chinese publications in the social sciences is very low. On the way to publishing internationally, China develops slowly with some visible changing points in 1978, 1997 and 1999 respectively. The adoption of the Opening-up Policy in 1978 had positive but limited impact on Chinese social sciences. The return of Hong Kong in 1997 has remarkable effect in increasing China’s world share. In fact, Hong Kong has become a major contributor to Chinese publications, although its role started to decline since 2005. While the rapid growth trend of the Mainland is speeding up, Hong Kong seems having reached its production potential. The year 1999 can be considered as a turning point of Chinese social sciences since publications from the Mainland increased sharply.

The development of the social sciences is slower than that in the natural sciences in China (Zhou & Leydesdorff, 2006, 2008). Although Chinese publications began to grow visibly in 1999, the gap between China and the West represented by the USA and the EU is too wide to be narrowed within a short period. Not only China, other major Asian countries including Japan, South Korea, New Zealand, Singapore, and India do not perform well in terms of internationalization. It seems that the SSCI reflects the publication performance of the West (Europe and the USA) better than
that of the East. As one of the major players in the natural sciences, Japan has a quite low world share in the social sciences. Publications from the USA and the EU-15 have higher citation impact than those from Asia. Furthermore, the world share of citations of most Asian countries including China and Japan were lower than their world share of publications. On the contrary, both the USA and the EU-15 have higher world share of citations compared to their world share of publications.

Regarding to publication activity in the three selected main fields (i.e., psychology; economics and business administration; social, political and communication sciences) in the social sciences, the USA sets the standard or world average. The EU-15 and Japan have similar patterns: both are active in publishing in psychology. China and Singapore are relatively more active in economics and business administration. Japan is an exception among Asian countries in this regard. Citation impact of the studied countries/region corresponds to their publication activities. The EU-15 and Japan have higher citation impact in psychology. China, South Korea, and Singapore share similar citation patterns with relatively higher citation impact in economics and business administration and less citation impact in psychology. But Asian countries have not yet reached the standard set by the USA.

1.5 The Chinese scholarly communication system is special

Communication among Chinese scholars is less active than that among international ones. In the domestic community, knowledge mainly flows from high-quality journals to the lower ones. High-quality international journals have a higher rank in the hierarchy than do their Chinese counterparts: knowledge flow between Chinese and international scholars are not balanced. Chinese authors mainly play as knowledge receivers while international authors play as knowledge contributors. Definitions about knowledge receiver, knowledge producer, and knowledge contributor are introduced in the third part (i.e., the Perspectives) of this chapter.

The international visibility of Chinese journals varies among disciplines. Among the selected fields including general science, materials science, mathematics, and the life sciences, journals in materials science and mathematics have a relatively higher visibility while that in the life sciences is the lowest.

Language is an important factor that affects a journal’s visibility. Both Chinese university journals and the CAS (Chinese Academy of Sciences) journals have high domestic citation rate. Both international and domestic visibilities of the CAS journals are higher than those of university journals. Journals in the general sciences are supposed to entertain citation relations with journals in a wide range of fields. But this is not always the case in Chinese journals. The English version of the CSB has this characteristic but the Chinese version of CSB has higher visibility in the geosciences.

Chinese journals with high Impact Factors (IF) do not necessarily have high local impact. Therefore, except the IF other elements like local citation impact and the specific role of a journal should be considered while conducting journal evaluation. For example, the JME (Journal of Mathematics Education) has the highest impact factor in the category of mathematics, but its citation impact on other journals is very weak. This is because most citations of the JME are within-journal citations. The local citation impact of the AMS-C (Acta Mathematica Sinica – Chinese version) is the
highest although its global impact factor is lower than that of the *JME*. It is also inappropriate to compare journals serving different functions. According to its title, the *JME* is a journal in mathematics education. This journal does not have citation impact on mathematics journals but do have citation impact on journals from educational institutions (i.e., university journals) especially journals of normal universities which mainly provide higher education to future teachers. In this situation, it is perhaps better to classify the *JME* into a subject category like education science.

To summarize, science development in China is unique: 1) Chinese knowledge production keeps exponential growth and there is no sign showing the increasing speed will slow down; 2) While having the publication characteristics of that of the formal socialist countries with extreme activity in chemistry and physics, the Chinese publication system is also very active in mathematics. 3) The Chinese pattern of international collaboration is different from most of those advanced countries: national share of international coauthored publications goes down while that of most countries grows up. But international cooperation helps raise China’s international visibility and impact; 4) Regional contributions to China’s knowledge production are highly skewed, which corresponds to the estimation of Cole and Cole (1972) about the productivity of scientists if we change the analytical unit from individual scientist to individual Chinese regions. The estimation of Cole and Cole (1972) is “roughly 50% of all scientific papers are produced by approximately 10% of the scientists”.

Being a leading nation in terms of publications in the natural sciences, China progresses slowly in the internalization of social sciences. The internationalization speed of Chinese social sciences is much slower than that of the natural sciences in China. But because of the coverage limit of the *SSCI* and the close tie between social sciences and the national, cultural, social, and political environment, publication in the social sciences can be very local or national. Therefore the current results which are based on an international database cannot tell the overall situation about China’s research in the social sciences. It is necessary to analyze Chinese domestic publication databases in the social sciences so as to better understand the Chinese situation in this regard. Unfortunately, data was lacking during the period of this dissertation research so that I was not able to analyze the Chinese domestic publication activity in the social sciences.

The Chinese government pays unprecedented attention to the development of knowledge production and the transition to a knowledge-based economy. More than any other country in the world, funding for R&D is growing not only absolutely, but also relative to the spectacular growth in the gross domestic product. Business investment in R&D increases even faster than government expenditure.

Compared to their international counterparts, Chinese scholars are less active in communicating through scientific literature since they provide fewer references in their publications. In the domestic community, knowledge mainly flows from high-quality journals to the lower ones. High-quality international journals have a higher rank in the hierarchy than do their Chinese counterparts: knowledge flows mainly from international scholars to Chinese scholars. Knowledge produced by Chinese scholars is not well-received by the international community. Chinese authors mainly play as knowledge receivers while international authors play as knowledge contributors.
2. Discussion

As the dissertation is based on a bibliometric methodology, it is necessary to introduce some basic knowledge about bibliometrics and clarify the merits and flaws in terms of bibliometric application so as to help readers better understand relevant results and conclusions.

2.1 Brief knowledge about bibliometrics

Since its emergence in the late 60s of last century, bibliometrics has become increasingly important in science policy and research management. The term “bibliometrics” was first defined by Pritchard (1969) as “the application of mathematical and statistical methods to books and other media of communication”. In the same year, Nalimov and Mulchenko (1969) proposed another term – scientometrics. They defined scientometrics as “the application of those quantitative methods which are dealing with the analysis of science viewed as an information process”. Although bibliometrics has wider coverage than scientometrics according to their respective definitions, both terms are almost used as synonyms (Glänzel, 2008a) in the bibliometric/scientometric community.

Modern bibliometrics is mostly based on the work of Derek J. de Solla Price and Eugene Garfield. The former adopted a new element in the historiography and sociology of science in the course of examining the major transformation of science as prefigured in his book: From Little Science to Big Science (Price, 1963). The latter invented the Science Citation Index, and founded the Institute for Scientific Information (ISI) which produces the Web of Science (WoS) and the Journal Citations Report (JCR) (Garfield, 1979).

Books, monographs, theses, and papers in serials and periodicals are the units of analysis in bibliometrics. Since certain standards are postulated for scientific papers published in refereed scientific journals, such units proved to be the unit of analysis most suitable for scientometric studies (Glänzel, 2008a). As an inter-disciplinary instrument, scientometrics originates from the information sciences. The original purpose was to improve bibliographic databases and to extend information services. After about 40 years’ development, the most important task of scientometrics has become serving for science policy and research management. Journal publications, (co-)authors, references, and citations are basic objects of scientometric study.

The ISI’ Web of Science (WoS) is the most commonly used data source and contains three important databases: the Science Citation Index Expanded (SCIE), the Social Science Citation Index (SSCI), and the Arts & Humanities Citation Index (AHCI). The Science Citation Index (SCI) has two versions: the SCI CD-ROM and SCI Expanded (SCIE). The SCI CD-ROM is simply called the SCI. The SCIE is the web version of the SCI and covers more journals than the CD-ROM version. The SCI was created by Eugene Garfield in 1963 and has become the most generally accepted source in the scientometric community. The ISI’s other database relevant for this study is the Journal Citation Reports (JCR) which are derived annually from the citation databases. The JCR is also used as an indirect subject assignment of individual publications. Journals in the JCR are assigned to various subjects. For
example, if a journal is assigned to the subject of chemistry, all publications in this journal are assigned to the same subject, which is chemistry.

In 2004, the Dutch publisher Elsevier established the SCOPUS which has similar functions as the corresponding databases of the WoS. Since the late 80s of last century, two Chinese science citation databases and one social science citation database were established successively. The first database, the China Scientific and Technical Papers and Citations Database (CSTPCD), was set up in 1987 by the Institute of Scientific and Technical Information of China. By 2006, China has around 5000 S&T journals and 3000 journals in the social sciences and humanities. The CSTPCD covered 1723 S&T journals in 2007. In 1989, the Documentation and Information Center of the Chinese Academy of Sciences (DICCAS) constructed a similar database – the Chinese Science Citation Database (CSCD). The CSCD covered 1083 journals in 2007 (CSCD, 2008). Two databases in the social sciences and humanities are seen in China.

The first Chinese citation database in the social sciences – the Chinese Social Science Citation Index (CSSCI) was established in 2000 by Chinese Social Sciences Research Evaluation Center affiliated to Nanjing University. The CSSCI covers 680 journals in the period 2007 (CSSCI, 2008). Another database entitled the Chinese Humanities and Social Science Citation Database (CHSSCD) is produced by the Centre for Documentation and Information attached to the Chinese Academy of Social Sciences. The first citation database of the CHSSCD appeared in 2000 (Zhou, 2002). The CHSSCD covered 662 journals in 2001. In terms of social visibility, the CSSCI is better known than the CHSSCD. All the Chinese databases have similar structures as their international counterparts, but are based on Chinese domestic journals.

With the development of science, the demand of supplementing the assessment of research with quantitative methods and linking research funding to performance indicators increases. Such requirement promotes scientometrics to evolve from a sub-discipline of information science to an inter-disciplinary specialty (Glänzel, 2008b). Library and information science is the foundation of bibliometrics/scientometrics. Mathematics is the critical tool for constructing bibliometric indicators and models. Sociology of science lays theoretical ground for scientometrics. Scientometrics can also be used for studying the sociology of science (Elkana et al., 1978; Leydesdorff, 1986, 1998; Wouters, 1999). Social network analysis like citation analysis and betweenness centrality among journals has become an important practice in scientometrics (Otte & Rousseau, 2002; Leydesdorff, 2007a; Leydesdorff, et al., 2008a; Park & Leydesdorff, 2009; Zhou & Leydesdorff, 2007a; Zhou & Leydesdorff, 2007b).

Present bibliometrics can be divided into three sub-areas (Glänzel, 2008a): 1) Bibliometrics for bibliometricians. This is the domain of basic bibliometric research focusing on methodological exploration; 2) Bibliometrics for scientific disciplines. This domain can be considered as an extension of science information by metric means. There is a joint borderland with quantitative research in information retrieval. 3) Bibliometrics for science policy and research management. This is the most important domain in bibliometrics which focuses on national, regional, and institutional structures of science and their comparative presentation.
After several decades of development, institutions engaged in scientometric research and education have been established in many countries. Here I just list some of them: the Institute of Science Information (ISI) in the USA, the Information Science and Scientometrics Research Unit at the Hungarian Academy of Sciences, The Center for Science and Technology Studies (CWTS) in The Netherlands, the Steunpunt O&O Indicatoren (SOOI) in Belgium, the National Institute of Science, Technology and Development Studies (NISTADS) in India, and so on. Since journals, professional societies, and international conferences are important indicators to determine if a new field is viable, let me provide information about the development of scientometrics. The first journal was founded in 1978 with exactly the name of the field – *Scientometrics*. Other journals pertinent to scientometrics include the *Journal of Informetrics*, the *Research Evaluation*, the *Journal of American Society for Information Science and Technology* (*JASIST*), and so on. In 1993, the International Society for Scientometrics and Informetrics (ISSI) was founded with members all over the world. In addition, the ISSI has its own publications – the *ISSI Newsletter* which is published monthly and provides a communication channel for scientometricians or informetricians. Important international conferences pertinent to scientometrics include the International Conference on Scientometrics and Informetrics organized by the ISSI biennially since 1987 and the biennial Conference on Science & Technology Indicators organized by the Centre for Science and Technology Studies (CWTS) in Leiden.

The development and consummation of data sources and the rapid progress in computer science and technology accelerates the development of this field of studies. Nowadays, bibliometrics has played an important role in science policy and research management. Significant compilations of science indicators, such as the Science and Engineering Indicators of the National Science Board of the U.S.A. and the European Reports on S&T Indicators, heavily rely on publication and citation statistics and other more sophisticated scientometric techniques. Furthermore, some governments have embraced scientometrics with great expectation for the purpose of research evaluation. The British government announced that a new framework for assessing and funding university research would be introduced following the completion of the research assessment exercise in 2008, intending to replace their current method for determining the quality of university research – the UK Research Assessment Exercise (RAE) (Universites UK, 2007). Metrics, rather than peer-review, will be the focus of the new UK system and it is expected that bibliometrics will provide the central indices for quality in this system.

In the Flemish region of Belgium, science policy has evolved very much into the direction of scientometric-based evaluation and allocation rules. Two mechanisms, the BOF and the IOF, rely heavily on bibliometric analysis. The BOF (i.e., the Bijzonder Onderzoeksfonds) mechanism distributes R&D funding to universities for basic research. The IOF (i.e., Industrieel Onderzoeksfonds) mechanism provides funding to universities for industry-relevant research. In order to better serve the bibliometric-based evaluation mechanisms, a specific organization, the Steunpunt O&O Indicatoren (SOOI), has been established since 2002. The SOOI is an interuniversity consortium with participation of all Flemish universities (K.U.Leuven, UGent, VUB, UA and UHasselt). The K.U. Leuven is responsible for indicators on research output and innovation. Ghent University focuses on Human Resources in Research (doctorates, doctoral careers and researchers’ mobility). The other three
Flemish universities (the Free University of Brussels, the University of Antwerp and the University of Hasselt) are partners in the project.

Some other countries also partly adopt bibliometric analysis in R&D allocation. For example, the link between research funding and quantitative performance measures has existed in Australian universities for a decade (Butler, 2004). In 2005, the Norwegian government introduced an output indicator for scholarly publications in the funding formula for the basic funding of research in the Higher Education Sector (Siversen, 2008). In the European Commission Bibliometric indicators also figure prominently in the Seventh Research Framework Program (FP7).

2.2 Problems in bibliometrics

While playing increasingly significant roles in S&T policy making and research evaluation, bibliometrics has faced more challenges. As mentioned before, bibliometrics was originated for improving the use of bibliographic databases and extending information services (Glänzel, 2008). The new application in research evaluation brings bibliometrics more challenges in addition to some flaws already exist (Edge, 1979; Chapman, 1989; MacRoberts & MacRoberts, 1986, 1989, 1996; Leydesdorff, 2007c). Caution should be taken while applying bibliometrics to assess research performance and assign research fund. Major problems of bibliometrics are generalized below.

2.2.1 The coverage limit of relevant data sources

Commonly used data sources in bibliometric community are the WoS in the USA and the SCOPUS in The Netherlands. These data sources mainly include publications in peer-reviewed scientific journals and conference proceedings. But not all peer-reviewed journals and conference proceedings are included. In addition, other forms of literatures such as books and none peer-reviewed journals are not covered. When some fields publish heavily in literatures are not included in the WoS or SCOPUS, scienotmetric results based mainly on journals can be severely biased (Figure 1).
Peer-reviewed journals and conferences are the major communication channels for most fields. But situation in the social sciences and arts and humanities are exceptional since more communication channels exist. In some traditional scientific fields such as mathematics, chemistry, physics, and biology, the share of peer-reviewed journals take more than half of the overall publication types. In other fields especially the applied sciences, the engineering sciences, the social sciences, and computer and information sciences, the shares of peer-reviewed journals are much less than other publication types like conference proceedings (Figure 2). Therefore, bibliometric results based on peer-reviewed journals can be more representative for the natural sciences than for the social sciences, arts and humanities, and computer and information science.

Another problem of these data sources is the language bias. First, language biases play an important role in the comparison and evaluation of national science systems (Leeuwen et al., 2001). For instance, the WoS databases contain very few non-English journals. Such coverage favours English speaking countries like the USA, the UK, and Canada. While the USA and the UK have barely any publications in other than English-language journals, but countries like Germany, France, and Switzerland still have significant number of publications in languages other than English. The Chinese situation is more exceptional. This country has around 5000 S&T journals among which majority are in Chinese. In 2006, the Chinese database the CSTPCD covered 1723 journals in which 407,808 papers were published (ISTIC, 2007). But only 76 Chinese journals were covered by the SCIE in 2007. Therefore, what one can get from the ISI databases is the internationalization of a nation in science.

2.2.2 Problems in citations
What are citations? The fact that there are a lot of definitions about the meaning of citations suggests that citations are complicated. Cozzens (1989) claims that citations are the result of two systems underlying the conduct of scientific publication, one a “reward” system and the other “rhetorical”. The first kind has the meaning most often associated with a citation – an acknowledgement that the citing paper has “intellectual debt” to the cited. The second, however, has a meaning quite different – a reference to a previous paper that explains some result, perhaps not a result of the cited author at all. Such kind of rhetorical citations is merely a way to carry on a scientific conversation, not establish intellectual indebtedness. Leydesdorff defines citations as references to other textual elements from the perspective of the citing article (Leydesdorff, 1998). Glänzel and Schoepflin (1999) interpreted citations as “one important form of use of scientific information within the framework of documented science communication” (1999).

Citations involve two major processes: the citing process of scientific authors and the process of inverting citation to the cited side. Both processes lack theoretical grounding. Since the citing behaviour of authors has a direct relationship to the value of citation analysis, citation analysis must be accounted for in terms of the citation behavior of authors. Merton (1977) first explained references in terms of the norms of science as “citations and references operate within a jointly cognitive and moral framework”. But reasons for making citations vary extensively. A proper and satisfactory theory of citing is still lacking (Cronin 1981, 1984; Cozzens 1981, 1985, 1989; Luukkonen 1990; Luukkonen 1997; Leydesdorff, 1987, 1998). Citation analysts invert the citation matrix to the cited side (Wouters, 1999). This inversion is a large step which requires theoretical justification.

Citation analysis examines the frequency, patterns and graphs of citations in published literatures. A basic assumption in citation analysis is that “all citations are equal” (Smith, 1981), which makes it possible to add citation frequency of a given article. Based on individual articles, citation frequencies of individual researchers, research groups or institutions, journals, countries, or disciplines can also be summed up at higher levels of aggregation. Nowadays, citation frequencies have become important indicators in research evaluation. Citation frequency is so important that it may affect researchers’ income or career promotion. Because of this significance, citations are compared as the “currency of science” (Wouters, 1999). Results of citation analysis may also affect the allocations of research funds.

Is every citation equal? Can citation frequencies (or counts, or rates) really measure quality? Let us first check why scientists make citation so as to answer the first question. Garfield and Weinstock (Garfield, 1964; Weinstock, 1971) summarized the following 15 reasons for why scientists refer others’ work:

- Paying homage to pioneers,
- Giving credit for related work (homage to peer),
- Identifying methodology, equipment, etc.,
- Providing background reading,
- Correcting one’s own work,
- Correcting the work of others,
- Criticizing previous work,
- Substantiating claims,
Alerting to forthcoming work,
Providing leads to poorly disseminated, poorly indexed, or uncited work,
Authenticating data and classes of facts – physical constants, etc.,
Identifying original publications in which an idea or concept was discussed,
Identifying original publications or other work describing an eponymous concept or term,
Disclaiming work or ideas of others (negative claim),
Disputing priority claims of others (negative homage).

It is clear that citing others’ work can be various reasons. The relation between the citing and cited works can be positive, neutral, or negative. For instance, reasons 1-4 can be considered as positive while list 5-7, 14 and 15 are negative. Citations are not equal even cited literatures contribute positively to the citing work, because the extent of contribution of different cited literatures may also differ. Therefore considering each citation the same in terms of values lacks empirical grounding. But citations can be treated equally if they are considered as use of information, no matter the relation between the citing and cited literatures is positive, negative, or neutral.

Nevertheless, it is still worth of discussing if the expression “all citations are equal” can really reflect the practical situation. In scientific papers, all cited literatures only appear in the reference list once no matter how many times they appear in the text of a citing paper. In other words, some cited publications are used more than once in the same citing paper but are treated the same as those only appear once: both types of publications are counted as ONE citation. Till now, this problem has not been solved yet.

Can citations be used to measure quality? The fact that citation relation between citing and cited papers can be positive, neutral, or negative implies that citations do not necessarily point to quality. Regarding to citation frequencies, a less frequently cited paper does not necessarily have lower quality. In addition to a paper’s quality, many other factors including time and disciplinary attribution may affect a paper’s citation counts. A less frequently cited or uncited paper may only tell that the paper is less or not accepted by the community by the moment the citation counts are calculated. Just as Braun and his colleagues remarked:

“(I)f a paper receives 5 or 10 citations a year throughout several years after its publication, it is very likely that its content will become integrated into the body of knowledge of the respective subject field; if, on the other hand, no reference is made at all to the paper during 5 to 10 years after publication, it is likely that the results involved do not contribute essentially to the contemporary scientific paradigm system of the subject field in question” (Braun, et al., 1985).

Citations analysis involves complex processes. In addition to different reasons and roles of citations in a specific citing paper, other factors especially in the processes of providing references and indexing citations, may also affect the result of citation analysis. Scientists cite others work by listing them in a reference list. This referring process may result in misrepresentation. A scientist may refer to nonexistent papers just because of typing wrong page number or year or making spelling mistakes. While making references, authors may cite sources only known through intermediary
publications. This may cause irrelevant sources be counted as citations and therefore misrepresent intellectual influence. Misrepresentation may also appear when senior researchers systematically over-cite the work of their students and young colleagues so as to “put them on the intellectual map”, thus indirectly enhancing their own standing and inflating the influence of young and less well-known scientists (Zuckerman, 1987).

Citation assignment for co-authored publications is another problem. Credit assignment to coauthors is difficult, even coauthors themselves are hard to agree on what led them to particular ideas or who did what, let alone specifying their scientific influences (Zuckerman, 1987). Sometimes, over-inclusion and under-inclusion also occur in co-authored publications. Some scientists maybe included in papers which they do not have any contribution, while some less well-known and junior contributors might not appear. It also happens that some prominent scientists decide not to show the name in coauthored papers although they do contribute to the research. Citation indexing workers produce citations by inverting the citation matrix to the cited side. Citation analysts collect data from large amount of citation data. Each process may bring errors (Smith, 1981; Egghe & Rousseau, 1990), which is the main reason that cleaning up the datasets is common practice in scientometric community.

The value of author self-citations is another disputed topic since author may cite their own publications on purpose so as to construct their professional credibility (Hyland, 2003) even if those works are not relevant to the present one. But authors may also cite their former work because of relevance. Glänzel and his colleagues confirm the positive role of self-citations with mathematic formulation and conclude that self-citation based indicators are valuable supplementary measures that can be used both in informetrics and research evaluation (Glänzel et al., 2004).

Although there is no unified statement about what citation can measure, bibliometricians frequently use citation indicators to measure (citation) impact at high aggregated (i.e., national or regional) levels. Major indicators pertinent to citations include absolute and relative indicators. For absolute indicators there are citation counts and share of citation counts. Relative indicators include Mean Observed Citation Rate (MOCR), Mean Expected Citation Rate (MECR), Field Expected Citation Rate (FECR), Normalized Mean Citation Rate (NMCR), Relative Citation Rate (RCR), High-impact Activity, and High-impact Attractivity. Detail information about these indicators can be found in Chapter 3.

2.2.3 Problems in ranking

Nowadays, bibliometric indicators are applied in various rankings such as university ranking, journal ranking, and even research individual ranking. According to Glänzel and Debackere (2009), ranking is positioning comparable objects on an ordinal scale based on a (non-strict) weak order relation among (statistical) functions of, or a combination of functions of measures or scores associated with those objects. The so called “statistical functions” are bibliometric indicators. Normally, a ranking result is based on different indicators which represent various aspects of quality. A combination of these indicators forms a composite indicator which determines the relative positions of objects in a compared set. But the use of composite indicators can
be problematic. Glänzel and Debackere (2009) list the following most significant problems.

- Possible interdependence of components,
- Altering weights can result in different ranking,
- Results might be obscure and irreproducible,
- Random errors of statistical functions are usually ignored,
- The multi-dimensional space is crashed into linearity.

In the following text, I will discuss problems in applying bibliometric indicators in different rankings.

**University ranking**

A university is an institution of higher education and research, which grants academic degrees in a variety of subjects. Since bibliometric results are based on large amount of data, a bottom line is to ensure the correctness of data collection and data processing (i.e., correct institutional assignment). Application of sound methodology is also critical. Because of the diversification of universities, even multi-disciplinary research and education institutions have usually more specific research profiles. Therefore comparison should be done among those with similar research profiles. In order to obtain a more realistic comparison, Glänzel and Debackere (2009) suggest apply standardized indicators.

**Journal ranking – the Impact Factor**

The IF was originally designed by Garfield (1972) for journal evaluation. It is defined as the average number of citations in a year given to those papers in a journal that were published during the two preceding years. Major problems arise from the IF can be the following:

- The calculation of the impact factor in the *Journal Citation Index* is not exactly the identification of the impact factor. Many journals publish non-substantive items such as letters or editorials which are seldom cited. These items are not counted in the denominator of the impact factor. But these items are sometimes cited and these citations are counted in the numerator. This makes the IF is not precisely the average citations per article.
- The citation data source providers may make mistakes while integrating data for the calculation of the Impact Factor. Rossner and his colleague (2007) found that in the *JCR* of the ISI there were numerous incorrect article-type designations. Many articles that the authors consider “front matter” were included in the denominator. The total number of citations for each journal was substantially fewer than the number published on the *JCR* website.
- The two-year citation window which was originally set for biochemistry and molecular biology (Garfield, 2003) can not reflect variations of citation patterns of journals in different fields since publications in different fields have different citation culture.
- Even within the same discipline, exogenous variation also exists among journals mainly publishing reviews, research articles, and letters. Review journals tend to have higher impact factors (Pinski & Narin, 1976).
- The normalization with journal size gives small journals a better chance of selection (Leydesdorff, 2008). As citations are dynamic and therefore IF varies
from year to year. The variation tends to be larger for smaller journals. For journal publishing fewer than 50 articles, the average change in the IF from 2002 to 2003 was nearly 50% (Amin & Mabe, 2000).

- Journals publishing articles in languages other than English will likely receive fewer citations because a large portion of scientific community cannot (or do not) read them.

The above list of flaws of the impact factor does not mean that the IF is useless. But it is necessary to be cautious while applying the IF to research evaluation. For alternatives, some researchers have proved that total citations correlate with perceived quality of journals more than impact factors (Bensman & Wilder, 1998; Leydesdorff, 2007b). Some organizations extend the citation windows in their evaluation work. The Information Science and Scientometrics Research Unit (ISSRU) of the Hungarian Academy of Sciences and the Research Association for Science Communication and Information (RASCI) in Germany use three-year or four-year citation windows (Glänzel, 2008a).

In addition to ranking journals, impact factor is also used to compare individual papers, people, programs, or even disciplines. For example, some universities classify journals into various levels according to their IF values and assign different scores to journals at different levels. A paper’s score is dependant on which journal it is published. There are two serious problems in understanding the IF. First, Papers in the same journal do not equally receive citations. A paper in a journal with high impact factor does not assure the paper receiving high citation counts because the distribution of citation counts for individual papers in a journal is highly skewed (Seglen, 1996; Garfield, 1987). Adler and his colleagues (2008) prove that around 70% of articles in the Proceedings of the American Mathematical Society (PAMS) in 2000-2004 received no citations in 2005, only a few receive 3 citations. In another journal, the Transaction of the American Mathematical Society (TAMS), over 50% articles published in journals in the same field with different impact factors does not mean the one in the journal with higher impact factor receives higher citations than the one in the journal with lower impact factors. If one ranks papers according to their journal impact factors, the probabilities of being wrong would be 62% (Adler, et al., 2008). Therefore, using impact factors to evaluate articles or their authors makes no sense and can be dramatically misleading.

If one does want to evaluate papers or their authors with citations, counting citations of those papers would be more reliable. But this is under the condition that the compared objects are in the same field and publication years should be the same, since citation culture varies in different disciplines and citation counts may change at anytime. Earlier publications may have more chances to be cited. For papers in the same field and publishing in the same year and receiving no citations, the impact factors of their publishing journals can be used for evaluation.

**Individual ranking – the h-index**

The Impact Factor (IF) is used for ranking journals and papers and h-index is mainly for ranking scientists. The h-index was proposed by Hirsch as an indicator for evaluation of researchers. It is defined as the highest rank of a scientist’s list of
publications such that the first $h$ publication received at least $h$ citations (Hirsch, 2005). The $h$-index can be extended to any set of documents (Braun, et al., 2006). Unlike the impact factor, the $h$-index cannot decrease for a given set of documents and can thus be considered as an accumulating indicator for lifetime achievement in the case of individual scholars. Glänzel (2006a) has found strong relation between both number of papers published and citations received with $h$-index for practically all Paretian distributions. While having some advantages in evaluating individuals (Glänzel, 2006b), the $h$-index also has the following shortcomings (Glänzel, 2006b, 2008a) because it

- puts new comers at a disadvantage since both publication output and citation counts of new comers will be relatively low;
- allows scientists rest on their laurels since the citation counts might increase even if no new papers are published;
- does not show decay in a scientist’s career;
- is not independent of subject-specific communication behaviour and cannot be normalized in a similar manner as other publication- or citation-based indicators;
- causes problems in finding appropriate reference standards for comparison even in the same subject field;
- puts small but highly-cited paper sets at a disadvantage because $h$-index cannot exceed the number of publications.

Based on $h$-index, a series of indices were suggested (Hirsch, 2005; Egghe, 2006a, b; Jin, 2006; Jin, et al., 2007; Burrell, 2007; Kosmulski, 2006). But mathematical sophistication alone cannot increase the validity of an indicator used in processes of research evaluation (Leydesdorff, 2008).

2.2.4 Problems in field classification

“Comparing like with like” (Martin & Irvine, 1983) has become a common sense in scientometric community. In other words, comparisons can be meaningful only when they are made within the same field and for comparable units of analysis. But this involves another problem: field classification is still an unresolved issue in scientometrics. Till now, no perfect field classifying schemes have been established. The common practice in field classification is based on journals. But journal cannot unambiguously be classified into categories on the basis of their aggregated citation patterns (Leydesdorff, 2008). All sets are overlapping and fuzzy (Bradford, 1934; Garfield, 1971; Bensman, 2007).

For lack of an agreed-upon alternative, the ISI subject categories are often used for comparison study. The ISI Subject Categories, however, are not suited for detailed evaluation (Leydesdorff & Rafols, 2008). According to the evaluation of Pudovkin and Garfield (2002), in many fields these categories are sufficient, but they then admit “in many areas of research these ‘classifications’ are crude and do not permit the user to quickly learn which journals are most closely related” (p. 1113). Boyack et al. (2005) estimated that the attribution is correct in approximately 50% of the cases across the file, but may be as high as 80% in some of the core fields (Boyack, personal communication, 14 September 2008). Leydesdorff and Rafols (2008) claim that the ISI Subject Categories can be used for statistical purposes—the factor
analysis for example can remove the noise—but not for the detailed evaluation. In the case of interdisciplinary fields, problems of potentially erroneous classifications can be expected.

In general, the existence of flaws and shortcomings in the application of bibliometrics implies that this specialty badly needs theoretical grounding. “We still have a theoretically underdeveloped understanding of what these bibliometric data actually mean. The continuous call for a theory of citation in quantitative science studies is itself indicative of the urgency to explore more systematically the relations between the use of scientometric methods and qualitative approaches in STS” (Leydesdorff, 1987).

2.3 What bibliometrics can and cannot do

Listing the problems in bibliometrics does not mean that bibliometrics is useless but does mean that we should be cautious while applying bibliometric indicators in research evaluation and that there are a lot of work to be done to make bibliometrics a well-established specialty.

The existing citation databases contain rich information about science, which ensures bibliometric study the following values:

- to master scientific information flood at overall or disciplinary levels;
- to monitor, describe, and model the production, dissemination, and use of knowledge;
- to map scientific collaboration at individual, institutional, regional, and national levels;
- to discover the emergence of or predict new scientific field or sub-field;
- to help policy makers in terms of understanding the development and trend of world science and national scientific strength and weakness so as to make feasible national scientific policy;
- to provide quantitative references for research evaluation and assignment of research funding.

In research evaluation practice, bibliometric results are suggested to be combined with those of peer-reviewed. The former is considered as objective and quantitative and the latter is subjective and qualitative. They two instruments are expected to compensate with each other so as to make evaluation results more reasonable and to ensure research funding more effective.

The reason for not only relying on peer review is because peer review has flaws as well (Cole, et al., 1977; Cole, et al., 1981; Martin & Irvine, 1983). The main problem of peer review is that the evaluation process is affected by many non-scientific issues. In their study on the evaluation procedures of the US National Science Foundation (NSF), Cole and his coauthors found that applicants from high ranking departments were rated lower by reviewers from high ranking departments than they were by reviewers from lower ranked departments, and an applicants past performance which is one of the most important criteria in the NSF procedure had only a marginal influence upon the probability of his or her proposal being granted (Cole, et al., 1977). Martin and Irvine (1983) considered peer review as a method “based on individual
scientists’ perceptions of contributions by others to scientific progress, perceptions arrived at through a complicated series of intellectual and social processes, mediated by factors other than the quality, importance or impact of the research under evaluation”. They summarized three major problems of using peer reviewed outcomes in a policy context: 1) evaluators may be influenced by political and social pressures within the scientific community, such as the possible implications of their judgments for their own work and that of their colleagues; 2) peer reviewers tend to evaluate in terms of their own research interests, and may not possess all the knowledge that is needed to form a balanced judgment; 3) peers tend to conform to conventionally accepted patterns of belief, and may, for instance, be influenced by a scientist’s reputation rather than his or her actual contribution to scientific progress. The relation between peers and scientists being reviewed may affect peers to make an objective and fair judgment.

Various studies have demonstrated strong correlation between results of citation analysis and peer review (Oppenheim, 1995, 1997; Bair & Oppenheim, 1994; Liu, 1994; Seng & Eillet, 1995; Ajibade & East, 1997; Hemlin, 1996; Zhu, et al., 1991). Holmes and Oppenheim (2001) even used citation analysis to predict the outcome of the 2001 Research Assessment Exercise (RAE) of the UK for the field of library and information management.

Bibliometrics is sometimes misunderstood in terms of its role in research evaluation. It is necessary to clarify what bibliometrics can not do. As mentioned before, bibliometrics aims at 1) building more quantitatively robust models of the development of the sciences, technology, and innovation (Elkana et al., 1978); and 2) using the variables in these models as indicators for performance measurement (Martin & Irvine, 1983; Martin, 1996). In terms of research evaluation, both bibliometrics and peer review are needed. The two tools compensate and cannot replace each other. Bibliometrics is designed to measure research performance not research results. Research results can be better assessed by peer review (Glänzel, 2006c).

For the purpose of my research, the language bias does not pose an analytical problem given the research questions. The focus is on the knowledge production and the translation of the Chinese S&T capacity into the international arena. The latter is partly operationalized as publications in English. Publications of Chinese authors in languages other than Chinese and English (e.g., in Russian) have not been considered. Given this research question, representation of journals in Chinese within the international databases are also found, and although this can obviously be considered as an underrepresentation of the Chinese potential which signals the danger of the relative isolation of publications in the Chinese language despite their inclusion in the ISI databases. Of course, the Chinese percentage world share of publications and citations in this database would increase further if more Chinese journals were included, but for the purpose of my research the possible underrepresentation only strengthens the conclusions about the emergence of China as a leading nation in science.

The disciplinary bias of the SCI in favor of biomedicine and the life sciences is a more important reason for concern. Park et al. (2005) signaled that the research portfolio of the Netherlands is much more compatible with the journal portfolio of the SCI than
that of South Korea. The authors conclude that this might have a considerable effect when comparing these two countries using this database. Consistent with these earlier studies, my study also shows that the Chinese portfolio different from those of the Western countries because of the strong activity in chemistry, physics and mathematics. If more journals in these disciplines are included in the SCI, the visibility of China would be higher. This effect may also partly explain the enhanced visibility of China in a subset like the one constructed as “nano-relevant.”

As noted, the “nano-core” journals are more deeply integrated into the elite journal structure of the United States. These journals can be expected to have a bias in favor of accepting papers from elite institutions in the USA and in other advanced countries, and may not be easy to access by scholars from more peripheral locations. The Chinese contribution in these core journals has been increasing considerably, as has the Chinese contribution to the one percent most highly cited papers. Part of this may be the result of international collaboration with Chinese authors.

Compared to the natural and life sciences, the social sciences have some special attributions: more fragmented literature, inherently more national oriented, and relying heavily on non-journal literature like working paper series. All these points remind us be cautious in studying performance in the social sciences using bibliometric methodology. But the SSCI is valuable when statistics is based on some fields that are relatively well covered or on research that is internationally oriented. It is also persuasive to use the dataset to describe a nation’s historical development and internationalization in the social sciences.

Many factors may affect the development of the social sciences. Except internal theoretical and practical issues, other factors such as the academic level of researchers, social and cultural environment, economical and political systems are also critical to the development of the social sciences. Regarding to the Chinese case, the following factors may affect its low international visibility:

- **The attribution of national orientation of the social sciences**
  The Social Sciences mainly focus on domestic social, political, and economical issues. Relevant research outputs are usually applicable in a target country or region, and therefore can be only valuable for and published in that country or region. Undoubtedly, research in the social sciences is very active in China: the fact that there are around 3000 journals in humanities and the social sciences can be a proof. The low world share of publications or citations may imply that Chinese social scientists are less active in international community.

- **Ideological difference between China and the West**
  Compared to the natural sciences, the methods in the social sciences are more difficult. Research in the sciences is less sensitive to official political ideologies. By contrast, the social sciences are often directly related to ideology and more intervened and controlled by rulers. In a socialist country like China the influence of governor’s ideology on research in disciplines like philosophy, political sciences, law, but also sociology, and psychology is perceptible. This might be considered one reason for the ‘phase shift’ in the growth of Chinese social sciences literature.
The separated administration systems for the natural sciences and the social sciences

Nowadays, cross-disciplinary research becomes increasingly important. To some extent, collaboration between the natural sciences and the social sciences may affect research output. In China, two top organizations are engaged in the administration of R&D: the Ministry of Science and Technology (MOST) is responsible for R&D in the natural sciences and technology; while the R&D in the social sciences is managed by the National Planning Office of Philosophy and Social Sciences (NPOPSS). Such separated management system may hinder collaboration between the natural and the social sciences at the highest administrative level.

When co-authorship relations are normalized, China appears to have become well integrated into the Asian-Pacific region in the natural sciences during the 1990s (Wagner and Leydesdorff, 2005). Some authors have recommended normalizing S&T indicators in terms of the size of the respective populations. In the case of China as a developing nation, such a per capita normalization would have dramatic effects, and the phenomena to which I wished to draw attention would completely disappear. The size of the scientific community in a nation could be considered as another factor. A large scientific community may lead to a relatively large within-country citation rate, while scholars in small nations may have to rely more on international colleagues. A correction of the citation rates of the USA or China for the within-country citations, however, would have very large effects on the citation indicator (Seglen, 1997). This indicator would have a meaning in terms of the networking of international collaboration and influence more than in terms of national performance.

3. Perspectives

3.1 Theoretical implications

China has become a major producer of scientific publications. But its citation impact is still low. Here I use citations per publication (c/p) to delineate the citation performance of Chinese publications. A three-year citation window is applied. Table 3 lists the c/p (i.e., the number of citations divided by the number of publications) received by papers published in 1994 and 2004. In ten years, the c/p ratios of all the selected countries have increased, among which China achieved the least growth.

Table 3. The c/p ratios of publications in 2004 (SCIE).

<table>
<thead>
<tr>
<th>Year</th>
<th>USA</th>
<th>UK</th>
<th>GERMANY</th>
<th>FRANCE</th>
<th>JAPAN</th>
<th>CHINA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>2.09</td>
<td>1.93</td>
<td>1.60</td>
<td>2.05</td>
<td>1.38</td>
<td>1.44</td>
</tr>
<tr>
<td>2004</td>
<td>6.80</td>
<td>6.07</td>
<td>5.80</td>
<td>5.19</td>
<td>4.40</td>
<td>3.15</td>
</tr>
<tr>
<td>Increases of c/p</td>
<td>4.71</td>
<td>4.13</td>
<td>4.20</td>
<td>3.14</td>
<td>3.02</td>
<td>1.71</td>
</tr>
</tbody>
</table>

Why are not only foreign but also Chinese authors less active in citing Chinese publications? A new term “knowledge contributor” may help in delineating the Chinese phenomenon. In a journal-based communication system, authors play three roles as knowledge producers, knowledge contributors, and knowledge receivers. A knowledge producer is the one who publishes papers while a knowledge contributor is the one whose publication is used or cited. Usefulness is the key to decide if one is knowledge producer or contributor. A knowledge producer does not necessarily
become a knowledge contributor. Only when a producer’s publication is cited can the author become a knowledge contributor. With this context, a strong academic country is not only a leading knowledge producer, but also a leading knowledge contributor. A knowledge receiver cites knowledge from other literature by placing references in his/her reference list.

In terms of indicators for the three types of players in scholarly communication, either numbers or share of publications can be used for a knowledge producer; normalized citations, i.e., citations per publications can measure knowledge contributions; and number of references listed in publications can be applied to measure a knowledge receiver. China is a big knowledge producer but not an influential knowledge contributor.

3.2 The Chinese way of knowledge production

The Chinese way of knowledge production is unique in terms of its rapid and continuous growth during the last 30 years. Such remarkable achievement can be attributed to two major causes: the exceptional growth in economy and the timely adjustment of science management. Since 1978 when the Opening – up Policy was adopted, science management has experienced three stages (Rednet, 2008):


Various levels of scientific administrative departments and research institutes which were damaged during the Cultural Revolution were recovered or established, and a series of scientific policies was put forward. But for historical reason, scientific administration in this stage was still central planning: research and funding was assigned by the central government. Research institutes did not need to worry about their budgets nor did it matter whether they did a good job or not. This led to a situation in which low-level and low-efficiency research was very common in the Chinese academic community.

**Competition and marketization (1985 – 1993)**

The low efficiency in scientific research had caused wide complaints and requirement for further institutional reform became fierce. Scientific administration in this stage aimed at importing competitive mechanisms into scientific administration and encouraging communication between academic institutes and industrial sectors. To some extent, academic institutes had more space in making their own research plans. This provided more freedom for academic institutes on the one hand. But it also made institutes more short-sighted because of budget problems: they do research for money.

**Adjustment and innovation (1993 – )**

The environment of knowledge production has been further improved since 1993. China has taken important actions to improve the development and management of science and technology. A series of important programs and laws have been carried out. For example, the “211 Program” adopted in 1993 and the “Knowledge Innovation Program” carried out in 1998 aim at supporting national research base. The former is for universities and the latter supports research in the Chinese Academy of Sciences.

In order to keep a stable research force and, in the meantime, encourage competition, China has adjusted its funding policy: from simply funding research projects to the combination of supporting both projects and construction of research base. Funding manners have been diversified. In addition to enhancing financial support to basic research, China established technological innovation projects for industries. For example, some industrial R&D centers in some large scale enterprises were funded by the government.

In this stage, the Chinese way of knowledge production has some signs of the Triple Helix. University spin-off firms, tri-lateral initiatives for knowledge-based economic development, government laboratories, and academic research groups appear and play increasingly important role in China’s project of constructing an innovative country.

In terms of the model of Triple Helix, Chinese knowledge production in science has entered the same stage as that of the some scientific leading nations. This means that China and the other leading scientific nations compete at the same level. Why, then, does China grow faster than its international counterparts in knowledge production?

The following factors may help to explain this:

1) Continuous and increasing investments in R&D. More than any other country, China’s R&D investments are growing not only absolutely but also relatively to the spectacular growth in GDP;

2) The huge reservoir of human resources. In addition to the domestically trained researchers, growing numbers of oversea Chinese PhDs have returned to China. Enlarged and enhanced international collaborations help Chinese scholars merge more easily and therefore more actively into the knowledge production at the global level;

3) Research evaluation mechanism. Publications and especially international publications have become an important indicator for evaluating Chinese researchers since the 80s of last century. Publishing a certain quantity of papers has become a must for researchers. Publishing in international journals receives higher score than publishing in domestic journals.

In general, China’s growing momentum in knowledge production will most likely continue. But the gap between the natural sciences and the social sciences will exist and may be enlarged since the speed and starting points of the two are very different.

3.3 The Chinese way of scholarly communication

The Chinese system of scholarly communication is special compared to the international ones: Chinese researchers are less active in providing references to the publications of other scholars and mainly play a role as knowledge receivers in relation with their international counterparts.
Journal can less easily be accessed in China than in Western countries. This hinders Chinese scholars from knowing updated research output and therefore unable to cite recent literature in their publications. Lacking updated academic information may cause Chinese researchers to do studies that have already been finished by others. To many researchers, accessing domestically published literature is a problem, let alone the international ones. With increased financial support, such accessibility has been solved in some academic institutes, but is still a problem for many researchers.

Even if accessibility is not a problem, the reading habit and poor English language proficiency of some Chinese researchers may affect the efficiency of communication. Knowing what others are doing or have done has not penetrated into the academic life of some Chinese researchers. In order to force researchers to read more, some Chinese journals require that a paper must contain a certain number of references. Some journals even require that the share of international references must be at least 40% of the total. This policy reflects the important role of international publications in Chinese scholarly communication, and may explain, to some extent, why Chinese authors are less cited than citing in the international communication system.

In the past, Chinese journals did not wish references to be included because of the special censorship of Chinese publications. While registering in the General Administration of Press and Publications (GAPP), Chinese journals are required to indicate how many pages are included in one issue. One is not allowed to surpass this number of pages in later publishing activity. Chinese journals charge authors who publish papers. The cost is calculated in terms of the number of pages. In order to publish more paper so as to earn more money, some journals only allow a certain number of references because of the page limit. Some journals even omitted references. This situation began to change and some Chinese journals shifted from limiting to requiring references. No matter what journals require about the number of references, such artificial involvement may distort the evaluation when using bibliometric methods to measure citation impact of either journals or publications.

To sum up, the Chinese communication system is moving towards the international one. But a gap still exists. A comparison of references per Chinese publications shows that more documents are cited in Chinese publications after ten years’ development (Table 12-1). The gap between China and the West is narrowing but still exists (Table 12-2).

<table>
<thead>
<tr>
<th>Table 1. References per Chinese article (SCIE data)</th>
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<tr>
<td>Chemistry, Multidisciplinary</td>
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<tr>
<td>Materials Science, Multidisciplinary</td>
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</table>

<table>
<thead>
<tr>
<th>Table 2. References per article of some countries (SCIE data)</th>
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<tr>
<td></td>
</tr>
<tr>
<td>Chemistry, Multidisciplinary</td>
</tr>
<tr>
<td>Materials Science, Multidisciplinary</td>
</tr>
</tbody>
</table>
Learning from the West is still the main stream in China even though this country is advanced in fields like nano-science and nano-technology. While international collaboration keeps increasing and with more and more overseas Chinese scholars’ returning, China’s role of a knowledge receiver will change. A communication balance between Chinese and the international community can be expected in the future.

3.4 Further studies

Based on the fact that Chinese authors favour publications of their international counterparts and the raise of the new term ‘knowledge contributor’, it would be interesting to figure out who are the major knowledge contributors in knowledge production in the world. Comparative analysis on the difference between knowledge producers and knowledge contributors and exploring reasons behind may come out some interesting implications. It is also worthwhile to investigate the distribution of lowly- or un-cited publications in terms of regions and disciplines and to explore the knowledge base of Chinese scientific community with further investigation into fields. Furthermore, exploring the possibility of increasing the efficiency of scholarly communication would be an interesting topic of relevant players in scholarly communication. The skewed productivity among Chinese provinces hinders regional development when knowledge has become a base of economy. How to reduce the gap between the developed and undeveloped regions would be a nice research project. Further study on Chinese scholarly communication in the social sciences based on a Chinese domestic database can compensate the incompleteness of the present study included in the dissertation.