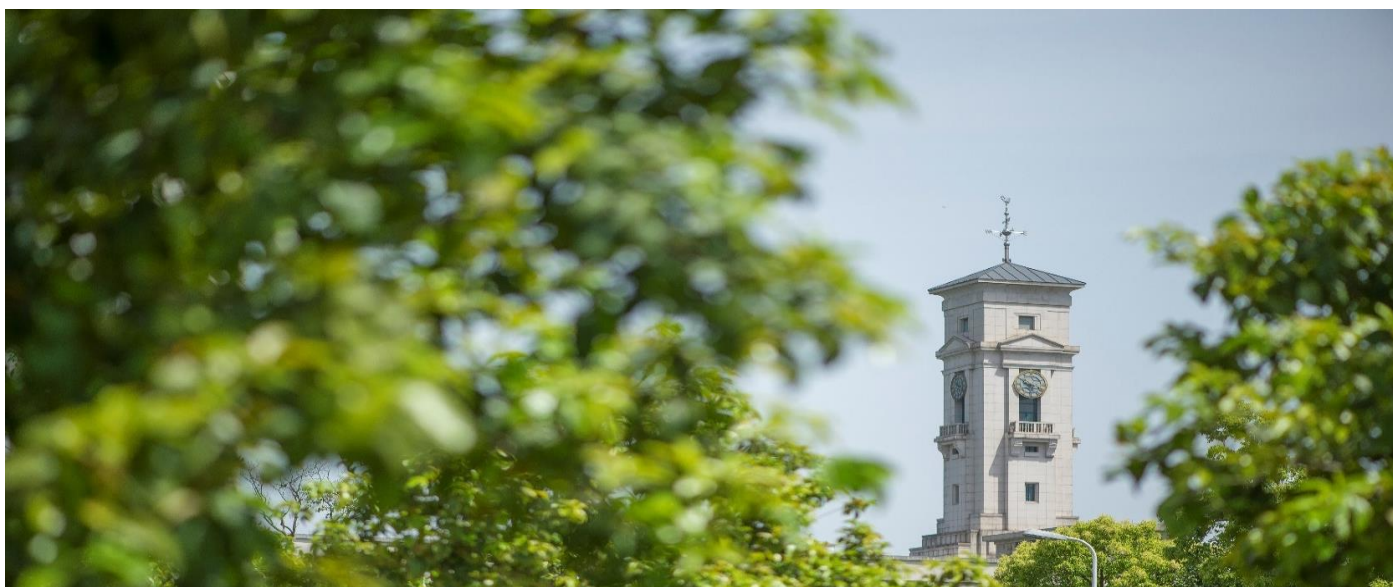


The dynamics of the studies of China's science, technology and innovation (STI): a bibliometric analysis of an emerging field

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**The Dynamics of the Studies of China's Science, Technology and Innovation (STI):
A Bibliometric Analysis of an Emerging Field**

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The Dynamics of the Studies of China's Science, Technology and Innovation (STI): A Bibliometric Analysis of an Emerging Field

Abstract

Since 1978, alongside China's rise as a leading country in science, technology and innovation (STI), the studies of the country's STI have been emerging as a field attracting increasing scholarly attention. Using the bibliometric method and the data from the Web of Science (WoS), this paper seeks to provide a comprehensive picture of the studies of China's STI. The findings show that scholarly interests in China's STI started in 1995 and have since developed rapidly; institutions in China, the U.S. and the U.K. are main contributors to the field, contributing 50%, 27.2% and 12% of the scholarship respectively, with Tsinghua University, Zhejiang University and the Chinese Academy of Sciences being three major institutional contributors. Seminal works have been focused on STI issues at the macro or national, meso or industrial and regional, and micro or organizational and firm levels. A possible agenda for further research is to develop new theories based on China's practice paying specific attention to issues including R&D expenditure, S&T performance evaluation, regional innovation ecosystem, SOEs in innovation and the role of the Chinese Communist Party in innovation.

Keywords: STI studies; China; bibliometrics; HistCite

The Dynamics of the Studies of China's Science, Technology and Innovation (STI): A Bibliometric Analysis of an Emerging Field

1 Introduction

Globalization, together with localization, blurs national boundaries but does not take critical roles away from the nation-state (Dicken 2007). The national interest still is of prime importance within global governance (Sun and Grimes 2016), which is best exemplified by the recent frictions between China and the United States in trade and technology. Over the past decade, China has prioritized transforming from the world's factory to a leading technological and innovation power. Consequently, studying science & technology and innovation (STI) activities in China is central to understanding its international competitiveness in the knowledge-based economy.

In 1978, China embraced a "spring of science" and launched the reform and open door policy. Some forty years later, in addition to displaying impressive achievements such as the increasing investment in research and development (R&D), the emergence of a very large talent pool whose quality also has been improving, and a steady rise in the contributions of its scientists to international publications, China's STI system has produced some major accomplishments in national defense, as well as in certain fields of basic research and technologies. All these demonstrate that China has the institutional capacity to mobilize talent and the financial and material resources required to achieve high-priority, national-security objectives (Xue 1997; Suttmeier 1981).

However, the general inefficiency of transferring R&D achievements to production, even amid the reform, also makes it clear that structural reform of China's STI system is imperative if the system were to meet the demand for successful innovation in an increasingly market-oriented and knowledge-based economy. Then, the question becomes why China cannot innovate or China has diligently pursued R&D activities but breakthroughs are still rare (Abrami et al. 2014). To answer the question, scholars have investigated China's STI development (e.g. Zhou and Leydesdorff 2006; Mu and Qu 2008; Hu and Mathews 2008; Fan 2014); international organizations such as the OECD, World Bank, and UNESCO also have produced comprehensive reviews (OECD 2008; Zhang et al. 2009; Cao 2015).

Moreover, scholars have reviewed the literature on national innovation and on China as a country. On the former, Fagerberg and Sapprasert (2011) examined the important role of the "national innovation system (NIS)" as a new approach within the innovation studies. Teixeira (2014) explicitly addressed the roots, evolution and

influence of the NIS literature using bibliometrics. Expanding the study of the NIS to that of national innovation, and also using bibliometrics, Sun and Grimes (2016) identified the most significant countries and institutions, major journals, seminal contributions and contributors, and clusters in national innovation studies. On the latter, Liu et al. (2015a) indicated that China's publications in the Social Science Citation Index (SSCI) database have been rising in terms of volume, world share, and global ranking, but China has yet to make contributions to the social science's literature. Liu et al. (2015b) also examined China-related SSCI publications bibliometrically, concluding that the contributors of these publications are largely limited to China's affluent regions and some of China's geographically proximate neighbors. The research interests of such studies have gradually shifted to the country's environmental issues, public health and the economy.

Unfortunately, there appears to be a lack of a systematic review of the studies of China's STI, a field at the intersection of the national innovation studies and China studies and one of rising interests with tremendous policy implications. Indeed, *answering such basic questions as what research has been done, who the major contributing countries and institutions and the leading contributors are, in which journals the research has been published, and especially what the research focuses are is useful to understanding this emerging field as well as its direction for future research.*

In conducting such a review, we aim to achieve a twofold goal. Theoretically, we seek to fill the gap in the review of the literature on China's STI by integrating the national innovation studies and China studies. Particularly, sketching the evolving studies of China's STI could help draw a more accurate and comprehensive picture of the literature of the field, and generalize the dynamic structure and pattern of the STI studies in an emerging economy. We also try to deepen our understanding of China's STI development reflected in the STI studies.

The rest of this paper is structured as follows: Section 2 presents methodology and data. Section 3 intends to draw a systematic and dynamic map through laying out major contributing countries/economies and institutions; seminal contributions and their contributors, and major journals; and research agendas, respectively. Section 4 discusses our findings and concludes the paper.

2 Methodology and data

The paper takes a quantitative approach to analyze the literature of China's STI. In particular, we use the bibliometric method to analyze citations to the publications on the subject under study. Doing so allows us to

process a large amount of bibliometric data and to describe the dynamic or evolving structure of a research field. The limitations of the approach are also obvious as the data retrieved, based on keyword search, may contain a certain amount of noise by either including some unrelated literature or excluding some important publications. But we are able to compensate for the problem by our more than 20 years of experience as researchers in and contributors to the studies of China's STI. Our interaction with scholars in the field also helps us to identify seminal contributions and leading contributors that the bibliometric analysis might have failed to do.

2.1 Data

Clarivate Analytics's Web of Science (WoS) is selected as the data source of this study. We consider the WoS to be a more appropriate database for our study for several reasons. First, as one of the global citation databases and comprehensive platforms, the WoS can track ideas across disciplines and time from its over 159 million records and over 1.7 billion cited references. Second, comparative and longitudinal studies have shown a consistent and reasonably stable quarterly growth for both publications and citations in the WoS. By comparison, Scopus is a new database including citation information of articles published since 1996, and Google Scholar is a free database but the level of accuracy of its citation counts has been seriously doubted (Levine-Clark and Gil, 2008; Jacsó 2010; Harzing and Alakangas, 2016). Third, previous studies have used the WoS to track progress in specific research fields (Zhou and Leydesdorff 2006; Liu et al. 2015a, 2015b; Sun and Grimes 2016).

This paper focuses on publications related to the studies of China's STI. Science Citation Index Expanded (SCIE) and Social Science Citation Index (SSCI) datasets in the WoS were used as our data source. SCIE covers over 9,200 journals across 178 scientific disciplines, having more than 53 million records and 1.18 billion cited references. SSCI covers over 3,400 journals across 58 social sciences disciplines, having more than 9 million records and 122 million cited references.

We extracted data from the WoS through several steps. First, we searched keywords – “China + innovation” or “China + science and technology” or “China + S&T” – as “topics” in the web page of “basic search” in the database of the “Web of Science™ Core Collection.” These keywords likely cover most of the literature in this field but would possibly miss some papers related to China's STI that are not captured by these keywords.

Second, we selected the “timespan” between 1978 and 2015 and the database settings were “Science Citation Index Expanded (SCI-EXPANDED) – 1978–present” and “Social Sciences Citation Index (SSCI) – 1978–present” in the “Web of Science Core Collection: Citation Indexes.” Doing so excludes records in the

Conference Proceedings Citation Index – Science (CPCI-S) and Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH), though they partially overlap with SCIE and SSCI (Bar-Ilan 2009). In fact, as a given work included in conference proceedings may later appear as a journal paper, our approach prevents the double-counting problem. Meanwhile, the studies of China’s STI related to social science is not a field where conference proceedings are major venues like in computer science (Bar-Ilan, 2010).

Third, we refined search results in “Research Domains” and selected following research domains: “Management/Business/Economics/Planning Development/Information Science Library Science/Multidisciplinary Sciences/Geography/Area studies/Political Science/Education educational research/Public Administration/Urban Studies/Social Sciences Interdisciplinary/Law/Business finance/Agricultural economics policy/Social Issues.” The studies of China’s STI as an interdisciplinary research domain may include publications in the natural sciences and social sciences. In this paper, we only pay close attention to papers in the research domains of the social sciences such as management, business and economics, and exclude publications in specific scientific and technical fields such as chemistry and information technology.

We cleaned the raw data carefully to ensure their accuracy. For example, institutions may be under different names. We performed a name disambiguation exercise and designated each institute by a unique name. The publication records are defined as a knowledge domain (collection) in HistCite. Our resulting aggregated database is defined as the research collection of China’s STI (RCSTI) including publications’ references and citations inside and outside of the domain. The citations of a cited publication are calculated by the frequency in citing publications’ references. The collection includes 2,041 published records in 506 journals and 71,255 cited references between 1978 and 2015. The paper will investigate the number of publications annually in analyzing the trend of the studies.

2.2 Research method

We used HistCite to perform the bibliometric analysis on the WoS data. As a good tool for a historical analysis of literature, HistCite is commonly used to analyze and visualize the development of a research field and to explore its evolutionary characteristics (Garfield et al. 2002; Lucio-Arias and Leydesdorff 2008; Garfield 2009). HistCite uses the databases of publications with cited references from the WoS or other similar databases to produce various tables and graphs showing informetric indicators of a research field (Garfield et al. 2006).

The number of received citations is a basic scientometric indicator reflecting the impact of a publication

record, and citations can show the evolution of a theme within a domain by describing the relationship between publication records. Particularly, local citations are calculated based on the citation frequency within the basic collection RCSTI, and global citation measures how often each paper was cited in the entire WoS realm (Garfield et al. 2002). This paper considers only local citations but not global citations. Therefore, local citation scores include only the citations within the basic collection RCSTI, and global citations scores include those within the SCIE and SSCI so well as those within the WoS realm. Consequently, global citation scores are higher than local ones. Global citations export domain-specific insider-knowledge into other knowledge domains and the scores can show multidisciplinary impacts. But there may be little relatedness of specialized knowledge between these cross-referenced articles (Garfield et al. 2006). Our main concerns were these publications' impacts within the basic collection RCSTI, which reflect the close communication between academic peers and relatedness of specialized knowledge in the same field. Obviously, one limitation of the approach is that we cannot explore the actual outreach of the knowledge domain of China's STI studies in other domains within the SCIE and SSCI realm, let alone that within the WoS realm.

Following Garfield et al. (2006), we used several citation-based bibliometric indicators. *Total local citations scores (TLCS)* means all local citations within the basic collection RCSTI. *TLCS/x* are total citation scores excluding self-citations. *Average local citation scores (ALCS)* are the local citation scores per publication. *LCS/t* means the local citations scores per year or the average citation score every year. *LCSe* denotes local citation scores in the last three years of the collection timespan, and *LCSb* local citation scores in the first three years of the paper published. *LCS (e/b)* equals *LCSe* divided by *LCSb*. A greater than 1 *LCS (e/b)* means that citations tend to increase in recent years; when *LCS (e/b)* is less than 1, citations tend to decrease.

3 Results

Applying the bibliometric method to the data from the WoS and combining our literature research and research experience, we have reached some results (see Table 1-6).

3.1 Descriptive statistics

We are interested in the distributions of publications by economies and institutions, seminal articles, leading contributing journals and main contributors. Table 1 shows descriptive statistics of the main indicators.

[Table 1 about here]

On a full-accounting basis, China-based scholars contributed half of the publications in the studies of China's STI and scholars from seventeen economies contributed at least one percent of the publications. Scholars from Tsinghua University and Zhejiang University contributed 90 or more publications and received 232 local citations while there are institutions that contributed a publication but did not receive any local citations.

Only about a third of the publications received local citations by the means of LCS; all publications being 1.52. Thus, the local citations in the studies of China's STI is small. The greatest number of papers published in a journal is 101 articles and the greatest number of papers an author published is 27 articles.

3.2 The growth of China's STI studies

The first paper that studies China's STI is "Education, Science, and Technology in China" (EST), published in *Science* in 1979. After China initiated the reform and opening-up policy in 1978, American Association for the Advancement of Science's (AAAS) Board of Directors organized a three-week visit to China aiming to arrange cooperation between the AAAS and its counterpart, the China Association for Science and Technology (CAST). Afterwards, *Science*, the flagship journal of the AAAS, published a special issue, *China in Transition*, which included EST as one of the papers. Although it is a personal reflection of an editor of *Science*, an outcome of science tourism as it was known, rather than an academic paper, it describes China's scene of S&T in 1979. At that time, most research was carried out at the institutes affiliated with the Chinese Academy of Sciences and a lesser amount at universities. China's leadership had little experience in the effective integration of advanced research and development into major industrial complexes (Abelson 1979). EST also for the first time raised a very critical question: "*Why hasn't China developed faster and more extensively?*" In fact, the question has hovered over the studies of China's STI for the decades to come.

[Figure 1 about here]

Before 1995, there were barely a couple of publications on China's STI each year (Figure 1). In fact, we managed to locate in our research collection only three papers on China's STI published between 1978 and 1985. The annual number of publications remained in the single digits between 1985 and 1995. After 1995, there has been a gradual increase in publications: about 30 after 2000 annually and 40 in 2005. Since then the

rise in publications has become more dramatic and monotonic. The annual number of articles had been about 100 after 2007 and reached 324 in 2015. This post-1995 rapid growth of the publications shows that China has attracted more international scholarly attention to its STI.

Such an interest has been increasing alongside China's growth in the investment into R&D and the reform of the S&T system. In 1985, China initiated the reform to ensure the close alignment of the S&T system with the economy with a Chinese Communist Party's Central Committee (CCPCC) "*Decision on the Reform of the S&T System.*" This was followed by a 1995 strategy of "*Revitalizing the Nation through the Science and Education*" and a 1999 "*Decision on Constructing a National Innovation System with Chinese Characteristics.*" These important policies have stimulated China's STI development and the studies of such development (Liu et al. 2011).

However, as a by-product of such policies, international technology transfer that is useful for improving China's technological sophistication might have hindered the development of its indigenous capability of creating cutting-edge innovation. To respond to the challenge of an excessive dependence on foreign technology for economic development, in early 2006, the CCPCC and China's State Council issued the "*Decision on Implementing S&T Plan and Strengthening Indigenous Innovation Capability*" while unveiling the Medium and Long-Term Plan for the Development of Science and Technology (2006–2020) (MLP). Both the indigenous innovation strategy and MLP have become a new milestone in China's innovation drive (Cao et al. 2006; Serger and Breidne 2007; Grimes and Sun 2014).

The studies of China's STI have become an emerging field since 1995 and particularly from 2006 onward also due to the increased demands from the policymaking community both inside and outside of China. Indeed, China's policymakers have shown interests in the ways to develop S&T and promote economic growth through S&T; meanwhile, international policymakers have desired to understand the policymaking mechanisms underlying China's rapid STI and economic development while concerning about the global impacts of such development. Scholars also have debated the existence of China's model of innovation and its usefulness to the understanding of its STI development.

Indeed, 1995 and 2006 are two critical years in both publication records in the studies of China's STI and China's R&D intensity, or its R&D expenditure as a percentage of GDP, reflecting to some extent their relatedness. It can be argued that China's R&D investment has promoted its S&T development and innovation, which in turn has attracted domestic and international academic community's attention to the studies of China's

S&T and innovation.

3.3 Contributions to the studies of China's STI

This section traces the growth of the studies of China's STI and analyzes contributing economies and institutions to the field. It consists of three parts. The first reviews the seminal contributions of China's STI studies. The next two parts analyze main journals publishing China's STI studies and leading contributors.

The contributing economies

Table 2 shows the records of full-counting-based papers published by scholars from various economies between 1978 and 2015. China is the undeniable leader, accounting for 50% of the 2,041 records that explicitly analyzed STI in the country, followed by the U.S. and the U.K., which together contributed 89.2% of the total.¹ It stands to reason that China-based scholars have paid most attention to the STI issues in their own country. Some of them have international visions and academic competence in the social sciences, and their research on China's STI has been accepted by the international academic community and published in international journals.

[Table 2 about here]

The top three countries and the rest differ in their approaches toward China's STI. U.S.- and U.K.-based scholars relative to those in other countries have paid more attention to China's STI. North America and Europe are the global leaders in STI. China has become the world's second largest economy since 2010 and a main S&T contender for the U.S. and the U.K. In particular, the U.S. is worried about the loss of its leading edge in S&T and innovation. Scholars from North America and Europe are increasingly focusing on rapid economic and innovation growth in China at the expense of attention given to STI in other Asian economies (Teixeira 2014). Certainly, a large number of expatriate Chinese scholars working at American and British academic institutions have facilitated a global research focus on China (Liu et al. 2015a, 2015b; Jin et al., 2007).

Geographically, South Korea and Japan have been and will continue to be influenced directly by China's development in STI. However, scholars from the two countries have paid more attention to their own nation's STI issues than those of China (Sun and Grimes 2016). Despite their much smaller economies, both Singapore and Malaysia have seen their scholars paying very close attention to STI in China. India, another emerging

¹ Most of the literature on China's STI has been published in local journals in Chinese, which are not catalogued by SSCI/SCI that favors journals published in English (Van Leeuwen et al. 2001). These publications are excluded from the analysis.

economy, did not show much interest in China, with contribution of its scholars to the studies of China's STI only being 1.7% of the total. The remaining nine economies accounting for 14.7% of the contributions are located at continental Europe. This confirms that outside of Greater China, North America and Europe are key centers for the studies of China's STI, which is consistent with the findings from the national innovation studies (Sun and Grimes 2016). Despite an increasingly diverse profile of contributing economies, the substantial rise of China's STI research has been largely limited to the key centers, with some of China's geographically proximate neighbors contributing to the field, differing from the research focusing on China as a country (Liu et al. 2015a, 2015b).

Although China as a rising STI power has attracted North America and Europe's attention, the studies of China's STI have yet to become a mainstream field on a global scale. For example, most of the work by scholars in East Asia, including China, has appeared in local journals with local languages (Sun and Grimes 2016). But language is not the primary reason deterring scholars of these economies from publishing their work internationally. Rather, the publication phenomenon may suggest that China has not generated enough influence and has not attracted sufficient global attention. As China's rise in the technological term could gradually change the geographical configuration of global R&D and innovation, North America and Europe are the first to feel China being their competitor and collaborator. Japan and South Korea, as two major R&D and innovation centers in Asia as well as in the world, still are closely watching the U.S. and Europe rather than neighboring China.

Leading contributing institutions

We identified top 20 of the 1,289 institutions that contributed to the studies of China's STI in terms of records and TLCS (Table 3). These are the institutions with which the primary authors – first and corresponding authors – are associated.

[Table 3 about here]

Tsinghua University stood out with most contributions from both its School of Economics and Management (SEM), in particular the Research Centre of Technology Innovation now led by Jin Chen, and the School of Public Policy and Management (SPPM) led by Lan Xue. Tsinghua's two subdivisions take different approaches toward China's STI – SEM scholars focus on technological innovation and development at the

levels of firms and industries while SPPM scholars pay more attention to institution, policy, and governance regarding technologies and the national innovation system. The research at both organizations is interdisciplinary.

Tsinghua's competitive advantage within the studies of STI in China is not significantly ahead of other Chinese universities, particularly Zhejiang University. Zhejiang has the second largest number of publications after Tsinghua. Similar to Tsinghua, Zhejiang University's School of Management and particularly the National Institution of Innovation Management led by Xiaobo Wu is the primary contributor while the College of Public Administration (School of Public Affairs) and particularly the Department of Information Resource Management led by Ping Zhou also published quite extensively. At its Department of Earth Sciences, Cassandra C. Wang, a geographer, published five papers on clustering and industrial innovation.

With some two-thirds of the publications of Tsinghua and Zhejiang universities, the Chinese Academy of Sciences (CAS) is the third major institution in the studies of China's STI. As a national institution for the natural sciences and high technology, the CAS also has several social science-oriented divisions. Those studying STI include the Institute of Policy and Management, the Institute of Geographical Science and Natural Resources, the Center for Chinese Agricultural Policy, Graduate University's School of Management, among others. To a certain extent, CAS is comparable to universities and its Graduate University evolved into the University of CAS (UCAS) in 2012. We treated CAS and UCAS as two different entities, although UCAS is part of the academy. The School of Economics and Management under UCAS, the former Graduate University's School of Management, also has been a major contributor to the studies of STI in China, although it is not among the top 20. Jiancheng Guan and Xielin Liu are two leading scholars at UCAS.

Greater China's leading position in the studies of China's STI has more to do with the contribution of a particular group of well-known universities in Mainland, Hong Kong and Taiwan, reflecting a localization effect where an economy's scholars likely pay more attention to academic issues within the economy. In fact, only four of the top 20 institutions contributing to the studies of China's STI are located outside of Greater China. They are the National University of Singapore in Singapore, the University of Manchester and the University of Nottingham in the U.K., and the Georgia Institute of Technology in the U.S. As main institutions of the STI studies, Manchester Business School's Manchester Institute of Innovation Research (MIOIR), and Georgia Tech's School of Public Policy and its Technology Policy and Assessment Center have made significant contributions to the studies of China's STI including main contributors such as Philip Shapira, Li Tang, and

Allen Porter. At Nottingham, major contributions came from its Business School and School of Contemporary Chinese Studies (SCCS) with Chengqi Wang, Cong Cao and Yutao Sun being major contributors (Tang who used to be at Georgia Tech, and Cao and Sun at Nottingham have returned to China and continue to be active in the field).

Our data on local citations, however, show a very different picture from those of the publications, with only one of the top five institutions located in Mainland China. A comparison of publications and citations shows several interesting findings. First, only four of the eleven Mainland Chinese institutions on the list of publications remain on the list of citations; that is, the impact of the work coming from these institutions was not as significant. Three of the four Hong Kong institutions moved to top five, and three of four non-Greater China institutions remain on the citation list. The Chinese University of Hong Kong (CUHK) is the undisputed leader in terms of TLCS. Its College of Business, College of Science and Engineering, and Department of Public and Social Administration all have academics studying China's STI.

Second, despite having fewer publications than those in the top 20 institutions, several Chinese and foreign institutions have shown a considerable impact measured by citations. For example, China's State Science and Technology Commission (SSTC), renamed Ministry of Science and Technology (MOST) in 1998, only has one publication, "Comparing innovation systems: A framework and application to China's transitional context" (Liu and White 2001), under its name, but the publication had received 92 local citations by 2015. At that time, Xielin Liu, the first author, was working at SSTC's Research Centre of Innovation Strategy Management (now Liu is at UCAS). As shown in further discussion, with fewer records, such institutions as Texas A&M University (6 records), Brandeis University (3 records), and the University of Miami (6 records) also had contributed some seminal papers receiving more local citations.

Third, in addition to the Research Centre of Innovation Strategy Management, the SSTC had its Institute of Scientific and Technical Information of China (ISTIC), a center for scientometric and informetric studies, now part of MOST, on the citation list. China's S&T agencies carry out in-house research and generate academic impact.

Seminal contributions

The number of citations that a publication received is related to factors including the type of documents (review articles attracting more citations), the number of authors, and others, while high citations are correlated with peer judgments about scientific excellence and the importance of the contributions (Garfield 1979).

Generally, the earlier a paper was published, the more citations it would receive, controlling for the quality of the paper and other factors. Considering that the timespan between the publication date and 2015 would influence the total number of citations, LCS/t – the average local citations scores per year since the publication date – is a more effective indicator than either TLCS or TLCS/x – total citation scores, excluding self-citations, in identifying seminal contributions. Only a small number of the 2,041 articles can be regarded as “seminal,” which is measured by LCS/t.

Table 4 lists 15 seminal, or academically influential, articles. They all have been published after 2000: three in 2001 and rest after 2006. This seems to suggest that the studies of China’s STI started to exert academic impacts in 2006 when China launched its indigenous innovation strategy, after which scholars have become more serious about China’s STI. All papers focused on China, some used data from China, and they approached their topics empirically rather than theoretically. “China” didn’t appear in the title of two papers (records 700 and 723): one examines the relations between new ventures’ ties with service intermediaries and their product innovation based upon a sample of new ventures in a technology cluster in China (Zhang and Li 2010), and the other examines the role of technological capability in product innovation at Chinese high-tech firms (Zhou and Wu 2010).

Of the 15 articles, seven appeared in *Research Policy (RP)*, four in *Strategic Management Journal (SMJ)*, and the remainder in four different journals. RP, now a *Financial Times* 50 journal, has become the preferred venue for authors in the studies of China’s STI, helping to develop a unique identity for this group of researchers (Sun and Grimes 2016). RP prefers to publish papers analyzing the STI system and policies at the national and regional levels. Innovation studies can be considered a subdomain of strategic management studies or linked closely with strategic studies. The studies of technology and product innovation at the firm level were published in SMJ and the *Academy of Management Journal (AMJ)*. Haiyang Li and Yan Zhang, two academics at Rice University in the U.S., contributed two or more papers to the seminal list. Authors with Chinese names contributed all but one (records 433) seminal articles and are main or first authors of most papers. They are either Mainland- or overseas-based Chinese authors, showing again a typical localization effect.

[Table 4 about here]

Among the topics of the seminal contributions were national innovation systems, innovation capacity and

policies, regional innovation strategy and capability, and firm's product innovation, capability and performance. Measured by LCS/t, TLCS and TLCS/x, the paper on top of the seminal paper list is "Comparing innovation systems: A framework and application to China's transitional context," mentioned above, published in RP by Liu and White. In fact, this paper not only examines China's innovation system in transition but also extrapolates directly from system modules to functions to address a fundamental weakness of the national innovation system research – "the lack of system-level explanatory factors." It focuses therefore on the five systemic activities: research (basic, development, engineering), implementation (manufacturing), end-user (customers of the product or process output), linkage (bringing together complementary knowledge), and education (Liu and White 2001). It will continue to receive a high level of citations as LCS (e/b) (17.5) indicates. Most seminal contributions have an LCS (e/b) larger than 1, implying an increasing trend of citations.

The indicator LCS/t surely has its own limitations. Newly published papers may have not reached their citation peaks and old papers may over time receive more citations after citation peaks. The publication date would also influence LCS/t. Fortunately, the results of LCS/t in Table 4 show that papers published in 2001 and before do not show significant citation disadvantage and papers published in 2011 and after do not show significant citation advantage as well.

Leading contributing journals

The 2,041 papers were published in 506 journals, with ten journals publishing 25.6% of them, showing a success-breeding-success phenomenon (Price, 1976). Measured by the number of records, the most important journals are *Scientometrics* (SCIM, 4.9% of the publications), the *International Journal of Technology Management* (IJTM, 3.4%), and *Technological Forecasting and Social Change* (3.1%), indicating a wide and diversified outlet (Table 5). SCIM is concerned with the quantitative features and characteristics of S&T activities, mainly analyzing publication and patent statistics. Emphasis is placed on statistical and mathematical methods used to analyze the development and mechanism of S&T; or plenty of China's STI studies are data driven.

[Table 5 about here]

In addition to the number of records, the average annual LCS since the publication date of papers (LCS/t) provides an indication of the impact of journals in the field of China's STI studies (Sun and Grimes 2016).

Measured by LCS/t, RP is the most important journal, followed by SCIM. Other journals on the citation list include *SMJ*, *World Development*, *Telecommunications Policy* and *Environment and Planning A*, while journals on the list by records also include *Chinese Management Studies (CMS)*, *Technology Analysis & Strategic Management*, *China Economic Review (CER)* and the *Journal of Business Research*.

In general, more than half of the journals can be classified as technology and innovation management (TIM) (Sun and Grimes 2016), while the remainder being economics, management, business and environment, and so on, pinpointing the interdisciplinary and multidisciplinary characteristics of the studies of China's STI. Launched by Christopher Freeman, its founding editor, at the Science Policy Research Unit, the University of Sussex, RP is a multidisciplinary journal devoted to the policy and management issues related to innovation, R&D, technology and science and has become an important journal in the studies of China's STI. The journal's high impact factor (4.667 in 2017) reflects its status as a leading academic journal in this field although the impact factor in measuring a journal's influence is debatable (Linton 2006; Van Leeuwen 2012). Founded in 2007, CMS documents and disseminates research on the Chinese processes of managing enterprises, firms and corporations. As a relatively new journal, its academic impact remains limited (2017 IF=0.857). CER publishes original research on the economy of China, and China's relation to the world economy. Founded in 1989, CER has a longer history than CMS. Obviously, the international academic community studied the Chinese economy earlier than its management.

The impact factor of SMJ is higher than those of TIM journals, although it is difficult to compare the impact factors of journals in different fields because of their varying missions and scopes (Dorta-González and Dorta-González 2013). TIM is a subfield of strategic management, and SMJ, founded in 1980, is the world's leading journal for research in strategic management.

The leading contributors

We used number of records, TLCS and LCS/t to identify the seminal contributors, which are important for understating a field. A total of 3,473 authors had contributed to China's STI studies, but name ambiguity implies the number of authors may be more. Bibliometrics has not been able to offer a valid overall alternative because of the almost overwhelming difficulty in identifying the true author(s) of each publication (D'Angelo et al. 2011). This is especially in our case because of the ambiguity of Chinese names (Cornell 1982).

Let's use a single example to illustrate the severity of name ambiguity. A contributor "Liu Y" ranks the third place contributing 23 records in our database. A manual reading turned out that the single entry "Liu Y"

refers to nine different individuals. Liu Yi from Xi'an Jiaotong University contributed 10 records, Liu Yun from the Beijing Institute of Technology contributed 2 records, two Liu Yangs – one from the South China University of Technology contributing 4 records and the other from the University of Science and Technology of China with 2 records, and Liu Ying from Tsinghua University, three Liu Yus – one each from Peking University, the University of Texas, El Paso and Capital Medical University contributing 1 record, and finally, Liu Ye from the China University of Geoscience also had 1 record. By comparison, the most common surname/initials combination is only shared by 1.2% of the authors of that surname in the Western case (Cornell 1982).

[Table 6 about here]

In order to identify prolific authors, we manually disambiguated leading authors by taking their affiliations, co-authors, cited authors into consideration (see Table 6). The most prolific author “Jianchen Guan” has 27 records in the studies of China’s STI. Having worked at Fudan University and the Beijing University Aeronautics & Astronautics, Guan is now a professor at UCAS. Indeed, Guan has become a very important contributor in the national innovation studies focusing mainly on China. Of the 19 leading contributors, eight scholars are from universities located in Mainland China, including UCAS, Sichuan University, Xi’an Jiaotong University, Shanghai Jiao Tong University, Tsinghua University and Zhejiang University. Yuan Li and Yi Liu once worked at Xi’an Jiaotong University, and Jin Chen once worked at Zhejiang University before moving to Tsinghua University.

Four scholars are from universities located in Hong Kong and Macau: Kevin Zheng Zhou and George Chu Sheng Lin at the University of Hong Kong, Jie Wu at the University of Macau, Dean Tjosvold at Lingnan University in Hong Kong. The other seven scholars are from universities and research institutions outside Great China.

3.4 Main topics in the studies of China’s STI

Identifying main topics is useful for deepening the understanding of any academic field. Topics identified based on citation network analysis reflect knowledge connection between publications and clear relatedness in the timespan of the publications, although co-citation network, bibliographical coupling, and co-word analysis can also identify topics of the publications. Here, we analyze the main topics in the studies of China’s STI based on

citation network, seminal contributions and our research experience.

First, main topics are essentially the ones that a large number of scholars pay attention to and publish extensively. Seminal contributions can come from main topics. Citation network is helpful in generating most highly cited publications and their citation linkages, thus shedding some light on the evolution of a field and how linkages have identified over time. Therefore, citation network is a useful but insufficient tool to identify the main topics. Some papers that can be regarded in the same topic had no citation linkages, which might be partly attributed to negligence or bias on the part of authors. For example, in the citation network, both node 57 and node 148 are related to the reform of the innovation system, but the node 148 did not cite the node 57; nodes 258, 293 and 336 all are about Zhongguancun Science Park, but there were no citation linkages between them. In addition, cross-referencing effects exist between different topics (Sun and Seamus 2016). Certainly, we can also achieve clustering by using other tools such as co-keywords and co-citations. However, similar to citations, the existence of co-keyword and co-citation relations does not necessarily suggest relations between research contents; what is intrinsically related may not necessarily have the above quantitative relations. Therefore, we also incorporated judgments based on our experience as participants in this field and especially our familiarity with the literature and leading contributors.

Second, as mentioned, the studies of China's STI is an epitome of studying China's STI development co-evolving with such development. There was only one node in 1994 and 1997 respectively. The main contributions in the studies of China's STI appeared after 2000. Thus, seminal contributions could reflect the main topics of the field (see Table 4). Third, some papers excluded in the network for few citations have certain significance and influence on China's STI enterprise so as to be included in our discussion.

[Figure 2 about here]

CiteNetExplorer generates 50 most cited papers based on LCS in the citation network (see Figure 2 and Table 7). In Figure 2, nodes show last names of the authors of the publications, with a minimum citation node of 14 and a maximum of 92. Starting from seminal contributions and using citation network, we classified seminal papers (15 most cited papers) into three levels – macro [system (record 148), reform (records 433), capability (records 298, 609, and 486), and policy (record 948)], meso [regions (records 558 and 586) and industries (record 384)] and micro [organizations, in particular firms (records 700, 154, 857, 723, 375, and 142)].

Macro

At the early stage of reform and opening-up, China focused on S&T activities. The concept of “innovation” was first introduced in 1987 when Ye (1987) argued that China should seize the opportunity of the new technological revolution, accelerate industrial technological development, and transfer the world’s new technology to China. Obviously, Ye’s discourse extended the innovation from technological to economic development.

S&T reform and innovation system development

The reform of China’s S&T system began in 1985 following the economic reform in 1978. Scholars started reviewing and assessing the reform some ten years later, and this line of work has continued to be active, generating a number of publications. Of them, in a pioneering work, Xue (1997) (record 57) pointed out that despite significant progress in the reform of its S&T system, China still faced challenges such as weak industrial innovation before achieving a true transition to an enterprise-centered innovation system. A seminal work by Liu and White (2001) (record 148) indicates that with the reform, China’s innovation system had been more effective than that under central planning in introducing, diffusing and exploiting innovations.

In the following year, Sun (2002) (record 177) indicated that the state plays a crucial role in the development, restructuring, and performance of China’s innovation system during the transition period. Updating Sun (2002)’s work, Sun and Liu (2010) found that China’s R&D funding has shifted from a government-led to an enterprise-centered model, while the central government leads in reforming its innovation system with “Chinese characteristics.” In addition, scholars have compared innovation systems between Mainland China and Taiwan (Chang and Shih 2004) (record 221) and investigated the linkages between science and industry in the innovation systems (Motohashi and Yun 2007) (record 384).

Indeed, the reform of the S&T system is a constant theme in the literature. Cao et al. (2013)’s work re-examined the reform, arguing that the problem of China’s S&T system lies in a lack of effective coordination between central government agencies and between central and local governments at the macro level; ineffectiveness in macro-level coordination that influences distribution of resources at the meso level; and a weak culture of performance evaluation at the micro level with an overwhelming “publish-or-perish” orientation. Further, in their review of China’s post-2012 S&T and innovation system reform, Cao and Suttmeier (2017) pointed out that new reform policies promise new problems while ignoring a deeper underlying obstacle, the state’s role in the pursuit of innovation.

Innovation policy and indigenous innovation strategy

As a developmental state, China has formulated a slew of innovation policies, which in turn have played a central role in the development of S&T and innovation. Huang et al. (2004) (record 227) identified the stakeholders involved in the design and implementation of Chinese innovation policy and compare it with those of the governments in selected OECD countries.

In January 2006, China initiated a 15-year MLP, calling for turning the country into an innovation-oriented nation by 2020 and a world leader in S&T by 2050. It commits China to strengthening capabilities for indigenous innovation. In 2008, *OECD Reviews of Innovation Policy: China* reached several conclusions. First, China is already a major global S&T player in terms of inputs. However, the quality of its outputs still lags behind that of the quantitative ones. Second, China's deficiencies of the current policy and governance for promoting innovation came from the inefficiency of its key actors and of the NIS in general. Third, if the government can address the shortcomings by following international best practices, China has the potential to develop an NIS that supports sustainable growth. Liu et al. (2011) (record 948) found that China has shifted its S&T and industrial policy-centered innovation strategy to pursue a series of better coordinated, innovation-oriented economic and technology initiatives that give greater attention to a portfolio of policies including critical financial, tax, and fiscal measures.

In 2012, *China 2030*, a World Bank's study, also looked at China's NIS. In order to raise the quality of research and development, the World Bank suggests, China's policymakers should focus on increasing various skills of university graduates, building world-class universities, fostering innovative cities, and increasing the availability of venture capital for private startup firms (World Bank 2012). Sun and Cao (2014) opened the "black box" of China's central government R&D expenditure and pinpointed the roles of various agencies with missions in R&D in China's NIS.

National innovation capacity

National innovation capability represents a main topic in the studies of China's STI, most of which is in bibliometric and patentometric analysis. Zhou and Leydesdorff (2006) (record 298) indicated that China had become a leading nation measured by its share of the world's scientific publications and that citations of these publications had exhibited an exponential growth. Similarly, Kostoff et al. (2007a) (record 393) indicated that the bulk of China's publications were in the physical and engineering sciences, while the U.S. publications were mostly in the medical, social, and psychological sciences. Kostoff et al. (2007b) (record 394) and Altenburg et

al. (2008) (record 433) also showed that China has rapidly outpaced India in both number and citation of publications, but mounting innovation efforts had only rarely been materialized in cutting-edge innovations. While finding that universities played a vital role in the building up of China's national innovative capacity, Hu and Mathews (2008) (record 486) were puzzled by an apparent lack of contribution of the public sector in reinforcing such capacity. According to *Science & Engineering (S&E) Indicators 2018* (National Science Board, 2018), in 2016, China produced the largest volume of S&E publications, accounting for 18.6% of global output volume, more than the US (17.8%).

Meso

The amount of papers on the geography of STI in China reflects the importance of knowledge stickiness in space and industry as well as the industrial context of innovation.

The territorial distribution of innovation

Region is important for STI development in a vast territory like China. Research on territorial distribution of innovation has considerable potential (Sun 2016). Sun (2000) (record 118) found that patents are highly clustered in coastal provinces with rapid economic growth and inland provinces with a large population base, but the degree of regional concentration of overall patents is declining over time. Li (2009) (record 558) indicated that regional disparity in innovation comes from not only regions' different level of R&D investment but also their inefficient innovation process.

Territorial distribution of the ICT industry is another interesting topic. Wang and Lin (2008) (record 458) revealed that ICT manufacturing has a strong tendency to conglomerate in the eastern coast, but there is no significant relationship between spatial agglomeration and innovation and economic performance. Their subsequent work confirmed that frequent and intensive production linkages among firms in Shenzhen's ICT cluster were unable to guarantee outstanding innovative performance of these firms (Wang et al. 2010) (record 746).

Zhongguancun Science Park

Moving from territorial distribution to a certain region, Zhongguancun Science Park in Beijing, and indeed, science parks in China as a whole, has become the focus of attention. In 2004, Cao (2004) asked whether Zhongguancun's transition represents a process of "growing pains" or "premature senility." He concluded that the overwhelming role of government had impeded the efforts of Zhongguancun from duplicating the Silicon Valley model. Zhou (2005) (record 258) examined the changing patterns of behavior and interaction among the

state, domestic and multinational corporations during three different stages of Zhongguancun Science Park's development. Liefner et al. (2006) (record 293) found that companies in Zhongguancun are linked to both sources of knowledge – foreign companies and domestic universities and public research organizations. Tan (2006) (record 336) found that Zhongguancun has played a vital role in facilitating technology transfer and innovation since its inception. However, within a relatively short period, Zhongguancun started to show signs of premature aging and decline, especially when compared with its role model, Silicon Valley, a conclusion that is similar to Cao (2004).

Technological learning and catching-up in industry

An emerging country like South Korea has gone through a technological learning and catching-up process (Lee and Lim 2001). China is not different. Lu and Lazonick (2001) (record 139) demonstrated state's strategic role in the increasing importance for economic success of the integration of investment and organizational learning in Chinese electronic publishing industry. Modifying and applying Lee and Lim (2001) to the study of China's telecommunication industry, Mu and Lee (2005) (record 265) found that the important factors in China's catching-up process are the "market for technology" strategy, knowledge diffusion from MNCs to domestic firms, and government-driven industrial upgrading. Fan (2006) (record 304) suggested that domestic firms should be engaged in in-house R&D activities to build up their indigenous innovation capability, supplemented with external alliances. Obviously, this body of literature stressed government's roles, huge domestic market and indigenous R&D in China's technological learning and catching-up.

Micro

Innovation has been extended from enterprises to other organizations of the innovation system. So, it's clear, the STI research at the micro level supplements and complements that at the macro and meso levels.

The determinants of enterprises' innovation and performance

Published work tries to determine the factors impacting an enterprise's innovation and performance. Pappy and Song (1994) (record 32) indicated that relative product advantage and the acquisition of marketing information were highly correlated with new product success based on a survey of 129 state-owned enterprises (SOEs) in China. As China has witnessed its enterprises' innovation performance rising continually, studies have shown the impacts of several crucial factors.

First, personal relationship, or *guanxi*, has become a very important construct in explaining a firm's performance in the Chinese context. Park and Luo (2001) (record 142) provided strong evidence that Chinese

firms develop *guanxi* as a strategic mechanism to overcome competitive and resource disadvantages. Gao et al. (2008) (record 472) found that absorptive capacity moderates the effect of managerial ties on a corporation's innovativeness. Sheng et al. (2011) (record 857) indicated that business ties have a stronger positive effect on firm performance than political ties, and both effects depend on institutional and market environments.

Second, organizational capability is central to innovation. Yam et al. (2004) (record 232) suggested that Chinese firms consider a more balanced focus on their harmonizing capabilities of technological innovation between R&D, resources allocation, learning, and organizing. Chen et al. (2005) (record 254) concluded that conflict management based on cooperation promotes productive and top management team's effectiveness, which in turn leads to organizational innovation. Zhou and Wu (2010) (record 723) proposed that technological capability has differential effects on exploitative and explorative innovation.

Third, ownership matters in innovation. Tan (2001) (record 146) indicated that managers from large SOEs are not as innovative and are less willing to take risks than entrepreneurs from small privately-owned enterprises (POEs). Zhou et al. (2017) showed that the state ownership enables a Chinese firm to obtain crucial R&D resources but makes the firm less efficient in using those resources in innovation, and that a minority state ownership is an optimal structure for innovation development in this context.

Finally, public policy can help create an environment conducive to innovation. Zhao (2006) (record 327) argued that weak intellectual property right protection leads to low returns to innovation and underutilization of innovative talent, and MNCs that possess alternative mechanisms for protecting their intellectual properties therefore find it attractive to conduct R&D in China. Hu and Jefferson (2009) (record 609) found that amendments to China's patent law that favor patent holders and ownership reform that has clarified the assignment of property rights have led to China's patent boom. Guan and Yam (2015) indicated that government financial incentives such as special loans and tax credits positively influenced firm's innovative economic performance; however, direct earmarks not only failed to enhance and sometimes negatively affected such performance.

Enterprises' indigenous innovation capability

Research on Chinese firm's indigenous innovation capability had already begun before China launched the indigenous innovation strategy in 2006. Sun (2002) (record 171) revealed that in-house R&D efforts, rather than imported technologies, are the primary sources of industrial innovation in China. Zhou (2006) (record 312) found that an innovation strategy performed better over an imitation strategy in new product development.

Clearly, both in-house R&D and indigenous innovation capability are more important than imported technologies and imitation.

After 2006, the studies of China's STI have paid more attention to the issue of indigenous innovation. Guan et al. (2009) (record 586) found that manufacturing firms had already started moving away from a reliance on imported technology and equipment and using indigenous R&D efforts to innovate in the market economy. Wang and Kafouros (2009) found that international trade, FDI and R&D do not always lead to a firm's positive innovation performance, and their effects are moderated by technological opportunities and foreign presence. Li et al. (2010) (record 739) suggested that firms that invest in R&D and marketing activities benefit further from access to foreign knowledge due to increased absorptive capacity.

University spin-offs and Ventures

University's central role in an STI system is also reflected on spinning off firms, collaborating with enterprises and so on. Just as Chen and Kenney (2007) (record 371) indicated, universities have helped the development of Zhongguancun Science Park as China's largest high-tech cluster; in contrast, Shenzhen has consciously made efforts to establish and attract institutions of higher education.

Unlike the university-industry (UI) relations advocated by the Triple Helix or the New Economics of Science models, China's UI relations show their own characteristics. Eun et al. (2006) (record 337) argued that since the market-oriented reform Chinese universities had a strong propensity to pursue economic gains and to invest strong internal resources to launch start-ups. Hong (2008) (record 450) showed a geographic decentralizing/localizing trend in the knowledge flows from universities to industry in China between 1985 and 2004 and her findings suggested that the geographic constraint on knowledge flows only became salient lately because of administrative decentralization and economic reform. Kroll and Liefner (2008) (record 452) indicated that some university spin-offs have begun to substantially contribute to the technological upgrading of China's economy.

New technology ventures promote innovation in China. Li and Atuahene-Gima (2001) (record 154) suggested the need for simultaneous consideration of environment- and relationship-based strategic factors as moderators in the discourse on product innovation strategy among new technology ventures. They (record 174) continued to find that successful agency business activity is positively related to new venture performance but negatively related to its product innovation efforts in Chinese high-tech new ventures. Yiu et al. (2007) (record 373) examined empirically that relationship between firm-specific ownership advantages and international

venturing is moderated by the degree of home industry competition and export intensity. Li and Zhang (2007) (record 375) demonstrated that managers' political networking and functional experience are positively related to new venture's performance.

Finally, Zhang and Li (2010) (record 700) proposed that new ventures' ties with service intermediaries enable the ventures to plug into these networks and contribute to the ventures' product innovation by broadening the scope of their external innovation search and reducing their search cost.

Summary

The studies of China's STI have been rapidly emerging since 1995, during which some hot topics have emerged. At the macro level, scholars have paid more attention to China's S&T reform and innovation system, innovation policy and indigenous innovation strategy, and national innovation capability. As the government's "unlimited power" is the nature of innovation system with "Chinese characteristics" (Fang 2010), the comprehensive reform of the S&T system will depend on the further reform of China's political system. China's innovation policy was shifting to a more market-based system through critical financial, tax, and fiscal measures; China's innovation capacity has improved measured by the indicators of publications and patents.

At the meso level, territorial distribution of innovation, Zhongguancun Science Park in particular, and technological learning and catching-up in industry have attracted significant scholarly attention. China's innovation tends to concentrate on coastal provinces, which has been fundamentally driven by R&D investment, industrial specialization and innovation efficiency. There is no significant relationship between spatial agglomeration and innovation in China's ICT industry. Zhongguancun Science Park has started to show signs of premature aging and relative decline in China's innovation with the rise other high-tech zones such as Shenzhen. And China's technological catching-up depends on in-house R&D development at enterprises to build innovation capability and governments' promotion.

At the micro level, scholars are interested in learning the determinants of Chinese enterprises' innovation and performance, enterprises' indigenous innovation and university's spin-offs and venturing. *Guanxi* and managerial ties lead to higher firm innovation performance, innovation at Chinese firms depends on learning, technological capability, and ownership and public policy as important institutional factors influencing innovation. Indigenous and foreign innovation efforts are complementary, and the assimilation of foreign technology depends on firms' in-house R&D and absorbing ability. Universities have played an extremely important role in innovation. However, theoretical contributions coming out of China's experience and context

are few and far between, except *guanxi* as a concept of management studies bringing such experience to the international scholarly community.

4 Conclusion and Discussions

Since 1978, the studies of China's STI have been emerging as a new field attracting extensive scholarly attention alongside the country's rise as a leading country in STI. This paper attempts to provide a comprehensive and synthetic picture of China's STI study literature both qualitatively and quantitatively. The study includes 2,041 papers published by scholars from 1,289 institutions in 506 journals with 71,255 references and citations, from which we have found the following key findings.

First, the year 1995 was an important starting point of the studies of China's STI. The rapid growth in the number of papers and citations to the papers from 1995 onward has been accompanied by China's increasing investment in R&D, which in turn was stimulated by the strategy of "revitalizing the nation through the science and education" formulated in that year. The studies of China's STI have become a rapidly emerging academic field in particular after 2006 partly in response to the increased demand of understanding China within the academic and policymaking communities.

Second, scholars from China, the U.S. and the U.K. have been main contributors to the field, accounting for 50%, 27.2% and 12% of the literature respectively. However, scholars from South Korea and Japan have contributed less to the field. Tsinghua University, Zhejiang University and the Chinese Academy of Sciences are top three institutions contributing to the emergence of the studies of China's STI and a group of well-known universities in Greater China (Mainland, Hong Kong and Taiwan) have been leading the studies, which could be explained by a home academic effect. The lists of top institutions by records and by citations show very different pictures: Mainland China's institutions had strong presence in the former but Hong Kong institutions performed better in the latter.

Most of the 15 seminal works were published in *Research Policy*, although *Scientometrics* had published the most papers in this field. More than half of the main journals publishing China's STI studies are in the field of technology and innovation management with the remainder being journals of economics, management, business and environment studies. In addition, ambiguity of Chinese names, a common problem in bibliometric analysis, has made it hard to identify the primary contributors. However, Jianchen Guan, a professor at UCAS now, can be confirmed as the most prolific author in China's STI studies and in national innovation studies in

general.

Third, we identified several key research areas at the macro, meso and micro levels of the studies of China's STI, which also prompt our consideration of agendas for future research. At the macro level, potential topics of research include examining the differences between China and developed economies in terms of their institutional environment of STI development, practically the role of state in the STI system. China's model deviates from the developmental state or the state-led innovation system. As a transitional economy, China has been shifting from a centrally planned economy to socialist market-oriented economy, and from a closed to open economy. In this context, we want to know more about China's system of R&D expenditure, such as structure of government funding and corporate investment on R&D, allocation mechanism of R&D funding, performance and efficiency of R&D expenditure, which is at the core of its innovation system determining China's innovation capacity; China's mechanism of S&T evaluation, the foundation of S&T governance, whose reform is central to improving China's efficiency of S&T activities.

At the meso level, there is a lack of theorization of the Chinese innovation practice, as scholars still prefer to use existing theories like Lee and Lim (2001)'s model of technological learning and catching-up to benchmark Zhongguancun Science Park against Silicon Valley, rather than coming up with novel theories explaining the characteristics of the Chinese case. Strengthening the theorization of territorial distribution of S&T and regional innovation ecosystem in China, big country geospatially, will make crucial contributions to the field. Meanwhile, China's model of technological learning and catching-up differ from Lee and Lim (2001)'s model based on Korea's practice.

At the micro level, China's increasing importance in global STI space requires scholars to theoretically examine China's practice, rather than merely empirically testing the Chinese experience against the existing theories developed under the Western context. For example, how do we understand the role of SOEs and collectively owned enterprises in innovation? What is the role of the Chinese Communist Party in enterprises' innovation? These point to important directions for the studies of China's STI.

Finally, our bibliometric analysis may suffer from two limitations. First, we limited our data to the publications indexed by SCI-E and SSCI included in the Web of Science, which favors English-language journals and excludes books. While probably incomprehensive, our analysis might not have missed that much as many scholars also had published their journal articles before tuning out book-length, more systematic analysis. Our study also excluded the database of conference proceedings – CPCI-S and CPCI-SSH, among others – in

the WoS. For example, Jin Chen and his group have published at least 14 papers at conference proceedings included in CPCI of the WoS since 2006. The second limit has to do with the drawback of the bibliometric method. For example, name ambiguity has failed us to identify all authors, although we managed to manually identify some leading contributors; citation analysis may not capture the organic linkage and evolution of the literature. Nevertheless, we tried to compensate such a problem with a careful reading of the entire body of the literature so as to figure out its essence at the macro, meso, and micro levels.

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Tables

Table 1 Descriptive statistics of indicators

Fields	Indicators	Max	Min	Mean
Distribution of publications by economies	Records	1020	1	47.87
	%	50	0	2.33
Distribution of publications by institutions	Records	90	1	3.02
	TLCS	232	0	4.59
The citations indicators of publications	LCS	92	0	1.52
	LCS/t	6.13	0	0.22
	LCSx	89	0	1.25
	LCSb	6	0	0.13
	LCS _e	35	0	0.55
	LCS(e/b)	17.5	0	0.42
Contributing journals	Records	101	1	4.03
	TLCS	450	0	6.14
	TLCS/t	54.36	0	0.88
Contributors	Records	27	1	1.5

Notes: These descriptive statistics were analyzed on the basis of software-HistCite statistics, and the problem of name ambiguity was not taken into account in the statistics, although we manually identified the major contributors. Name ambiguity will influence the results of LCSx and the records of contributors a little.

Table 2 Distribution of full-counting-based publications in the studies of China's STI by economies

No.	Economies	Recs	Percent (%)	No.	Economies	Recs	Percent (%)
1	P.R. China	1020	50	11	Japan	38	1.9
2	the U.S.	556	27.2	12	India	34	1.7
3	the U.K.	244	12	13	Spain	32	1.6
4	Taiwan	121	5.9	14	Denmark	30	1.5
5	Australia	87	4.3	15	France	30	1.5
6	Canada	84	4.1	16	Sweden	29	1.4
7	Germany	70	3.4	17	Italy	23	1.1
8	South Korea	62	3	18	Belgium	21	1
9	Singapore	50	2.4	19	Malaysia	17	0.8
10	Netherlands	49	2.4	20	Switzerland	16	0.8

Note: Total percentage exceeds 100%.

Table 3 Institutional distribution of publications in the studies of China's STI: by number of records and TLCS

#	Institution	Recs	#	Institution	TLCS
1	Tsinghua Univ	91	1	City Univ Hong Kong	232
2	Zhejiang Univ	90	2	Tsinghua Univ	188
3	Chinese Acad Sci	64	3	Univ Hong Kong	182
4	City Univ Hong Kong	62	4	Chinese Univ Hong Kong	169
5	Peking Univ	56	5	Texas A&M Univ	116
6	Univ Hong Kong	55	6	Calif State Univ Northridge	103
7	Fudan Univ	39	7	Rice Univ	94
8	Renmin Univ China	38	8	State Sci Technol Commiss China	92
9	Natl Univ Singapore	34	9	Fudan Univ	83
10	Xi An Jiao Tong Univ	34	10	Beijing Univ Aeronaut & Astronaut	82
11	Shanghai Jiao Tong Univ	33	11	Zhejiang Univ	82
12	Chinese Univ Hong Kong	32	12	Inst Sci & Tech Informat China	79
13	Univ Nottingham	31	13	Natl Univ Singapore	79
14	Sichuan Univ	29	14	Univ Amsterdam	78
15	Hong Kong Univ Sci & Technol	28	15	Lingnan Univ	75
16	Wuhan Univ	26	16	Peking Univ	69
17	Georgia Inst Technol	24	17	Brandeis Univ	62
18	Natl Taiwan Univ	23	18	Univ Nottingham	61
19	E China Normal Univ	22	19	Georgia Inst Technol	54
20	Univ Manchester	22	20	Univ Miami	54

Table 4 Top 15 seminal articles in studies of China's STI by LCS/t

#	Record #	Publication	LCS	LCS/t	LCSx	LCSb	LCSe	LCS(e/b)
Macro								
1	148	Liu XL, White S Comparing innovation systems: a framework and application to China's transitional context RESEARCH POLICY. 2001 AUG; 30 (7): 1091–1114	92	6.13	89	2	35	17.50
8	433	Altenburg T, Schmitz H, Stamm A Breakthrough? China's and India's transition from production to innovation WORLD DEVELOPMENT. 2008 FEB; 36 (2): 325–344	31	3.88	30	3	22	7.33
2	298	Zhou P, Leydesdorff L The emergence of China as a leading nation in science RESEARCH POLICY. 2006 FEB; 35 (1): 83–104	59	5.9	53	5	23	4.6
5	609	Hu AG, Jefferson GH A great wall of patents: What is behind China's recent patent explosion? JOURNAL OF DEVELOPMENT ECONOMICS. 2009 SEP; 90 (1): 57–68	30	4.29	30	5	18	3.6
10	486	Hu MC, Mathews JA	29	3.63	25	3	12	4.00

		China's national innovative capacity						
		RESEARCH POLICY. 2008 OCT; 37 (9): 1465–1479						
15	948	Liu FC, Simon DF, Sun YT, Cao C						
		China's innovation policies: Evolution, institutional structure, and trajectory	15	3	13	2	13	6.5
		RESEARCH POLICY. 2011 SEP; 40 (7): 917–931						
Meso								
7	558	Li XB						
		China's regional innovation capacity in transition: An empirical approach	29	4.14	27	6	17	2.83
		RESEARCH POLICY. 2009 MAR; 38 (2): 338–357						
11	586	Guan JC, Yam RCM, Tang EPY, Lau AKW						
		Innovation strategy and performance during economic transition: Evidences in Beijing, China	24	3.43	20	3	17	5.67
		RESEARCH POLICY. 2009 JUN; 38 (5): 802–812						
14	384	Motohashi K, Yun X						
		China's innovation system reform and growing industry and science linkages	27	3	23	0	16	16/0
		RESEARCH POLICY. 2007 OCT; 36 (8): 1251–1260						
Micro								
3	700	Zhang Y, Li HY	34	5.67	31	4	30	7.5

		Innovation search of new ventures in a technology cluster: The role of ties with service intermediaries							
		STRATEGIC MANAGEMENT JOURNAL. 2010 JAN; 31 (1): 88–109							
4	154	Li HY, Atuahene-Gima K							
		Product innovation strategy and the performance of new technology ventures in China	81	5.4	74	0	34	34/0	
		ACADEMY OF MANAGEMENT JOURNAL. 2001 DEC; 44 (6): 1123–1134							
6	857	Sheng SB, Zhou KZ, Li JJ							
		The Effects of Business and Political Ties on Firm Performance: Evidence from China	21	4.2	19	4	19	4.75	
		JOURNAL OF MARKETING. 2011 JAN; 75 (1): 1–15							
9	723	Zhou KZ, Wu F							
		Technological capability, strategic flexibility, and product innovation	22	3.67	18	6	16	2.67	
		STRATEGIC MANAGEMENT JOURNAL. 2010 MAY; 31 (5): 547–561							
12	375	Li HY, Zhang Y							
		The role of managers' political networking and functional experience in new venture performance: Evidence from China's transition economy	30	3.33	24	2	21	10.50	
		STRATEGIC MANAGEMENT JOURNAL. 2007 AUG; 28 (8): 791–804							
13	142	Park SH, Luo YD	48	3.27	49	0	23	23/0	

Guanxi and organizational dynamics: Organizational networking in Chinese firms

STRATEGIC MANAGEMENT JOURNAL. 2001 MAY; 22 (5): 455–477

Table 4 Top 10 journals publishing work by records and TLCS/t

#	Journal ranking by Recs	Recs	%	2017IF
1	SCIENTOMETRICS	101	4.9	2.173
2	INTERNATIONAL JOURNAL OF TECHNOLOGY MANAGEMENT	70	3.4	0.869
3	TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	64	3.1	3.129
4	CHINESE MANAGEMENT STUDIES	61	3	0.857
5	RESEARCH POLICY	50	2.4	4.667
6	TECHNOVATION	43	2.1	4.802
7	ASIA PACIFIC JOURNAL OF MANAGEMENT	36	1.8	2.474
8	TECHNOLOGY ANALYSIS & STRATEGIC MANAGEMENT	36	1.8	1.273
9	CHINA ECONOMIC REVIEW	33	1.6	1.800
10	JOURNAL OF BUSINESS RESEARCH	29	1.4	2.509

#	Journal ranking by TLCS/t	TLCS/t	TLCS	2017IF
1	RESEARCH POLICY	54.36	450	4.667
2	SCIENTOMETRICS	31.67	157	2.173
3	STRATEGIC MANAGEMENT JOURNAL	23.25	204	5.482
4	TECHNOVATION	21.13	166	4.802
5	TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	17.7	96	3.127
6	WORLD DEVELOPMENT	15.62	121	3.166
7	ASIA PACIFIC JOURNAL OF MANAGEMENT	15.38	85	2.474
8	TELECOMMUNICATIONS POLICY	12.22	57	2.087
9	ENVIRONMENT AND PLANNING A	12.21	96	2.152
10	INTERNATIONAL JOURNAL OF TECHNOLOGY MANAGEMENT	10.93	74	0.869

Notes: LCS/t shows the average LCS per year since the publication date. The impact factor considers all journals currently listed in the 2017 Journal Citation Reports (Thomson Reuters 2018, <http://admin-apps.webofknowledge.com/JCR/JCR?PointOfEntry=Home&SID=1BoxsbQ4ouoHlvAhGNQ>)

Table 6 Top 20 contributors in the studies of China's STI by records

No.	Name	Recs	Institutions
1	Jianchen Guan	27	Univ Chinese Acad Sci, Sch Management
2	Yuandi Wang	24	Sichuan Univ, Sch Business
3	Yuan Li	15	Shanghai Jiao Tong Univ, Antal Coll Econ & Management
3	Kevin Zheng Zhou	15	Univ Hong Kong, Sch Business
5	Jin Chen	13	Tsinghua Univ, Sch Econ & Management
6	Haiyang Li	12	Rice Univ, Jesse H Jones Grad Sch Business
6	Xiaobo Wu	12	Zhejiang Univ, Sch Management
8	Lutao Ning	11	Queen Mary Univ London, Sch Business & Management
8	Ingo Liefner	11	Univ Giessen, Dept Econ Geog
8	Yifei Sun	11	Calif State Univ Northridge, Dept Geog
8	Dean Tjosvold	11	Lingnan Univ, Dept Management
8	Chan-Yuan Wong	11	Univ Malaya, Fac Econ & Adm
13	Shanxing Gao	10	Xian Jiaotong Univ, Sch Management
14	Yi Liu	9	Shanghai Jiao Tong Univ, Antal Coll Econ & Management
14	Jie Wu	9	Univ Macau
14	Ronald N. Kostoff	9	Off Naval Res
14	Loet Leydesdorff	9	Univ Amsterdam, Amsterdam Sch Commun Res
14	George Chu Sheng Lin	9	Univ Hong Kong, Dept Geog
14	Xielin Liu	9	Univ Chinese Acad Sci, Sch Management

Notes: First, the main contributors ranked by their contributions in studies of China's S&T and innovation, and by the number of papers they published, without distinguishing whether they were first author, correspondence authors or other authors. Second, the author's institution is the latest institution signed in their latest publication during the period of this study, and these do not represent their current and previous institutions. For example, now Yuan Li works in Tongji University. Third, indeed, there are only 19 authors whose number of publications equal to or more than nine.

Table 7 A reference to the literature in Figure 2

No.	Code	Publication	LCS	GCS
1	32	Parry ME, 1994, J PROD INNOVAT MANAG, V11, P15	14	75
2	57	Xue L, 1997, J ENG TECHNOL MANAGE, V14, P67	21	35
3	118	Sun YF, 2000, REG STUD, V34, P441	18	29
4	139	Lu QW, 2001, RES POLICY, V30, P55	17	30
5	141	Liu H, 2001, TECHNOVATION, V21, P175	15	34
6	142	Park SH, 2001, STRATEGIC MANAGE J, V22, P455	49	455
7	146	Tan J, 2001, J BUS VENTURING, V16, P359	38	73
8	148	Liu XL, 2001, RES POLICY, V30, P1091	92	206
9	154	Li HY, 2001, ACAD MANAGE J, V44, P1123	81	326
10	171	Sun YF, 2002, ENVIRON PLANN A, V34, P1059	27	37
11	174	Li HY, 2002, STRATEGIC MANAGE J, V23, P469	25	92
12	177	Sun YF, 2002, EURASIAN GEOGR ECON, V43, P476	16	24
13	185	Jefferson G, 2003, CHINA ECON REV, V14, P89	32	73
14	209	Cheung KY, 2004, CHINA ECON REV, V15, P25	33	131
15	216	Chen SH, 2004, RES POLICY, V33, P337	14	52
16	221	Chang PL, 2004, TECHNOVATION, V24, P529	23	44
17	227	Huang C, 2004, R&D MANAGE, V34, P367	15	31
18	232	Yam RCM, 2004, RES POLICY, V33, P1123	19	101
19	250	Tan J, 2005, STRATEGIC MANAGE J, V26, P141	15	116
20	254	Chen GQ, 2005, J MANAGE STUD, V42, P277	15	83
21	258	Zhou Y, 2005, ENVIRON PLANN A, V37, P1113	15	36
22	265	Mu Q, 2005, RES POLICY, V34, P759	23	79
23	293	Liefner I, 2006, ENVIRON PLANN A, V38, P111	19	37
24	298	Zhou P, 2006, RES POLICY, V35, P83	59	204
25	304	Fan PL, 2006, TECHNOVATION, V26, P359	21	54
26	312	Zhou KZ, 2006, IND MARKET MANAG, V35, P394	20	76
27	327	Zhao MY, 2006, MANAGE SCI, V52, P1185	17	132

28	336	Tan J, 2006, J BUS VENTURING, V21, P827	20	64
29	337	Eun JH, 2006, RES POLICY, V35, P1329	19	49
30	371	Chen K, 2007, WORLD DEV, V35, P1056	22	43
31	373	Yiu DW, 2007, J INT BUS STUD, V38, P519	18	169
32	375	Li HY, 2007, STRATEG MANAGE J, V28, P791	30	154
33	384	Motohashi K, 2007, RES POLICY, V36, P1251	27	43
34	393	Kostoff RN, 2007, TECHNOL FORECAST SOC, V74, P1539	15	29
35	394	Kostoff RN, 2007, TECHNOL FORECAST SOC, V74, P1609	15	26
36	433	Altenburg T, 2008, WORLD DEV, V36, P325	31	86
37	450	Hong W, 2008, RES POLICY, V37, P580	15	33
38	452	Kroll H, 2008, TECHNOVATION, V28, P298	18	34
39	458	Wang CC, 2008, ISSUES STUD, V44, P145	15	21
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