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University technology transfer in China: a literature review and taxonomy

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Abstract The Chinese university system is one of the world's largest academic research performers and technology transfer is one of the system's central roles. Academic interest in Chinese university technology transfer in both the West and China has increased in parallel. This review aims to outline what is known and evaluate the state of research about university technology transfer in China. To be comprehensive, uniquely this review considers the relevant journal articles in both English and Chinese languages. The major themes and methodologies used by authors are identified. The evolution of the literature, particularly those in Chinese from general discussions often with minimal citations to more empirically rigorous studies is documented. It is also shown that the English and Chinese language literatures have little overlap in terms of citations, thereby indicating that the two research communities are still largely disconnected. It is found that the sources of data have remained quite limited and the quantitative research is based almost entirely upon government statistics collected for administrative purpose. The concluding discussion suggests possible avenues for future progress in terms of developing new data sources and increasing the cross-fertilization of two research communities.

Keywords China · Universities · Technology transfer · University–industry linkages

JEL Classification O1 · O2 · O3 · P2

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1 Introduction

China is now the second largest performer of research in the world and its universities are rapidly improving their research performance (e.g., Zhou 2015). While China, of course, wishes to contribute to the global knowledge base, it also expects its universities to transfer research results to society and assist in economic development. Given the importance of China, it is remarkable that university technology transfer (UTT) in Europe and North America has received enormous scholarly attention, but far less is known about transfer in non-European nations.[1] Until recently, this may have been justified because nearly all universities in developing countries were focused on pedagogy. This has changed as many developing countries, particularly China, have increased their investment in academic research (Altbach and Balan 2007).

While China began serious investment in university research only in the late 1980s, it has since then increased university research spending at a compound annual growth rate of 15 %—a sustained rate of increase only rivaled by the U.S. in the post-Sputnik era. China, in 2014 surpassed Japan, in purchasing power parity terms, to become the second largest investor in university R&D (U.S. National Science Foundation 2016).[2] It is the developing country that has most dramatically embarked upon building its research universities, due, at least in part, to a belief that they will make major contributions to its economic development. Due to its size and visibility, China's investment in university research and deliberate emphasis on technology transfer are of particular importance, especially since the consensus has been that in developing countries UTT has been ineffective (Brundenius et al. 2011; Wu 2010; Yusuf and Nabeshima 2007).

Despite nearly two decades of research, there has been no comprehensive review and assessment of the state of global knowledge of Chinese university technology transfer (CUTT) activities.[3] Interestingly, in China, as is the case in Western nations, there is no standard definition of what university technology transfer is. In the journal articles reviewed for this article the working definition in China has for all intents and purposes been, with the exception of the unique university-owned enterprises (discussed below), roughly the same one as discussed in the preponderance of the English-language technology transfer articles, namely patents, technology licenses, and university spin-offs. In the English-language technology transfer literature, this reduction of UTT to patents, licenses, and spin-offs is receiving increased criticism as an impoverished perspective. This simplification is also a problem in the studies of CUTT (for Western nations, see Kenney and Mowery 2014; Perkmann et al. 2013).

To provide a comprehensive assessment of CUTT, and to address the lamentable fact that many Western studies of Chinese innovation draw nearly exclusively upon the English-language sources, we assess research in both languages. This should encourage scholars in both languages to gain greater awareness of each other's efforts, thereby maximizing cross-fertilization. Our comprehensive review provides insight into how the literature has evolved and, in particular, how research questions, theory, and methodology have changed. The resulting identification of key issues in CUTT can contribute to both a

[1] Early research suggested that investment by developing countries in higher education was negatively related to economic development (Psacharopoulos 1994). However, later research found more positive returns to higher education (Psacharopoulos and Patrinos 2004).

[2] In real dollar terms, Japan still spends more on university research than China.

[3] We identified one general review of all types of technology transfer in China (Chan and Daim 2011).

deeper understanding of the state-of-the-art discussion in China and to comparisons with other nations.

A comprehensive review of the entire corpus of academic work on CUTT also provides an opportunity to conduct a "meta-analysis" of the differences in styles between Chinese- and English-language academic journals. Not surprisingly, there are noticeable differences in the types of articles published and the academic presentation styles as measured in terms of data used and even the number of references. The meta-analysis also suggests that there may be a convergence occurring in terms of topics and presentation underway.

The review begins with a brief introduction to the Chinese universities and technology transfer. This is followed by a methodology discussion for identifying articles dealing with CUTT. The third section is a meta-analysis of the coherence of two literatures in terms of topics, citation patterns and interaction between and among the articles. The next section identifies five major research themes that encompass the research topics of the CUTT articles reviewed. The discussion and conclusion summarize our results, identify gaps in the literature, and suggest opportunities for future research.

2 Chinese university R&D and technology transfer

China has a long history of institutions of higher learning, but the establishment of modern Western-style universities began only in the 1890s. By the 1930s, after a series of administrative reforms, the Chinese university system had a modicum of scientific and engineering training. With the formation of the People's Republic of China in 1949, the new leadership's primary objective was to revive and modernize the industrial capacity. In 1949, the Communist Party adopted the Common Program, its main constitutional document, which declared that natural science should be placed "at the service of industrial, agricultural and national defense (Hayhoe 1989: 68)" and presumably any technologies developed should be transferred. As Table 1 indicates, as a party with Leninist roots, the Chinese Communist Party had a fundamental belief in the power of science and technology to benefit society.

The adoption of the Russian higher education model largely relegated universities to teaching, while the Chinese Academy of Sciences specialized in basic research and the research institutes were tasked with applied research. Various plans were adopted to develop Chinese research capabilities but little of this research was undertaken in universities (Liu and White 2001). The Cultural Revolution of 1966–1976, further affected China's scientific capabilities as activities at universities and research institutions were dramatically curtailed.

With the end of the Cultural Revolution, in the late 1970s and the transition to a socialist market economy, the Chinese government introduced policies to encourage industrial and technological development. At the time, there was little transfer of research results from either research institutes or universities to industrial production (Chen and Kenney 2007). In 1978, China introduced a new science policy stating that Chinese science and technology should meet the needs of the social and economic development. It concluded that the connection between academic research and industrial needs was weak and that it must be encouraged (see Table 1). Despite having little research underway at the time, universities were included in the critique (Chen ch 1986).

As part of the transition to market socialism, the Chinese government implemented a series of policies aimed at encouraging technology development (see Table 1). For

Table 1 Main university technology transfer-related laws and regulations enacted from 1949–2015. *Source*: Collected and organized by authors

Time	Main legislation	Goal
September, 1949	Common Program of the Chinese People's Political Consultative Conference	Basic definition of the role of science in development of Chinese society
March, 1951	Instructions on Strengthening the Contact between the Chinese Academy of Sciences and Industry, Agriculture, Health, Education and National Defense	Scientists should engage in research with benefits to society
January, 1975	Constitution of the People's Republic of China	Research should be combined with productive labor
March, 1978	National Science and Technology Development Plan Outline from 1978–1985	S&T should play an increasingly large role in production and research should be combined with production and application
March, 1984	Patent Law of the People's Republic of China	Granted inventors the right to patent inventions
January, 1985	State Council's Interim Provisions on Technology Transfer	Encouraged a market for state-funded technology
November, 1986	High-technology Research and Development Plan Outline (namely the 863 Program)	Program funded to stimulate the development of defense-oriented technologies
May, 1987	Opinions on Science and Technology Reform in Universities	University education and research should contribute to production and URIs and firms should cooperate
June, 1987	Technology Contract Law of People's Republic of China	Guaranteed technology contracting parties' lawful rights and interests and maintain order in technology markets
August, 1988	China Torch Program	High-technology development plan that eased regulations, provided support for facilities to attract foreign companies, and encouraged the establishment of indigenous firms in special zones throughout China, many of which were located close to URIs. This facilitated the development of USPs
July, 1993	Scientific and Technological Progress Law of the People's Republic of China	Called the Chinese "Bayh-Dole Act" and granted universities the rights to commercialize government-funded technologies and IP
May, 1996	Law on Promoting the Transformation of Scientific and Technological Achievements	Meant to promote, guide, and standardize state-funded IP technology transfer at URIs
May, 1998	Law meant to create world-class Universities (985 Project)	Provided massive funding to selected universities so that they can become world-class
March, 1999	Regulations on Promoting Scientific and Technological Achievement Transformation	Encouraged S&T personnel to invent new technologies and transfer them to develop high-tech industries
April, 1999	Regulations on Universities' Intellectual Property Protection and Management	Gave university IP rights and encouraged them to contribute to S&T industrialization
August, 1999	Decisions on Enhancing Technological Innovation, Developing High Technology, and Realizing Industrialization	Encouraged and supported universities to establish USPs and improved their IP management systems

Table 1 continued

Time	Main legislation	Goal
November, 1999	"211 Project" Construction Planning	Funded construction at approximately 100 universities in a variety of key subjects
June, 2002	Opinions on Giving Full Play to the Role of Universities' Scientific and Technological Innovation	Further encourage university S&T innovation and promote the combination of science and education in order to improve NIS
December, 2003	Enterprises' State Assets Transfer Interim Measures Order No. 3	Meant to regulate and standardize technology transfers to firms of state assets under SASAC's purview
December, 2007	National Technology Transfer Promotion Action Program	Meant to build an innovation system of industry–university–institute to promote the transformation of S&T into productivity
December, 2007	National People's Congress (NPC, the Legislature) Revised the Science and Technology Progress Law	Meant to enhance technology transfer and encourage local government support for research cooperation between industry and universities
June, 2008	National Intellectual Property Strategy Outline	Meant to increase China's IP creation, utilization, protection, and management ability
November, 2010	National Patent Development Strategy (2011–2020)	Declared 2020 goal to become a country with high levels of patent creation, utilization, and protection
September, 2012	Opinions on Deepening the Reform of Scientific and Technological System and Speeding up the Construction of National Innovation System	Supported enterprises and URIs in working with each other by setting up an R&D platform and innovation strategy alliance
March, 2015	Opinions on Deepening the Reform of Systems and Mechanisms and Speeding up the Implementation of Innovation-driven Development Strategy	Plan to gradually separate URIs and their subsidiary enterprises (UOEs) and they should no longer create UOEs. Also, to strengthen IP management.
August, 2015	Law of Promoting Scientific and Technological Achievements transformation of the People's Republic of China (2015 Revision)	Meant to standardize and speed-up the transformation of S&T achievements into economic benefits

example, in 1984 the Chinese government legalized patenting in an effort to encourage invention and its application to economic purposes. In 1985, the inauguration of a patent law and interim provisions for technology transfer were issued with the aim of making technology licensing attractive. In 1986 the Chinese government initiated large-scale national technology research programs, including the 863 Program. In a major rethinking of the role of the university, in 1987, the State Education Committee stated that universities must more actively participate in the development of science and technology that could assist in national development and enterprise growth. With this rethinking, the Chinese government began to dramatically increase university research funding. In 1987, the Technology Contract Law was passed to further encourage technology transfer from Chinese universities. In 1988, China launched the Torch Program, which funded an initiative to encourage the establishment and growth of technology firms in special zones built near universities and research institutes (Bi ch 2006).[4]

Although, in principle, a communist system should be supportive of technology development to advance economic activity, in reality the organization of the Chinese political economy was not conducive to either university technology development or transfer. At the time, Chinese universities had little research-based technology to transfer (Zhu and Frame 1987). Yet there were remarkable exceptions including Legend (now Lenovo) which was a spin-off from the Chinese Academy of Sciences in 1984, Stone Computer which was established by a group of Tsinghua University alumni in 1984, and Founder Computer which was a Beijing University spin-off in 1986 (Kenney et al. 2013; Lu 2000). Other university-owned enterprises (UOEs), such as Tsinghua Tongfang, Qingdao Tianqiao, and Zheda Wangxin (Eun et al. 2006), also commercialized university technology.

In 1993, the government, recognizing that Chinese university research was woefully inadequate, passed the Scientific and Technological Progress Law guaranteeing scientific research freedom, encouraging scientific exploration and technological innovation, and protecting intellectual property rights (see Table 1). In 1993, a law was passed that required university employee-inventors to transfer ownership of any inventions to the university (this was roughly comparable to the U.S. Bayh-Dole Act) (Jia ch 1996).

In 1999, the legal system was further changed by a set of regulations stipulating that universities could use a variety of strategies to commercialize high-technology achievements, including establishing their own firms. Researchers were permitted to take sabbaticals to establish new firms or assist in technology transfer. The same year, the Ministry of Education issued regulations encouraging researchers to invent and transfer technology by clearly defining university responsibilities in intellectual property protection. In 2002, the Ministry of Science and Technology and Ministry of Education jointly formulated policies meant to increase the role of universities in the national innovation system (Bi ch 2006). This led to increased support for university science parks (USPs), incubation networks, and UTT organizations.

In 2007, in the hope of further improvement, the Ministry of Science and Technology, the Ministry of Education, and the Chinese Academy of Sciences released the National Technology Transfer Promotion Action Program, which emphasized the creation of an enterprise-centric innovation system. Also in 2007, the National People's Congress (NPC, the legislature) revised the Science and Technology Progress Law, yet again, to enhance domestic technology transfer and encourage local government support for research cooperation between industry and universities. In 2008 the State Council of China (ch 2008) issued the National Intellectual Property Strategy Outline to promote intellectual property creation, utilization, protection, and management to build an innovative country. In 2010, the National Patent Development Strategy (2011–2020) was issued by the State Intellectual Property Office (ch 2012) to further encourage intellectual property creation.

In the 1990s, China continued its concerted effort to improve the university research capabilities through major research funding initiatives. The largest of these were the 211 Project initiated in 1995 that increased research funding for 116 top universities with the goal of having the improved research contribute to local economic development and the 985 Project launched in 1998 that anointed 39 universities for major new research funding to propel them to world-class status (Zhang et al. 2013b).

[4] As a convenience, every Chinese-language reference is marked with a "ch" before the date.

These changes are reflected in the growth of university R&D expenditures. After the deep budget cuts in the 1980s, in the 1990s, the Chinese government reversed course and initiated an astonishing growth in university R&D funding (Hershberg et al. 2007). In 1991, China's R&D investment was RMB 15.08 billion, or approximately 0.7 % of the gross domestic product (GDP), and by 2013, R&D investment had increased to RMB 1.185 trillion, or approximately 2.01 % of GDP. The plans announced in 2015 plan to further increase funding to 2.5 % of GDP. Both University and research institute R&D experienced this increase. From 2004 to 2013, university R&D expenditures increased at an 18.9 % compound annual growth rate (CAGR), a historically unprecedented expansion, while the research institutes, which had a CAGR of 20.55 %, increased their budgets even more rapidly.

The massive investment contributed to a rapid increase in the publication of academic journal articles (see Fig. 1). Although this boom in publication affected both domestic and foreign journals, after 2009 foreign journal publication continued to increase, while domestic publication stagnated. This reflects two changes. First, most likely, Chinese R&D capacity has increased in quality and scholars increasingly targeted international journals. Second, university administrations and the government began to emphasize foreign journal publications more highly and began offering financial rewards to scholars for articles in foreign publications. Effectively, the Chinese government uses the global academic evaluation system to gauge researchers' quality. The sheer scale of investment in university R&D by a still developing economy within the context of an expressed goal of technology transfer makes China particularly interesting for researchers and policy-makers globally.

3 Methodology

Our literature review began by examining the Chinese and English-language journals, most likely to publish articles on CUTT. The English-language journals were *Research Policy*, *Journal of Technology Transfer*, *Technovation*, *World Development*, *Journal of Higher Education*, *R&D Management*, *Journal of Business Venturing*, *Management Science*, *Small Business Economics*, *International Journal of Industrial Organization,* and *International Journal of Innovation and Technology Management*. The keywords used were "technology transfer" and "Chinese university." Because it was not clear which journals would publish articles on CUTT, we conducted a search of all Chinese-language journals. The number of articles that emerged was vast, and many were in obscure internal department or university journals. To limit the number of articles to the most significant, we then restricted the search to journals found in the Chinese Social Sciences Citation Index (CSSCI). Established in 1997, the CSSCI indexes publications in more than 500 academic journals and is the most authoritative source for Chinese social sciences and humanities publications.

To identify the articles, keyword combinations or variations thereof including, but are not limited to, UTT (大学技术转移), technology transfer in universities and colleges (高校技术转移, 高校技术转让, and 大学技术转让), patents in universities and colleges (大学专利 and 高校专利), scientific and technological achievement transformation in universities or universities and colleges (高校科技成果转化 and 大学科技成果转化), university or universities and colleges knowledge transfer (大学知识转移 and 高校知识转移) were used. Each article's bibliography was examined for additional articles. We also examined the references in Chinese-language books on UTT to find other relevant articles.

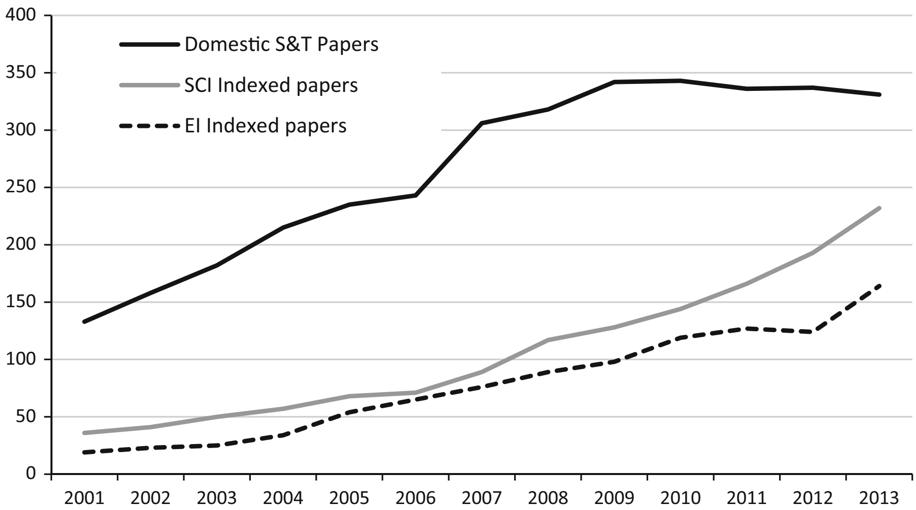

Fig. 1 Domestic S&T papers by higher education and Chinese S&T papers published in international journals and indexed by the SCI and EI (in thousands of papers), 2001–2013. *SCI* Science Citation Index, *EI* Engineering Index. *Source*: China Science & Technology Statistics Data Book, various years

We excluded all articles in which UTT was only a part of the article's study. All articles that were identified as possibly fitting the criteria were reviewed for relevance, and their bibliography was examined for possible additional articles. In both languages, the literature search was not ended until we reached saturation—that is, all references we encountered led back to articles already included in our database or had been excluded due to relevance. We did not include book chapters in edited collections and chapters on UTT in books.

For each article, our database includes: (1) author name(s), (2) article title, (3) year published, (4) journal, (5) numbers of citation in Google Scholar, and (6) journal impact factor. The articles were classified into categories according to whether they were theoretical, empirical, case studies, narratives, or "commentary" contributions.[5]

4 Descriptive results

Our search identified 191 articles focusing on some aspect of CUTT. The 33 English articles were published in 15 different journals, and 158 Chinese articles were published in 40 different journals. There has been an increasing interest in CUTT that we attribute to an increase in interest globally in UTT, increased Chinese government attention to the topic, and an interest in the growing contributions by Chinese researchers to the global scientific community. Although government policy encouraging UTT began in the 1980s, there was little academic awareness of this as a topic of, and only in the late 1990s did scholarly interest increase. This resulted in an increase in the number of articles on CUTT in both the English- and Chinese-language literature (see Fig. 2). While the number of English-language articles increased, the growth lagged that of Chinese-language articles.

[5] The commentary classification refers to the large number of Chinese journal articles that are comments upon the general nature of technology transfer or its desirability. They are not based upon research and, for the most part, are not even descriptive.

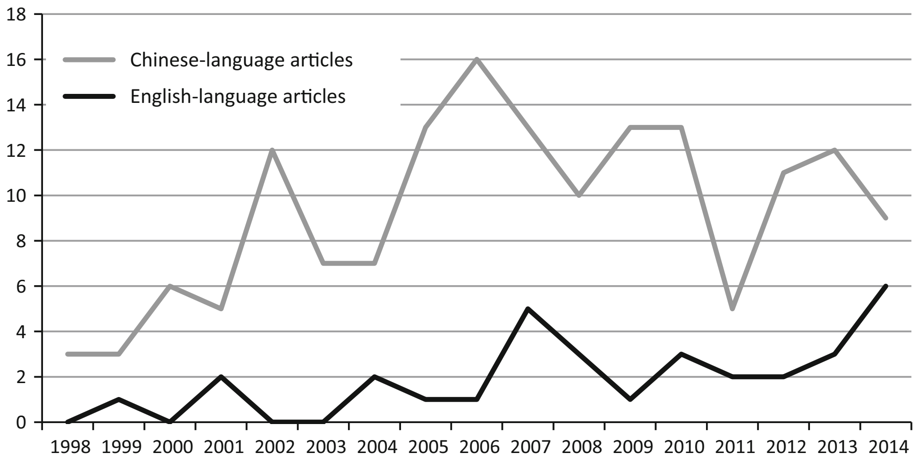

Fig. 2 Chinese university technology transfer articles published per year, 1998–2014

University technology transfer is a specialized field and thus would be expected to be concentrated in specialized field journals. The two English-language journals that published the greatest number of articles were the *Journal of Technology Transfer* and *Research Policy,* which together accounted for 39 % of all articles (13 articles) (see Fig. 3). Only four other journals published more than two articles and nine English-language journals published only one article. Not surprisingly, a similar pattern is observed in China (see Fig. 4). Six journals published 65 % of the total (102 articles). *R&D Management* published the greatest number of articles, followed by *Science and Technology Management Research*—together, they accounted for 33 % of the total. Twenty-five different Chinese journals published only one article.[6]

Each article was classified into one of five methodologies; theory, case study, history, empirical, and empirical with hypothesis testing. These classifications are quite broad but are helpful in analyzing the literature and its development over time. For Chinese scholars, this was a period of rapid change in research methodologies. In terms of methodology 120 out of 158 total Chinese-language articles relied on qualitative, non-empirical methods. Sixty-nine of the articles, especially during the early period, were largely exhortations for increased technology transfer. Their distinguishing feature is a lack of any data and these have been classified as “commentary” discussions. Such articles constituted more than 50 % of all Chinese-language articles prior to 2010.

Among the 89 Chinese-language articles that have been classified under one of the five methods listed above, 19 were case studies based typically on one or more universities (Beijing University, Central South University, Fuzhou University, Nanchang University, Shanghai Jiaotong University, Tsinghua University, and Wuhan University). The English-language case studies were also skewed toward the same elite Chinese universities. Prior to 2006 only two Chinese-language articles were empirical, and the first empirical study in which hypotheses were tested did not appear until 2007. By 2013, though, 75 % of all Chinese-language articles were based on empirical methods. There was a similar use of

[6] In other academic literature reviews, such as, Rothaermel et al. (2007) on academic entrepreneurship and Certo et al. (2009) on IPO research, there is a greater level of concentration because they narrowly circumscribed the journals searched. We chose to examine a far broader population of articles.

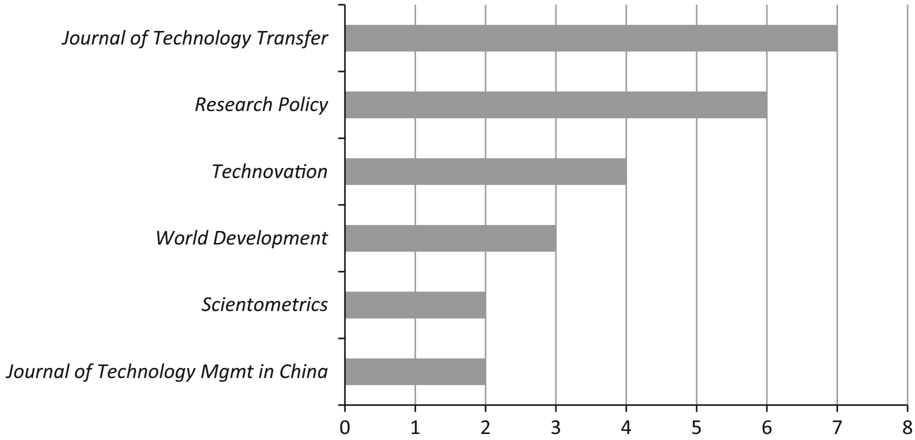

Fig. 3 Chinese university technology transfer articles published in English-language academic journals, 1987–2014 (N > 1)

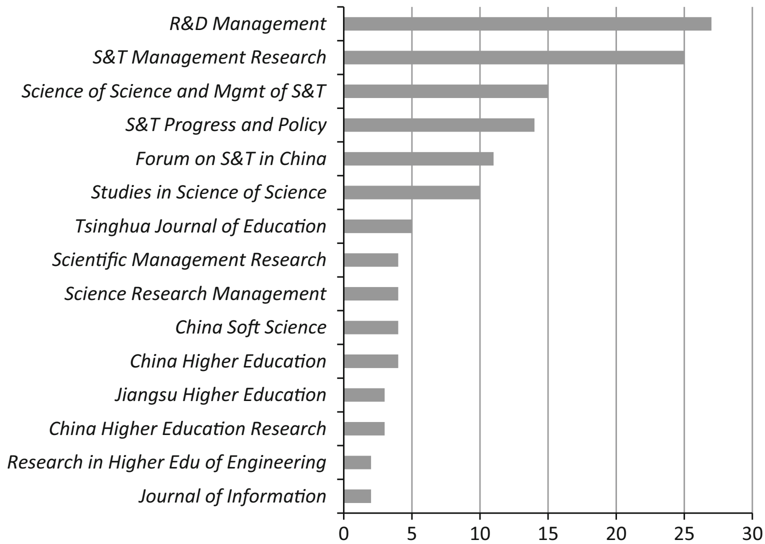

Fig. 4 Chinese university technology transfer articles published in Chinese-language academic journals, 1998–2014 (N > 1)

qualitative methods in the early English-language articles, though a number of these articles used interviews, historical, and archival methods. Later, the English-language articles would also rely more on empirical methods.

4.1 Citations in the two article populations

Citation of the work of previous work is one of the hallmarks of the Western academic tradition. This section explores the citation behavior of the two article language

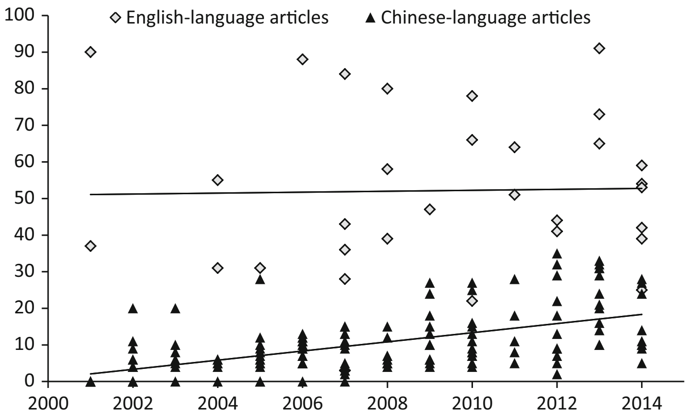

Fig. 5 Number of references in English- and Chinese-language publications by year, 2001–2014

populations to understand whether they interact or draw upon each other. Large numbers of cross-citation would suggest that a unified body of knowledge has emerged. However, prior to examining cross-citation, it is important to understand whether citation behavior differs in the two intellectual traditions.

Citation, ultimately, is nothing more than a style of presentation, so it would not be surprising to find differences between the two literatures. What is evident from Fig. 5 is that Chinese authors did not rely on citations in the same way as those in the West. Our database included 21 Chinese articles that had no citations at all. This lack of citation among Chinese articles may be because Chinese-language articles differ significantly from those in English in other ways. Interestingly, over time the average number of Western references per article was roughly unchanged, while the number of Chinese references exhibited a steady increase. And yet, nearly all Chinese articles have fewer references than their Western counterparts. From 1998 through 2002, the modal number of Chinese references per article was zero. Prior to 2009, Chinese articles had less than 20 % of the reference of the English-language articles. By 2014, as Fig. 1 indicated, Chinese scholars increased their propensity to publish in SCI-indexed journals, the preponderance of which are Western. It is possible that the competition with or emulation of foreign journals may be increasing either the appearance of or the actual scholarly rigor of Chinese journals. The evidence suggests that the Chinese authors began with a different academic tradition, which is not surprising as Chinese social sciences have been less integrated into the global intellectual conversation than the sciences.

One measure of whether Western and Chinese social scientists studying CUTT are in a conversation is to examine whether they are citing each other. If we examine this from inside the two populations, we see citation pattern differences. As Fig. 6 indicates, the English-language articles form a more coherent and self-referential body of studies as the 33 articles cite one another 73 times. The 158 Chinese-language articles cite one another only 148 times. In part, this difference may be due to the fact that Chinese articles typically have fewer references than do English-language articles, but it also reinforces the impression that the two scholarly traditions differ.

The relationship between the two cohorts is remarkable. As Fig. 6 shows they seem nearly oblivious to each other. Only one English-language article cited a Chinese-language article, while seven Chinese-language articles cited eight English-language articles. This

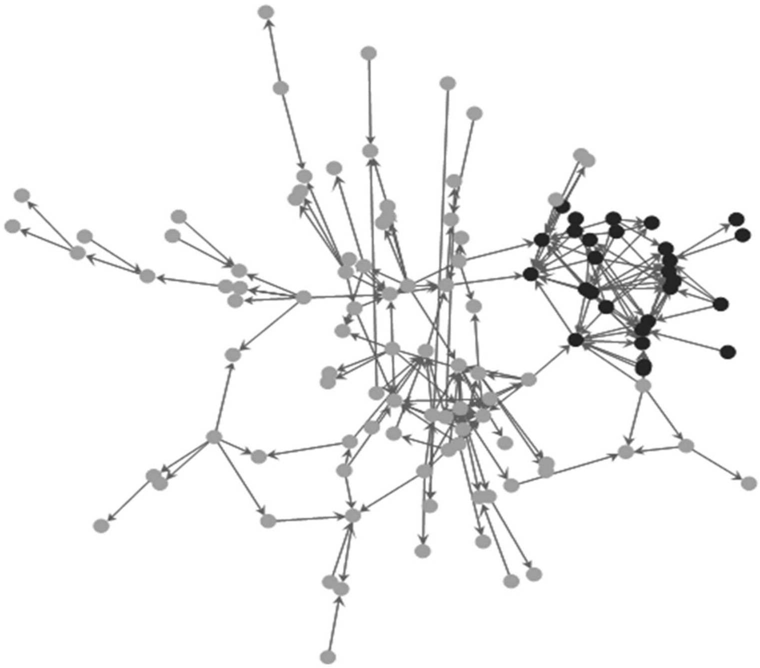

Fig. 6 English-language and Chinese-language article citation network. *Grey nodes* are Chinese-language articles and *black nodes* are English-language articles. *Arrows* indicate direction of citation

might be assumed to be due to a language barrier, but this is unlikely to be the case for English-language articles, as almost every article has an author or co-author with Chinese-language skills. Similarly, nearly all the Chinese-language authors have English-language skills, as evidenced by the fact that they cite articles in English-language journals. Despite the distinct possibility that the authors should be able to read each other's work, they do not cite each other.

In terms of citations to sources external to the articles studied, the two cohorts do cite materials in the other language. For example, 25 out of 33 English-language articles do cite Chinese-language sources, and 73 out of 158 Chinese-language articles cite English-language sources. Chinese-language sources for the English-language cohort are largely official, such as government statistics and reports. There also are a few citations to Chinese-language academic publications and popular media.[7]

These cohorts have two sources in common. The first of these is government statistics, particularly from the *Chinese Science and Technology Yearbook*. The second common source is the English-language literature dealing with UTT, particularly as it applies to the U.S. university system. To analyze this material, we identified 48 English-language authors or co-authors of two or more cited articles or books other than those discussed in this literature review. In Fig. 7 the number of articles that cited these authors and distinguishes

[7] Twenty-four of the 33 articles cited are official sources, primarily Chinese government statistics. Sixteen articles cited some type of academic source, typically a Chinese book or article on Chinese technology or industry. Only four articles cited the popular media.

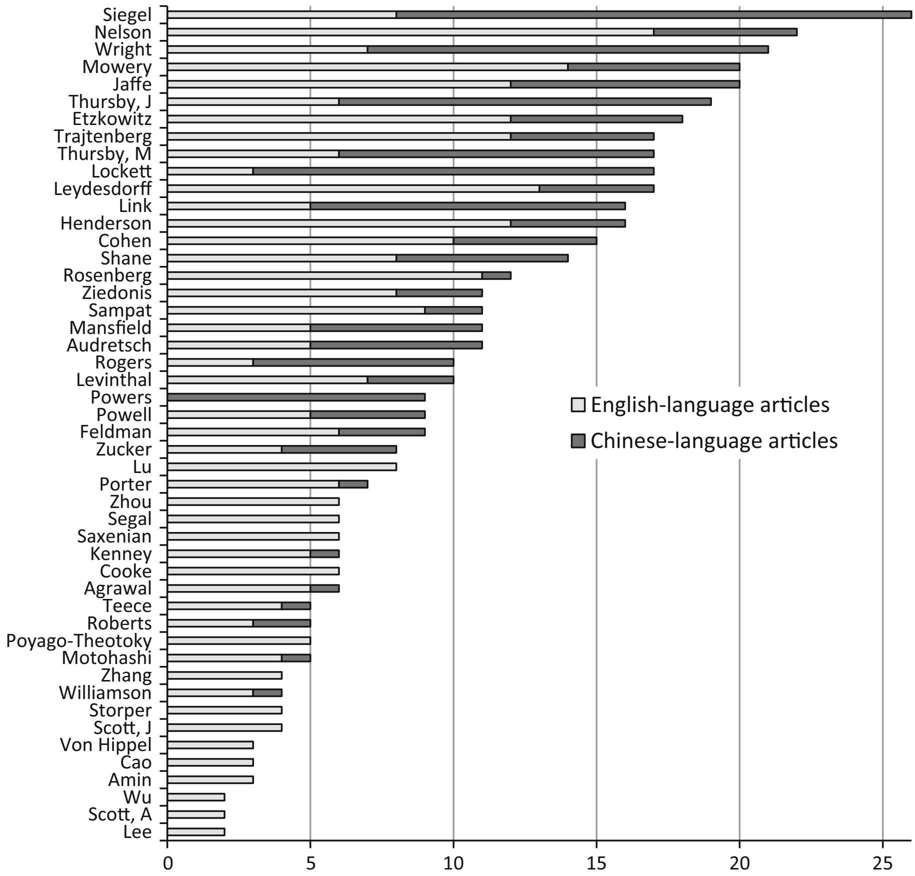

Fig. 7 The number of CUTT articles that cite the following English-language authors (this count is based on English-language articles that are external to the CUTT literature reviewed in this study)

these articles by whether they were from English-language or Chinese-language publications.

The two cohorts do not share many common sources. To illustrate, among the 26 authors that are cited by less than 10 articles, 15 are cited exclusively by the English-language cohort, one is cited exclusively in the Chinese-language cohort, and only 10 are cited by both. All the authors cited in 10 or more articles receive citations from both language cohorts. However, significant differences emerge even here. For example, citations to Richard Nelson, Nathan Rosenberg, and David Mowery are highly concentrated among the English-language authors, while some English-language authors, such as Michael Wright and Andrew Lockett, receive more citations in Chinese-articles.

In summation, this meta-analysis finds remarkable differences between the two literatures. These differences suggest that, at least in the early period, there was a different understanding of publication in scholarly journals. Unfortunately, because our study was narrowly confined to CUTT, it is not possible to know whether this was characteristic of all Chinese social science or simply in our narrow area of study. Regardless of the reasons for the differences in style, our data suggests that, at least, in terms of the use of references, recently Chinese studies of CUTT are adopting a style more like that of the Western journals. Given the initial novelty of the topic of CUTT, it may not be surprising that the early publications were qualitative in nature or general descriptions. By the 2000s more quantitative data became available; much of it collected by the central government as part of various assessment exercises, and this, together with a possibly greater acceptance of Western research standards, led to an adoption of more rigorous methods and presentation. This comports with Rothaermel et al.'s (2007) finding that hypothesize that the transition from qualitative to more deductive quantitative studies can be attributed to a life cycle, in which early development-stage research is qualitative, with an emphasis on theory development, either inductive or deductive, and it later gives way to empirical testing and validation. It is likely that both an adoption of Western standards and the life-cycle process were synchronic.

5 Common themes

Our analysis identified five topical themes that emerged roughly in chronological order. These themes were inductively generated by reading every Chinese article and discussing their content with Patton, while Chen and Patton read each English-language article. The articles were classified by their main topic. Each article, except those that were commentary, were then aggregated into following the five themes: (1) government policy and the national innovation system (NIS), (2) university-operated enterprises (UOEs), university science parks (USPs), and spin-offs, (3) university–industry linkages (UILs), (4) university policy and technology transfer offices (TTOs), and (5) university patents and licensing (see Figs. 8, 9). All of the articles classified under these five themes are summarized in an appendix that is available from the authors. The evolution in themes appears to have been a function of both changes in the political economic environment and government policy initiatives. The shift in themes also reflects changes in the way in which universities tried to transfer technology. For these reasons, an article written on CUTT in 2004 describes a quite different system than the one in 2014. For example, as the importance of UOEs waned and patenting and concomitant licensing increased, scholarly

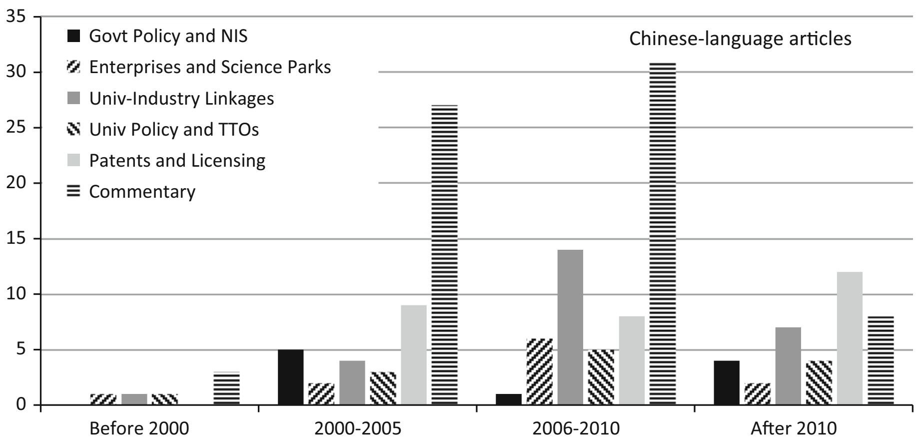

Fig. 8 Changes in CUTT research themes in Chinese-language literature

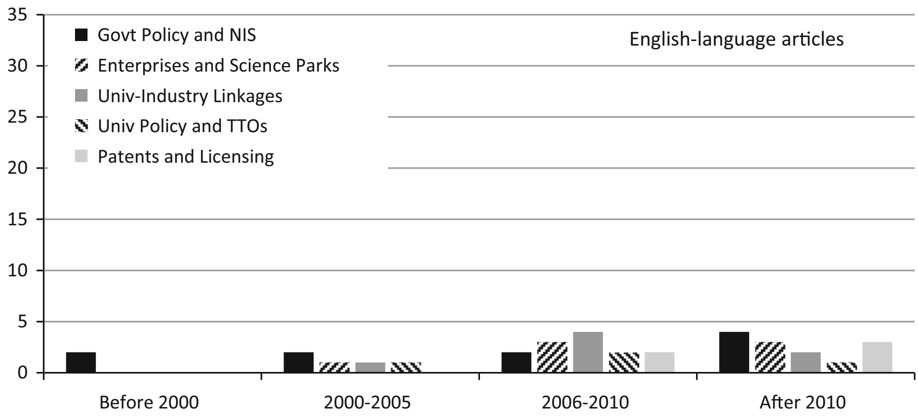

Fig. 9 Changes in CUTT research themes in English-language journals

interest also shifted. Further, there was a change in the format of academic articles that could be published in China, as Western standards were increasingly adopted by Chinese journals.

The earliest articles, especially in English-language journals, examined government policy and NIS, but later declined in relative numbers. These were followed by studies of UOEs and USPs, along with UILs, which were relatively more important between 2006 and 2010 than the period from 2011 to 2015. Currently, empirical studies using patent and licensing data are the most prevalent. Most striking is the extent to which the number of commentary articles with little empirical data of any kind grew rapidly in the early years and then became less important after 2010.

5.1 Research themes

5.1.1 Theme 1: National innovation system (NIS) and government policy

The first theme is also the first chronologically as it was the focus of the earliest articles examining CUTT. The English-language authors concentrated upon the general outlines of the innovation system and the role of the universities within it (see Table 2 for a summary). Not surprisingly, in the initials studies of CUTT much of the research attention was focused on government policies and how universities fit in the overall Chinese innovation system.

The NIS perspective pioneered by Lundvall (1992) and Nelson (1993) is widely accepted as a theoretical frame capable of explaining the ways in which different social institutions interact to produce and commercialize innovations. With 668 citations, the first and most highly cited article to discuss the Chinese NIS was Liu and White (2001), published in Research Policy. A total of six articles, four in English and two in Chinese, employed the NIS theoretical framework with particular attention to the Chinese university system. Liu and White (2001) observed that NIS studies of developed countries focused upon the actors, rather than on their activities. They suggest that such an approach is not effective in a comparative analysis involving non-Western countries where actors perform different NIS functions. To address this issue, they suggest a framework that explicitly

Table 2 Summary of articles on national innovation system (NIS) and government policy

References	Cit.	Article method	Article focus
Zhu and Frame (1987)	3	History	Early history of CUTT
Gephardt (1999)	9	Theory	Multinationals and CUTT
Weng (ch 2000)	12	Theory	China's TT policy compared with US and Japan
Liu and White (2001)	668	Theory	China NIS framework
Li (ch 2002)	19	Theory	Local government TT policy and the China NIS
Lei and Huang (ch 2003)	41	Empirical	China's TT policy compared with other countries
Chang and Shih (2004)	131	Theory	China and Taiwan NIS compared
Lv et al. (ch 2005)	28	Theory	Universities in the China NIS framework
Bi (ch 2006)	9	Theory	General discussion of government TT policy
Li (ch 2006)	7	Case study	Guangdong and Hong Kong TT policy
Chen and Kenney (2007)	175	Case study	Beijing and Shenzhen Regional Innovation Systems
Liu (ch 2007)	24	Theory	General discussion of government TT policy
Hu and Mathews (2008)	198	Empirical*	Assessment of China's NIS and other Asian nations
Qu (ch 2010)	4	Theory	China's TT and IP policy compared with US
Chan and Daim (2011)	13	Theory	General discussion of China's TT policy
Rao et al. (ch 2012a)	6	Empirical*	Impact of government R&D projects on CUTT
Zhai and Li (ch 2012)	4	Theory	General discussion of government TT policy
Zhang et al. (2013b)	24	Empirical*	985 Project impact on publications
Baglieri et al. (2014)	2	Empirical	UTT and nanotechnology in China and Japan
Fisch et al. (2014)	4	Empirical*	985 Project impact on patent quantity and quality

* An empirical study in which hypotheses were tested, usually through regression analysis. All citation counts are from Google Scholar on August 25, 2015

focuses on activities—such as education, R&D, production, end use, and coordination—rather than actors.

Reforms beginning in 1978 altered incentives and relations among NIS actors in two important ways: First, performance was based on economic considerations, and, second, decision making was decentralized. This led to profound changes in how and where R&D was conducted and how universities performed their mission. R&D, once exclusively the domain of research institutes, was redistributed to a number of actors, including universities and firms. Moreover, the government's central transfer function contracted, necessitating the building of transfer mechanisms between commercial and noncommercial organizations.

Roughly contemporaneously, Chinese authors also recognized these changes. Li (ch 2002) and Lv et al. (ch 2005) specifically examined the role of the university in China's NIS. Li concluded that, although Chinese universities could assist enterprises in their innovation efforts, firms were the main sources of technology innovation. Lv et al. (ch 2005) suggested that Chinese universities take on a larger role in the NIS, primarily by providing firms with an ability to integrate technologies across multiple disciplines.

In a comparative study of Taiwan and China, Chang and Shih (2004) found that the essential difference between Taiwan and China is that Taiwan develops some of its own technology, while China generally imports technology. Based on their examination of nanotechnology patents, Baglieri et al. (2014) found that Japan and China organize their respective NISs differently, with China relying on a small number of actors including universities, while Japan relies on an extensive firm network. In an extension of their earlier work on South Korea, Taiwan, and Singapore, Hu and Mathews (2008) measured the drivers of Chinese innovation. The number of patents was their dependent variable, and they used it as a function of existing knowledge stock, total R&D, R&D personnel, the availability of venture capital (VC), and university R&D. They found that China differed from the much smaller East Asian Tigers, where the university pedagogical role was most important. While training was important in China, universities also were a significant source of new firms. In later work, Chen and Kenney (2007) situated Chinese universities in their regional innovation system.

The first article discussing government policy regarding CUTT was Zhu and Frame's (1987) article in the *Journal of Technology Transfer*. The authors point out that, prior to the mid-1980s, technology transfer as it is currently practiced in market economies simply did not exist in China. It was the 1978 reforms that led to the introduction of mechanisms of technology transfer. Gephardt (1999), drawing upon interviews with foreign firms operating in China and Taiwan, found that technology transfer capabilities were enhanced as a result of collaborations between transnational corporations (TNCs) and local universities.

The first Chinese-language study of government policy was Weng's (ch 2000) comparison of CUTT with that in the United States and Japan. Weng noted that Chinese universities have an even greater responsibility for technology transfer than do Japanese or U.S. universities, but that effective transfer was limited. Lei and Huang (ch 2003) compared Chinese USPs and technology transfer offices (TTOs) with those in several developed countries and concluded that China had to rely on the government as the main source of research funding. In an interview-based comparison of the government's role in UTT in Guangdong province and Hong Kong, Li (ch 2006) concluded that Hong Kong's government was more effective. Qu (ch 2010) found that in the United States protection of IP is greater and the TTOs were more professional. In a general study, Chan and Daim (2011) argued that the government should consider the receiving firm's perspective when formulating NIS policy. Government statistics have also been used to examine CUTT. Bi (ch 2006) finds that the government's role is crucial. Liu (ch 2007) and Zhai and Li (ch 2012) are critical of CUTT and conclude that Chinese efforts are not professional and not in tune with the market.

Scholars also examined the results of Chinese government initiatives instituted in the 1990s to improve university research performance. The most important of these programs, the 985 Project, was specifically directed to develop world-class universities in China. For example, Rao et al. (ch 2012a) examined the effect of the 985 Project and other government R&D investment programs on university technology contracts with firms and found that the programs significantly increased the number of and revenue from industrial research contracts. Zhang et al. (2013b) found that the number of publications from lower-ranked 985 universities grew more rapidly than did publications from the two highest-ranked universities: Peking and Tsinghua. Fisch et al. (2014) used patents to study two government policies to promote university research by encouraging patenting and found that the number of patents for which a university applied was significantly affected by its participation in both programs but that only the 985 Project improved patent quality.

Despite agreement about the importance of government policy, little systematic research has been conducted on whether the policy changes have improved technology transfer. Because of the rapid changes in the NIS, ample opportunities exist for increased empirical research on government policy impacts. Also, historical and interview-based research on S&T policy-making could provide significant insight into the reasons for the various policy changes.

5.1.2 Theme 2: University-operated enterprises, science parks, and spin-offs

The two earliest commercialization initiatives, permitting the establishment of UOEs and creating USPs, began in the 1980s. Both of these initiatives expanding rapidly in the 1980s and continued to be important into the 1990s. In the mid-1990s, the government rethought the UOE strategy, and began shifting policy to encourage university spin-offs that were independent of the university. The discussion below follows the chronology of the initiatives (for a summary see Table 3).

The UOE is a unique organizational form that has, perhaps, only emerged in China. The UOE is an outcome of the early and mid-1980s when university funding was massively curtailed creating powerful pressures to both cut costs and find alternative sources of income. In response, many university operations were reorganized into commercial entities including both technology-based operations and miscellaneous activities including food services, language translation services including publishing houses, and land development. The UOE also was a mechanism for Chinese universities to commercialize a newly developed technology. The UOE was established, staffed, funded, owned and managerially controlled by the university administration (Qiu ch 2002; Eun et al. 2006). This allowed the university to capture the income from any technologies they developed.

Table 3 Summary of articles on university-operated enterprises, science parks, and spin-offs

References	Cit.	Article method	Article focus
Li (ch 1999)	19	Theory	General discussion of science parks
Fan and Chen (ch 2000)	17	Theory	General discussion of science parks
Li et al. (ch 2002)	7	Theory	General discussion of science parks
Qiu (ch 2002)	4	Theory	Analysis of University-operated enterprises
Xu and Mei (ch 2003)	10	Case study	Tsinghua University Science Park
Feng and Wang (ch 2003)	27	Theory	The university role in UOEs
Cao (2004)	80	Case study	Critical review of Zhongguancun science park
Liu and Peng (ch 2004)	0	Case study	Nanjing University Science Park
Chen et al. (ch 2005)	14	Theory	UK and Chinese USPs compared
Eun et al. (2006)	193	Theory	Analysis of University-operated enterprises
Meng et al. (ch 2006)	3	Case study	Tsinghua University Science Park
Yang et al. (ch 2007)	22	Theory	Analysis of University-operated enterprises
Kroll and Liefner (2008)	115	Case study	Analysis of University-operated enterprises
Hu (ch 2010)	7	Theory	Tsinghua University and Nuctech
Zhou et al. (2010)	7	Case study	Tsinghua University spin-offs
Su et al. (2011)	4	Case study	Tsinghua and Peking University spin-offs
Li and Zhang (ch 2013)	1	Case study	Tsinghua University and Nuctech
Zhou and Minshall (2014)	4	Case study	Case study of four university spin-offs
Zou and Zhao (2014)	4	Case study	Tsinghua University Science Park

Citation counts are from Google Scholar on August 25, 2015

In a highly cited article, Eun et al. found that three factors influence the formation of UOEs: the university's technological capability, the local firms' absorptive capacity, and the university's desire for new sources of funding (Eun et al. 2006; Yang et al. ch 2007). During this early period Chinese university technological capabilities were superior to those of domestic firms as local firms and ecosystems did not have sufficient absorptive capacity to commercialize new technologies. Further, these UOEs had access to skilled university personnel to which the then still fledgling private sector did not have access (Xue 2004).

While many of the UOEs had little impact, others were quite successful. In 2010, the top ten UOEs earned nearly RMB 6.8 billion ($1 billion) in profit. Beijing University–affiliated enterprises had approximately RMB 62.69 billion ($9.25 billion) in revenue and RMB 3.01 billion ($440 million) in profit, while Tsinghua University-affiliated enterprises had RMB 35.03 billion ($5.1 billion) in revenue and RMB 1.14 billion ($165 million) in profit (Ministry of Education 2010). At the time, the UOEs were a significant source of revenue.

In the late 1990s, as the environment changed and Chinese firms had become more capable technologically, the number and importance of UOEs declined. Further, the government began dramatically increasing university budgets, thereby removing the previously intense pressure to create income. Increasingly, government policy makers and researchers questioned the wisdom of university administrators managing the firms (Feng and Wang ch 2003). These two changes mitigated both the need and opportunity for establishing UOEs. As the number of UOEs declined, the number of privately financed university entrepreneurial spin-offs increased (Kroll and Liefner 2008). In 2015, the central government introduced a new policy that would gradually phase out the UOEs.

As was true for UOEs, Chinese scholars have been more interested in USPs than their Western counterparts. The impetus for USP formation was based on the same government policies that encouraged UOEs, namely, the reduction in university funding. The foundation of UOEs led the universities to establish science parks to house them, but the USPs were also real estate developments that could attract other firms and generate rental income (Zou and Zhao 2014). The first USPs were founded by Southeast and Northeastern Universities in 1983. While the National Hi-Tech Development Zones Program was not directly targeted at creating USPs, many of them were established near universities and would contain or encompass USPs. In 1999, the central government recognized USPs and fully approved USPs at Beijing and Tsinghua Universities. This decision ignited a spate of USP formations (van Essen 2007). Not surprisingly, given the "bottom-up" nature of USP formation, the initial articles developed frameworks for classifying USP types and functions (Li ch 1999; Fan and Chen ch 2000). While others examined park functions, including personnel training, research, and high-technology firm incubation (Li et al. ch 2002).

The USP literature is composed largely of case studies and thus has limited generalizability. Tsinghua University Science Park (TSP), likely the most successful, has been the subject of multiple studies (Xu and Mei ch 2003; Meng et al. ch 2006; Zou and Zhao 2014), while Liu and Peng (ch 2004) examined Nanjing University Science Park, and Chen et al. (ch 2005) compared the operation and objectives of Chinese USPs with those in the UK. In general, researchers find that the most important factors in USP success are support from the government, effective leadership, entrepreneurship, and innovation.

There have been critiques of the USPs. For example, Cao (2004) claimed that many of the reported statistics are misleading and concluded the following. First, most of the park growth has not been driven by indigenous technology; rather, USPs served mainly as distribution centers for foreign technology firms. Second, a large proportion of R&D

personnel in these parks work for foreign firms. Third, Chinese high-technology firm success has been due to entrepreneurial talent (e.g., creating new business models), rather than building upon technological capability.

Due to recent government policy changes, commercialization of university technology has shifted from the formation of UOEs to the encouragement of university spinoffs, i.e., independent firms formed to commercialize university technology (Kroll and Liefner 2008). More recently, studies of university spin-offs have emerged. In fact, the Tsinghua University spin-off, Nuctech, has spawned a cottage industry of studies (see, for example, Hu ch 2010; Li and Zhang ch 2013; Zhou et al. 2010). Su et al. (2011) studied UOE performance at Peking University and Tsinghua University. Zhou and Minshall (2014) argue that spin-off success was predicated upon their adoption of indigenous university innovations. This shift from the UOE to a spinoff organizational form that more resembles the situation in Western universities offers a significant research opportunity.

The current research focus has shifted to components of the technology transfer system, rather than the interdependent processes that make up the system as a whole. The Chinese experience with the formation of USPs offers significant opportunities for researchers interested in their impact on technology transfer. It would also be useful to further explore the ways in which USPs are embedded in and contributed to the growth of larger university or regional industrial ecosystems. Despite the research already undertaken, it is unclear how important USPs, UOEs, and the more recent university spinoffs have been in encouraging successful UTT.

5.1.3 Theme 3: University–industry linkages (UILs)

Beyond UOEs, USPs, and spinoffs, the Chinese government has actively encouraged universities to establish UILs and, in particular, take an active role in technology-led growth. This theme explicitly deals with contract research and consulting, but not technology transfer through licensing, which is examined in Theme Five.

It is possible to argue that Chinese universities may have greater technology transfer relations with industry than those of the U.S. For example, drawing upon the fact that approximately 35 % of all research conducted by Chinese universities is funded by industry, while in the U.S. it is only approximately 8 %, Li et al. (ch 2014) argue that Chinese universities undertake more technology transfer.[8] This poses the interesting question of whether contract research, while certainly a UIL, is also technology transfer? If contract research is technology transfer, then one might conclude the Chinese UILs are excellent.

Research on UILs began in the early 2000s (see Table 4). Many of the earliest studies classified UILs and identified their stage of development (Guo ch 2013; Hu ch 2009; Mei and Meng ch 2009; Xie et al. ch 2002; Zhou ch 2011). The first English-language study of UILs by Guan et al. (2005), in a survey of innovation activities at 948 Beijing firms, found that 18 % of technology firms used university research, but that usage not correlated with economic performance. Wang and Lu (2007) applied Eric von Hippel's (1988) concept of sticky knowledge to categorize UILs by four modes of interaction. Each mode required a different type of UIL to facilitate successful transfer. In a study of Shanghai Jiaotong (SJTU) and Fudan universities, Wu (2007) found that the different strengths in subject matter at the two universities shaped their respective UILs. There are also Chinese-

[8] In contrast, U.S. university income from patents was approximately 4 % of total R&D funding, while in China it was less than 1 %.

Table 4 Summary of articles on university–industry linkages (UILs)

References	Cit.	Article method	Article focus
Hu (ch 2002)	54	Theory	General discussion of UILs
Xie et al. (ch 2002)	32	Theory	General discussion of UILs
Li (ch 2003)	24	Theory	General discussion of UILs
Guan et al. (2005)	80	Empirical*	Analysis of UILs in Beijing
Bai and Wang (ch 2006)	8	Empirical	Methods to evaluate UILs
Lin and Zhou (ch 2006)	25	Theory	General discussion of UILs
Yan and Zhou (ch 2006)	24	Empirical	Methods to evaluate UILs
He et al. (ch 2007b)	27	Empirical*	UILs and economic growth in Beijing
Hershberg et al. (2007)	74	Theory	Discussion of UILs and regional economic growth
Wang and Lu (2007)	29	Case study	Tsinghua University's linkages with Nuctech
Wang and Ma (2007)	9	History	Development of Chinese patent law
Wu (2007)	78	Case study	Comparison of SJTU and Fudan UILs
Xu et al. (ch 2008)	16	Theory	General discussion of UILs
Hu (ch 2009)	5	Theory	General discussion of UILs
Liao and Xu (ch 2009)	20	Empirical	UTT revenues among provinces
Liu and Shi (ch 2009)	2	Empirical*	UILs and national economic growth
Mei and Meng (ch 2009)	17	Case study	Tsinghua University and UILs
Yang and Ling (ch 2009)	0	Empirical*	UILs and economic growth in Guangdong
Liu and Fu (ch 2010)	14	Theory	General discussion of UILs
Wang (ch 2010)	7	Case study	UILs and Xinjiang University
Wu and Dong (ch 2010)	10	Empirical*	Factors influencing UTT revenues
Yang and Li (ch 2010)	11	Case study	Tsinghua University and MIT UILs compared
Yu et al. (2011)	0	Empirical	Methods to evaluate UILs
Zhou (ch 2011)	7	Theory	General discussion of UILs
Brehm and Lundin (2012)	9	Empirical*	UILs at the province level
Rao et al. (ch 2012b)	3	Empirical*	R&D impacts on provincial UILs
Wu and Zhou (2012)	27	Theory	The Third Mission has stalled
Fan and Yu (ch 2013)	1	Empirical*	Funding and personnel impacts on UILs
Guo (ch 2013)	5	Theory	General discussion of UILs
Yuan et al. (ch 2013a)	1	Empirical*	Funding and personnel impacts on UILs
Zhang et al. (ch 2013a)	0	Empirical*	985 Project impact on UTT contracts
Zhou et al. (ch 2013)	1	Case study	Nanchang University TT case study
Li et al. (ch 2014)	0	Empirical	China and US UILs compared

* An empirical study in which hypotheses were tested, usually through regression analysis. Citation counts are from Google Scholar on August 25, 2015

language articles on methodologies for evaluating UTT (Yan and Zhou ch 2006; Bai and Wang ch 2006; Yu et al. ch 2011).

As has been found to be the case in the West, UILs are strongly influenced by environmental factors, including government laws and policies, the availability of information (Liu and Fu ch 2010; Wang and Lu 2007; Wang and Ma 2007; Wu 2007), intellectual property (IP) protection, the geographic distance between the enterprise and the university

Table 5 Factors influencing UILs as measured by UTT revenue and number of contracts

References	Unit of analysis	Major findings
Wu and Dong (ch 2010)	Universities	Engineering universities produce more UTT revenue, as do more prestigious schools
Rao et al. (ch 2012b)	Provinces	R&D funding has a greater positive impact on the number of R&D contracts than on UTT revenue
Fan and Yu (ch 2013)	Provinces	R&D funds from government have a negative impact on UTT revenue, while funds from firms have a positive impact
Yuan et al. (ch 2013a)	Project 211 universities	R&D funding from the university and local government all have positive effects on UTT revenue and number of R&D contracts
Zhang et al. (ch 2013a)	Project 985 universities	R&D funding from government and enterprises have no significant impact on either the number or revenue of R&D contracts

(Xu et al. ch 2008), the economic environment and intermediary organizations (Li ch 2003), and organizational culture (Lin and Zhou ch 2006).

More recently, a number of studies have measured the effectiveness of UTT quantitatively (for a summary, see Table 5). For example, using the revenue from technology transfer contracts as a dependent variable; Wu and Dong (ch 2010) found that university type and academic reputation were important. The number of R&D personnel and the amount of corporate funding had a positive impact on UTT (Fan and Yu ch 2013), while local market uncertainty had a negative effect (Yuan et al. ch 2013a). In another study, Zhang et al. (ch 2013a) found that the same variables measuring R&D inputs have a more significant impact on the number of UTT contracts than on revenue—suggesting that the relationship is more important than the amount. However, substantial provincial disparities are evident in the level of technology transfer revenue (Liao and Xu ch 2009).

Conflicting findings arise regarding the impact of external funding. One study concludes that the availability of government research funds has a negative effect, and another finds that local government research funding is also not strongly positive (Fan and Yu ch 2013; Zhang et al. ch 2013a). In contrast, Yuan et al. (ch 2013a) and Rao et al. (ch 2012b) find that local government funds have a positive impact on UTT. The empirical findings on the effect of corporate funding are also mixed, while Fan and Yu (ch 2013) indicate that it was positively related to UTT (Zhang et al. ch 2013a), while other studies could not confirm any impact. Adopting a firm-level perspective, Brehm and Lundin (2012) demonstrate that variables measuring university technological capacity and UILs are positively associated with firm performance, but this is contingent upon the firm's absorptive capacity. Researchers have found that UTT in economic centers such as Beijing, Shanghai and Guangdong contributed to regional growth (He et al. ch 2007b; Hershberg et al. 2007; Yang and Ling ch 2009). Testing the robustness and validity of these regional findings, Liu and Shi (ch 2009) found a positive relationship between UTT and economic growth at the national level.

Higher education reforms have encouraged universities to develop UILs, but the transfer efficiency is believed by many to remain inadequate. Three technological transfer shortcomings have been identified. First, faculty promotion guidelines reward scholarly achievement more than commercialization (Yang and Li ch 2010). Second, the increased research capacity by both domestic and foreign firms may have decreased the need for academic research (Wu and Zhou 2012; Guan et al. 2005). This may explain why UTT appears to have declined in importance after the successes in the 1980s and 1990s.

Echoing research in the West, the third shortcoming identified is the historical legacy of a lack of communication between universities and firms. In China, UIL has a short history, property rights are somewhat unclear, and most academic research is not sufficiently advanced to provide economic promise. This finding has led some scholars to suggest that technology transfer could be improved by strengthening communication and building better collaboration (Wang ch 2010; Zhou et al. ch 2013; Hu ch 2002).

While a consensus has developed that UILs promote economic growth, an understanding of how they do so in China has been a research objective. Future research could examine the different modes and stages of UILs, particularly from an evolutionary perspective. Little is known about the role of consulting or the ways in which graduates act to transfer technology. The conflicting conclusions may have a variety of causes. First, the rapid change in every aspect of the Chinese innovation system makes comparisons of results across periods difficult. Second, statistical methods vary, and unobserved heterogeneity arises, therefore, variables affecting UILs might be missing and more complicated interrelationships might not be captured. Third, the true magnitude of technology that is transferred through contract research is unknown. Another promising line of research would aim at developing a better understanding of the quality and economic applicability of the university research and measuring the absorptive capacity of domestic firms. In addition to quantitative studies, substantial opportunities may be available to conduct fine-grained case studies of particular UILs to understand the dimension of technology transfer.

5.1.4 Theme 4: University policy and technology transfer offices (TTOs)

Because of the centralization of Chinese university governance, internal university policy is deeply affected by national-level policy changes (Zhao et al. ch 1998). Chinese researchers were particularly interested in the policies of elite U.S. universities (Min and Ma ch 1999). The first English-language article to describe CUTT policy was by Liu and Jiang (2001). As Table 1 indicated, during the first stage of reform, starting in 1986, universities were given responsibility for their own budgets. The second stage, beginning in 1995, continued the move toward greater independence. Initially, many policy articles were normative and exhorted universities to improve technology transfer (Min and Ma ch 1999; Lu and Yang ch 2005; He et al. ch 2010). They claimed that transferring technology and innovative capacity to enterprises would improve teaching and research capability and promote the university's reputation (He et al. ch 2007a). Zhang et al. (ch 2008) found that 76.6 % of Chinese universities engage in R&D of some sort, but only 6.7 % of them were effective at technology transfer.

With China's adoption of a Bayh-Dole-like regulation in 1993, it became necessary to change university policies and build a technology transfer (licensing) organizations to actualize any transfers (for a summary, see Table 6). In this theme, policy and the operation of the TTOs are reviewed. However, because quantitative studies of patent and patent licensing are almost devoid of any reference to TTO or university operations policies, we defer discussion of this phenomenon to Theme Five.

Scholars have examined these university policy issues empirically, although the nature of the data and subject precludes statistical analysis. For example, using case studies of the Fudan University and Shanghai Jiaotong University TTOs, Wu (2010) summarizes technology transfer policies. Based on national UTT data from 2000 through 2004, Wu found that technology contracts earned ten times the revenue generated by patent licensing and

Table 6 Summary of articles on technology transfer policies and offices (TTOs)

References	Cit.	Article method	Article focus
Zhao et al. (ch 1998)	2	Theory	General UTT policy
Min and Ma (ch 1999)	6	Case study	Beijing University TT policy
Liu and Jiang (2001)	115	Theory	General UTT policy
Wang et al. (ch 2004)	4	Case study	SJTU and Michigan University compared
Zhang and Cao (ch 2004)	6	Case study	Central South University TT policy
Lu and Yang (ch 2005)	6	Case study	Huazhong University of Science and Technology TT policy
Xu and Chen (ch 2005)	2	Case study	University use of Internet in promoting TT
He et al. (ch 2007a)	7	Theory	General UTT policy
Lu and Tan (ch 2008)	8	Case study	TTOs in Shanghai
Zhang et al. (ch 2008)	20	Empirical	University R&D impacts on UTT
Cao et al. (2009)	11	Case study	SJTU and Fudan University TTOs compared
Wu (2010)	41	Case study	University policy and UREs at SJTU and Fudan U
He et al. (ch 2010)	10	Theory	Evaluating UTT policy
Zhang and Liu (ch 2012)	3	Theory	Evolution of TTOs
Hu et al. (ch 2014)	1	Case study	Sun Yat-Sen University TTOs
Kaneva and Untura (2014)	0	Theory	China as a model for Russia

Citation counts are from Google Scholar on August 25, 2015

twice the revenue from technology spin-offs. Second, as in the United States, patent licensing was not an important source of income, accounting for less than 3 % of university R&D revenue in 2003. Third, the number of university spin-offs declined in the late 1990s, and their contribution to universities' finances also declined.

A variety of problems have been identified as contributing to the low efficiency of UTT. The problems identified can be separated into those relating to universities, firms, and broader problems that included the Chinese context. These include the immaturity of university research (He et al. ch 2010), promotion systems do not provide incentives (He et al. ch 2010; Cao et al. 2009; Wu 2010), insufficient funds to support transfer (He et al. ch 2010), and a shortage of technology transfer skills (Wu 2010). The problems with Chinese recipient firms are many (Wang et al. ch 2004). They include the lack of absorptive capacity in domestic firms—a condition that was especially true in the 1980s and 1990s (Liu and Jiang 2001; Wu 2010); ineffective communication between firms and universities; lack of financial resources among firms (Liu and Jiang 2001), and the emphasis by firms on quick results (Wu 2010).

The causes found to contribute to a lack of transfer were insufficient IP protection (Liu and Jiang 2001), a lack of intermediaries such as venture capitalists (Cao et al. 2009; Wu 2010), and a mismatch between the needs of the firms and the university research results (Wu 2010). On a more positive note, though lacking empirical data, Kaneva and Untura (2014) argue that the government has played a leading role in China's technological advance and suggest that Russia should consider adopting similar policies and mechanisms.

A variety of policy proposals have been offered to address the shortcomings, including creating connections between students and the business sector, providing faculty members with greater incentives to engage in technology transfer (He et al. ch 2010; Zhang and Cao ch 2004), facilitating networking between universities and enterprises (Liu and Jiang 2001), and establishing an UTT evaluation system (He et al. ch 2010).

A second area of research is devoted to an analysis of TTOs. The first group of Chinese TTOs were termed "National Technology Transfer Centers" and in 2001 the first ones were established at six elite universities (Tang 2006). Not surprisingly, scholars from an evolutionary perspective have considered the changes in TTOs. For example, Zhang and Liu (ch 2012) suggest that over the past 20 years, UTT organizational forms have evolved administratively. There have been case studies of TTO management at Shanghai universities (Lu and Tan ch 2008) and at Sun Yat-sen University (Hu et al. ch 2014). Finally, one article proposed the establishment of an Internet TTO platform in Zhejiang to support university technology transfer (Xu and Chen ch 2005).

Most scholarship on university policy has considered strategies for increasing technology transfer. As has been the case in the West, for the most part, studies have been confined to a few elite universities. Future studies should include a larger number of universities. Further, the TTO studies have been largely institutional. They do not examine the challenges TTOs face in the Chinese environment. Given the government investment and initiatives to shape university policy and the increased attention being given to TTOs, as vehicles for technology transfer, this area is still remarkably understudied. As is the case in the West, the predominant measure of TTO success is through patent and licensing income and we examine this particular form of technology transfer in the final theme.

5.1.5 Theme 5: University patents and licensing

In China, university research-based patents are owned by the university and thus are licensed by the TTO. Because data concerning patents and licensing income is easily available, it has formed the basis of significant number of articles. The most salient characteristic of the research on patenting is that it is tractable to statistical measurement, but we note that in contrast to Theme Four, these articles provide very little information on the context within which technology transfer occurs.

While the original Chinese rules were promulgated in 1993, the concern about a lack of technology transfer continues. In response, since the mid-2000s, to incentivize universities and professors, the Chinese government began to emphasize patents in performance evaluations for individual faculty and universities. To remove any financial obstacles, filing costs for both universities and individual researchers are defrayed through government subsidies (Luan et al. 2010; Wang et al. 2013).

Given that patenting had become a metric by which university performance was measured and rewarded, universities and researchers responded. In 1999, institutions of higher education applied for 988 Chinese patents, while by 2013 they filed 98,509 applications, an annual growth rate of 39 %. Patent grants increased from 425 in 1999 to 33,309 in 2013, an annual growth rate of 37 %. In 2012, U.S. universities, by contrast, were granted only 4,797 U.S. patents. If we make the heroic assumption that the patent offices in both countries award equally high-quality patents, this suggests that the Chinese university system is roughly six times as productive as that of the United States in terms of patents and thus technology transfer—a dubious proposition. Chinese universities also patent in the United States. For example, from 2010 to 2014, Tsinghua University was granted 767 patents by the USPTO, followed by the Chinese Academy of Telecommunications Technology, which was granted 104 patents. By comparison, during the same period the far larger University of California system was granted 1751 U.S. patents and Stanford University was granted 753 patents. Clearly, China's universities responded to the government's goal of increasing the number of patents granted, both domestically and in the United States. The open question regarding this explosion of patenting is their quality (Liang 2012).

University patents and licenses, because they are so easily observed, have received scholarly interest globally, even though it is now universally recognized that they are only a small part of UTT (see, e.g., Kenney and Mowery 2014). Paralleling work in the West, patent studies as a CUTT output have proliferated (for a summary, see Table 7). The research has examined the impact of university patents on the national economy, the types of patents that are licensed or sold to Chinese firms, and co-patenting relationships between universities and firms. Accordingly, we first discuss articles examining university patenting as a general output and then turn to articles treating university patenting as a measure of technology transfer. Typically, these studies measure patenting performance by the number of patent applications, grants, licenses, licensing contracts, and licensing revenue.

Paralleling the change in policy emphasis from UOEs to less direct methods of UTT, there was a proliferation of studies examining patenting as a channel for technology transfer. The first university patenting study was of Tsinghua University (Wu et al. ch 2001). This was followed by descriptive introductions to Chinese university patenting (Liu et al. ch 2007; Yang ch 2008). Interestingly, while Liu et al. (2007) concluded that the increase in patents was an indicator of increased commercialization, Yang found that patenting is concentrated in a small number of technologies and at a few top universities.

Luan et al. (2010) compared the remarkable increase in Chinese university patent applications to global trends in university patenting and found that, globally, patent applications increased steadily from 1998 to 2007. In 2008, the total global increase was due almost entirely to increased Chinese university applications. At that time, Chinese universities made up 14 of the top 20 world-leading university patentees. When measured by patent quality, Tsinghua was one of the top six universities globally—a surprising result. The authors conclude that the Chinese 2003 Bayh-Dole Regulations contributed to this rise in university patent applications, but had no impact on their quality. A more recent overview found that out of the 2498 universities and colleges in China, 14.2 % (354) had licensed some type of patent (Gao et al. 2014). In keeping with international findings, in a study of Tsinghua University patents, Ma et al. (ch 2012) found that the university patent citation network was highly clustered and dominated by a few key patents.

Most scholars study factors influencing Chinese university patents from an input–output perspective. An advantage of patent data is that it allows for rigorous hypothesis testing, so that patents can be modeled as a function of R&D funding sources, the quality of R&D personnel, and other university attributes—all of which have been found to be positively and significantly related to the number of university patent applications (Zhou and Zhu ch 2007; Yuan et al. ch 2013c; Rao et al. ch 2013b; Wu et al. ch 2008; Shi et al. ch 2009; Fu et al. ch 2010; Li et al. ch 2010; Wang et al. ch 2012; Yuan et al. ch 2012a). However, Xu and Gao (ch 2008) find the direct relationship between R&D expenditures and scientific research output as measured by the number of patent applications and papers published is weak. Moreover, the government policy of subsidizing patent filing was found to have a negative effect on the structure of patent applications and grants in Shanghai universities (Xiao and Li ch 2014). Also, the number of patent applications at merged Chinese universities increased significantly (Yuan et al. ch 2013b). The findings on the relationship between funding and personnel inputs and university patent outputs are summarized in Table 8.

Patents have often been used as a measure of UIL. Using patent data, scholars have shown that CUTT became more decentralized from 1985 to 2004 (Hong 2008). Beijing has

Table 7 Summary of articles on university patents and licensing

References	Cit.	Article method	Article focus
Wu et al. (ch 2001)	1	Case study	Tsinghua University patenting
Guo and Liu (ch 2005)	19	Empirical	General discussion of university patenting
Chen et al. (ch 2007)	22	Theory	General discussion of university patenting
Liu et al. (ch 2007)	22	Theory	General discussion of university patenting
Zhou and Zhu (ch 2007)	23	Empirical*	Impact of R&D and personnel on patents
Hong (2008)	111	Empirical*	Patent patterns in China
Wu et al. (ch 2008)	15	Empirical*	Impact of R&D personnel on patents
Xu and Gao (ch 2008)	24	Empirical*	Impact of R&D on patents and publications
Yang (ch 2008)	11	Empirical	General discussion of university patenting
Shi et al. (ch 2009)	10	Empirical*	Impact of government funding on patents
Yuan et al. (ch 2009)	10	Empirical*	University types and patenting output
Fu et al. (ch 2010)	19	Empirical*	Impact of R&D on patents
Hong (ch 2010)	17	Empirical	Patterns of patents across provinces
Li et al. (ch 2010)	11	Empirical*	Impact of R&D on patents across provinces
Luan et al. (2010)	15	Empirical	Chinese Bayh-Dole Act
Rao et al. (ch 2011)	8	Theory	Chinese and European university patenting
Ma et al. (ch 2012)	8	Case study	Tsinghua University patenting
Wang and Lei (ch 2012)	1	Theory	Comparison of Chinese and US university patenting
Wang et al. (ch 2012)	0	Empirical*	Impact of R&D on patent quantity and quality
Yuan et al. (ch 2012b)	4	Empirical*	Impact of government funding on research outputs
Yuan et al. (ch 2012a)	2	Empirical*	Impact of government funding on patents
He and Fan (ch 2013)	1	Empirical*	Patterns of patents over time and across regions
Hong and Su (2013)	28	Empirical*	Geography of university–industry patent links
Rao et al. (ch 2013b)	1	Empirical*	Impact of R&D personnel on university patents
Rao et al. (ch 2013a)	4	Empirical*	Impact of R&D projects on university patents
Wang et al. (2013)	3	Empirical*	University's Third Mission has not stalled
Xu (ch 2013)	0	Empirical	University patent protection is too great
Yuan et al. (ch 2013c)	0	Empirical*	Impact of funding on university patents
Yuan et al. (ch 2013b)	0	Empirical*	Impact of university mergers on patent applications
Chen et al. (ch 2014)	0	Empirical	Chinese patenting compared to US, UK, Japan
Gao et al. (2014)	0	Empirical*	General discussion of Chinese patents
He et al. (ch 2014)	0	Case study	Jilin University patenting
Xiao and Li (ch 2014)	1	Empirical*	University patenting policy in Shanghai
Ye et al. (ch 2014)	0	Empirical*	Impact of R&D funding and staff on patents

* An empirical study in which hypotheses were tested, usually through regression analysis. Citation counts are from Google Scholar on August 25, 2015

always been the UTT center, due to the concentration of elite universities, the large concentration of venture capital and venture capital-funded firms, and the proximity of key government ministries. Beijing's importance in terms of patenting has declined, and by the end of 2004, Beijing, Shanghai, and Shenzhen were of roughly equal importance, though an overall regional imbalance remained (Hong ch 2010). Using patent data, Hong and Su (2013) studied the impact of geographic and institutional proximity and found that

Table 8 Factors influencing the number of university patent applications and patent grants

References	Dependent variable	University R&D funding	Govt. provided R&D	Enterprise provided R&D	Quantity of R&D personnel	Quality of R&D personnel
Zhou and Zhu (ch 2007)	Applications	+	+	n.s.	n.s.	+
Wu et al. (ch 2008)	Applications	+			+	
Xu and Gao (ch 2008)	Applications	n.s.				
Shi et al. (ch 2009)	Applications		+			
Fu et al. (ch 2010)	Applications	+			+	
Li et al. (ch 2010)*	Applications	+				
Wang et al. (ch 2012)	Applications		+			
Wang et al. (ch 2012)	Grants		n.s.			
Yuan et al. (ch 2012a)	Applications		+			
Rao et al. (ch 2013b)	Applications				+	+
Rao et al. (ch 2013b)	Grants				+	+
Yuan et al. (ch 2013c)	Applications	+	+		+	

* Analysis was conducted at the province level, all other studies were at the university level. All indicators of sign are statistically significant

geographic distance is significantly and negatively related to university–industry collaboration, though the relationship was mitigated by prior collaboration, being part of the same ministry and local government, or institutional proximity.

The issue of university-firm collaboration from the firm perspective has also received attention. For example, Wang et al. (2013) found that licensing a university patent is positively influenced by previous experience, such as having already licensed patents from universities or engaged in co-patenting with universities. In contrast to these positive assessments, Xu (ch 2013) could not confirm that the current university patenting regime promoted technology transfer. Based on a theoretical model and data analysis, Xu argues that increasing university IP increases the cost of innovation for firms and that publicly funded university technology should remain in the public domain.

The factors influencing the level of patent licensing and contracts have received much attention. In addition to geographic proximity, other factors—such as the quality of university R&D personnel (Zhou and Zhu ch 2007), R&D and technology transfer funding (Ye et al. ch 2014), and regional industrial endowments and structure—significantly influence patent licensing performance (Hong ch 2010; Gao et al. 2014; He and Fan ch

Table 9 Factors influencing the number of university patent license contracts and license revenue

References	Dependent variable	University R&D funding	Govt. provided R&D	Enterprise provided R&D	Quantity of R&D personnel	Quality of R&D personnel
Zhou and Zhu (ch 2007)	Contracts	+			n.s.	+
Zhou and Zhu (ch 2007)	Revenue	+				+
Wang et al. (ch 2012)	Revenue		n.s.			
Yuan et al. (ch 2012b)*	Revenue		+			
Rao et al. (ch 2013b)	Contracts				+	+
Rao et al. (ch 2013a)*	Contracts	+				
Ye et al. (ch 2014)	Contracts	+			n.s.	+

* Analysis was conducted at the province level, all other studies were at the level of universities. All indicators of sign are statistically significant

2013; Hong 2008). Universities that receive support from the central and local government, have large patent stocks, have a TTO, and are located in economically prosperous regions also license more patents (Gao et al. 2014).

University type also affects patent licensing (Yuan et al. ch 2009). Not surprisingly, the amount of R&D expenditure has a significantly positive effect on the number of and revenue from patent licenses (Zhou and Zhu ch 2007; Yuan et al. ch 2012b), though this may vary depending upon their type. Similarly, the number and quality of academic staff, R&D staff and R&D service staff, all positively influenced the number and the revenue of patent license contracts (Rao et al. ch 2013b). In other studies, R&D and technology transfer staff were found to have no effect on the number and revenue of Chinese university patent licenses (Ye et al. ch 2014; Zhou and Zhu ch 2007). The findings on the effects of government R&D funding are complex. Wang et al. (ch 2012) found that government R&D funding had no effect on patent licensing revenues. The number of 973 Program projects, which were directed toward basic research, had a positive impact on patent revenue, while the number of 863 Program projects, which were directed toward indigenous technology development, had no effect (Rao et al. ch 2013a). The relationship between funding and personnel inputs and university licensing is summarized in Table 9.

The speed with which Chinese university technology is licensed lags that of developed countries (Chen et al. ch 2014). In a case study of Jilin University, He et al. (ch 2014) find that most technology applications are suited for the domestic market and narrow in scope (see also Yang ch 2008). A number of articles focus on policy and conclude that the technical characteristics of these patents and the larger environment for commercialization are problematic (Chen et al. ch 2007). Ultimately, the low quality of patents (Luan et al. 2010), and flawed management systems result in an asymmetry between the level of R&D

expenditure at Chinese universities and the quantity and quality of university patent applications (Guo and Liu ch 2005).

These scholars argue that the problems are rooted in the organization and development of the Chinese university system and the current state of the domestic industry (Luan et al. 2010). Solutions that have been advanced to improve Chinese university patenting include: improving the skills of technology managers (Wu et al. ch 2001; Chen et al. ch 2007), strengthening technology transfer laws (Liu et al. ch 2007), and motivating faculty and research personnel more effectively (Chen et al. ch 2007). Mirroring debates in the developed nations, some believe that Chinese universities should place more emphasis on the technology transfer (Rao et al. ch 2011; Wang and Lei ch 2012), while others disagree and believe that too much emphasis has been placed on technology commercialization (Xu ch 2013).

Research on university patenting and licensing suggests that, although the number of patents has increased dramatically, the growth of licensing has been far slower. In part, this may be a result of incentives to increase the number of patents, thereby resulting in increased numbers of narrow and economically less valuable patents. In addition, problems seem to be continuing with regard to interest by Chinese firms. Because of the availability of patent data and its relative ease of use, we expect more research on university patenting to be published. In terms of patenting, the results regarding patents are largely congruent with findings in developed nations. This literature does not address whether patents and licensing are valid measures of technology transfer.

6 Implications for future research

Research on CUTT has increased, though given the greater salience of Chinese university research to the global scholarly community; it is still in a very early stage. The focus on patents, spinoffs, USPs, and UILs mirrors the state of research in developed countries more than a decade ago. In developed countries, researchers are increasingly focused on measuring the role of students, both graduate and undergraduate, in technology transfer (see, e.g., Conti and Liu 2015) and the multifaceted ways in which knowledge is transmitted from the university to the surrounding industry (see, e.g., Kenney and Mowery 2014; Nelson 2012). This shift in interest is likely to diffuse to China.

To organize the discussion, we classified the articles into five major themes. These are inductively derived key themes, but several issues transcend these categories. One topic that emerged in several themes was the impact of increasing R&D inputs, such as funding and personnel, on the quantity and quality of technology transfer. In general, research found that increases in R&D funding increased the number of patents but did not necessarily improve the patent quality or revenues (Fisch et al. 2014; Luan et al. 2010; Wang et al. ch 2012; Zhang et al. ch 2013a). Government R&D programs had differential impacts on technology transfer outputs and that policies building university research capability, such as the 985 Project, had an impact on not just quantity but quality as well.

The studies reviewed here yielded many results that were not unique to China. For example, the studies showed that technology transfer required receptivity and capacity on the part of both parties—and many of the firms did not yet have significant absorptive capacity. The results repeatedly confirmed that technology transfer success differed remarkably by region, with Beijing, Shanghai, and Guangdong, the most economically advantaged regions, being the most successful in absorbing and profiting from university knowledge. As is the case in other nations, particularly the United States, research has focused on technology transfer from elite universities, while far less is known about the situation at average universities particularly in less advantaged regions.

A second topic particularly salient in the English-language literature is the hypothesis that the Chinese university system has experienced mixed results in terms of its mission of technology transfer. Wu and Zhou (2012) concluded the technology transfer mission was stalling, while Wang et al. (2013) disagreed. This debate is part of a larger question about the evolution of CUTT and is directly connected with one of the most important shortcomings in both the English- and Chinese-language literature: sophisticated studies of university-based entrepreneurship. This is despite the fact that both English- and Chinese-language articles cited publications examining university entrepreneurship in general and academic spin-offs in particular. Is the reason for the lack of studies due to the limited number of university spin-offs or difficulty in identifying them? This is particularly interesting, because the UOE, as an organizational form, is declining. Does this mean that spin-offs based on university technology and personnel, but that are not licensed by the university, are rare or unimportant? Observations indicate that such spin-offs are indeed numerous suggesting that their absence as an object of study is the result of insufficient data, a problem that affects all CUTT literature, both Chinese- and English-language.

The reliance upon government statistics is striking. Very few researchers collect their own data. An inventory of the data sources used by the articles in this review revealed that with few exceptions these articles relied completely on Chinese government data sources. The exceptions were data collected from interviews and case studies, and patent data other than that found on the State Intellectual Property Office database. Our knowledge, then, is dependent upon government statistics, nearly all of which were collected for monitoring performance, and it is widely acknowledged that officials are under tremendous pressure to meet or exceed government targets.

This lack of diverse data sources produces two effects. First, studies are limited to data that has been thoroughly explored in earlier articles. This in turn produces incentives to pursue research areas based on the extent to which relevant data is available rather than the inherent importance of the particular phenomenon. This could partially explain the significant increase in interest in the Chinese-language literature in patents and licensing since 2010 relative to enterprise and science parks (see Fig. 8). The second result from this lack of diverse data sources is that studies on certain important topics, such as spin-offs based on university technology, have received minimal attention. To ensure greater accuracy, science funding agencies could fund researchers to undertake independent data collection and to build databases that can directly address questions of interest.[9]

7 Conclusion

Over the past three decades China has made unprecedentedly large investments in university research and Chinese universities are now becoming major contributors to the global scientific community. This investment has been fueled by a belief that universities can create human talent and scientific knowledge that will improve the innovative performance of the economy (for a discussion of Chinese economy's innovative performance, see Fu 2015; Lewin et al. 2016). Unfortunately, the extant research provides little analysis or even discussion of the full spectrum of UTT benefits to society. For example, it would

[9] In the U.S. the National Science Foundation's Science of Science Policy has done exactly this.

be of great interest to understand whether and how Chinese university research has contributed to formation and/or development of particular industrial clusters.

The meta-analytical section allowed significant observations about the differences in referencing between English- and Chinese-language articles. The Chinese articles not only had a significantly smaller number of references than did those in English, but they also did not cite each other. Further, as opposed to the English articles, a large number of the Chinese articles were in the form of commentary rather than being substantive. Since 2010 the number of commentary articles have declined precipitously, while the average number of references increased and the publication of articles with no references at all ended. Nevertheless, a larger meta-analysis of the changes in Chinese social science publication practices could provide insight into the differences in academic practices between the two nations and determine whether a convergence was emerging.

The disconnection between the English- and Chinese-language literatures remains substantial. Whether this is true in the larger arena of the social sciences is a promising field for future research particularly for scholars using more sophisticated scientometric techniques. This disconnect is unfortunate, as researchers in China and abroad would benefit from greater interchange and cooperation. One avenue for overcoming the differences in research methods could be through enhanced collaboration among Chinese, U.S. and European funding agencies to establish international forums to discuss research techniques results and possibly launch comparative studies. This could be particularly beneficial for forming cross-national teams aimed at conducting rigorous cross-national comparisons.

The fact that researchers in both languages do not appear to be cross-fertilizing each other to deepen the global knowledge pool suggests that this may be a more general problem. If Chinese social science research is disconnected from international research, then it means that both sides are losing out. Western researchers, whenever possible, should incorporate the results of Chinese-language articles. Given the increasing importance of China as a contributor to global knowledge base, the lack of cross-fertilization will be a handicap to global scientific progress.

Given the increasing role of Chinese universities in the global research community, increased and more rigorous research on CUTT is important, not only for China and the West, but also because many other developing nations are increasing their investments in university research. These governments are searching for information on the efficiency and effectiveness of UTT mechanisms and policy instruments used in developing economy contexts. Not surprisingly, policy-makers have been drawn to university upgrading because it creates public goods, and is one of the most tractable policy levers governments have as it does not require intervening directly into the private sector. Universities have multiple, not easily priced, outputs that include trained students, research outputs, faculty as a cadre of potential technology-savvy consultants, and a stronger national absorptive capacity. This review summarized the current state of the art in thinking about CUTT and shows a significant opportunity for further research.

Our review suggests that there may be a larger opportunity for studying the differences between "local" academic cultures of knowledge creation and their intersection with the English-language journals as they are now considered to be international journals. As political authorities in an increasing number of nations demand that their universities compete in the global ranking schemes that almost always rate international journals of greater value than domestic journals, there may be an erosion of local knowledge cultures and hence what might be termed "intellectual diversity."[10] Does this matter and, if so, in what ways?

[10] For a similar concern in a quite different context, see Piñeiro and Hicks (2014).

The success of the Chinese government's drive to upgrade its economy and encourage innovation will depend in no small measure upon the continuing improvement of its research universities and their ability to exploit the knowledge they develop. As the second largest university research system in the world, better understanding of the complex ways in which Chinese universities transfer knowledge is of vital importance to scholars and policy-makers globally.

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References

Altbach, P. G., & Balan, J. (Eds.). (2007). *World class worldwide: Transforming research universities in Asia and Latin America*. Baltimore: Johns Hopkins University Press.

Baglieri, D., Cesaroni, F., & Orsi, L. (2014). Does the nano-patent 'Gold Rush' lead to entrepreneurial-driven growth? Some policy lessons from China and Japan. *Technovation, 34*(12), 746–761.

Bai, L., & Wang, X. (ch 2006). An analysis on the transformation of scientific and technological achievements in Shanxi province universities based on fuzzy comprehensive evaluation method. *Journal of Information, 25*(7), 46–48. **(translation from Chinese language)**.

Bi, H. (ch 2006). The role of the government in university technology transfer. *Science and Technology Management Research, 1*, 17–20, 23. **(translation from Chinese language)**.

Brehm, S., & Lundin, N. (2012). University–industry linkages and absorptive capacity: An empirical analysis of China's manufacturing industry. *Economics of Innovation and New Technology, 21*(8), 837–852.

Brundenius, C., Lundvall, B. Å., & Sutz, J. (2011). The role of universities in innovation systems in developing countries: Developmental university systems–empirical, analytical and normative perspectives. In B. Å. Lundvall, K. J. Joseph, C. Chaminade, & J. Vang (Eds.), *Handbook of innovation systems and developing countries: Building domestic capabilities in a global setting*. Cheltenham, UK: Edward Elgar.

Cao, C. (2004). Zhongguancun and China's high-tech parks in transition: "Growing pains" or "premature senility"? *Asian Survey, 44*(5), 647–668.

Cao, Y., Zhao, L., & Chen, R. (2009). Institutional structure and incentives of technology transfer: Some new evidence from Chinese universities. *Journal of Technology Management in China, 4*(1), 67–84.

Certo, S. T., Holcomb, T. R., & Holmes, R. M, Jr. (2009). IPO research in management and entrepreneurship: Moving the agenda forward. *Journal of Management, 35*(6), 1340–1378.

Chan, L., & Daim, T. U. (2011). Technology transfer in China: Literature review and policy implications. *Journal of Science and Technology Policy in China, 2*(2), 122–145.

Chang, P.-L., & Shih, Hsin-Yu. (2004). The innovation systems of Taiwan and China: A comparative analysis. *Technovation, 24*(7), 529–539.

Chen, Z. (1986). Unprecedented activity in bringing together science and technology with production. *Renmin Ribao (Overseas edition)*, (February 14): 1.

Chen, J., Huang, C., & Zuo, L. (ch 2005). Research on the building and managing styles between a Chinese university science park and a UK science park. *Science of Science and Management of S. & T., 8*, 50–54. **(translation from Chinese language)**.

Chen, K., & Kenney, M. (2007). Universities/research institutes and regional innovation systems: The cases of Beijing and Shenzhen. *World Development, 35*(6), 1056–1074.

Chen, K., Li, X., & Yang, G. (ch 2014). A comparison of technology transfer efficiency of domestic and foreign universities: Based on the DEA-Malmquist method. *Science of Science and Management of S. & T., 35*(7), 98–106. **(translation from Chinese language)**.

Chen, H., Song, Z., & Yang, M. (ch 2007). A factor analysis and primary study on patent implementation in Chinese universities. *R&D Management, 19*(4), 101–106. **(translation from Chinese language)**.

Conti, A., & Liu, C. C. (2015). Bringing the lab back in: Personnel composition and scientific output at the MIT Department of Biology. *Research Policy, 44*(9), 1633–1644.

Eun, J.-H., Lee, K., & Wu, G. (2006). Explaining the “UREs” in China: A theoretical framework for university–industry relationship in developing countries and its application to China. *Research Policy, 35*(9), 1329–1346.

Fan, C., & Chen, Y. (ch 2000). The rise of the university science park in China. *Science Research Management, 21*(6), 101–106. **(translation from Chinese language)**.

Fan, B., & Yu, J. (ch 2013). The influence of resource input, regional environment on university technology transfer: An analysis based on the panel data of China’s provinces in 1994–2009. *Studies in Science of Science, 31*(11), 1656–1662. **(translation from Chinese language)**.

Feng, G., & Wang, D. (ch 2003). A study of the function and role of research universities in industry–university–institute cooperation. *Tsinghua Journal of Education, 24*(2), 92–95. **(translation from Chinese language)**.

Fisch, C. O., Block, J. H., & Sandner, P. G. (2014). Chinese university patents: Quantity, quality, and the role of subsidy programs. *Journal of Technology Transfer*, Published online: 10 December 2014.

Fu, X. (2015). *China's path to innovation*. Cambridge: Cambridge University Press.

Fu, Y., Zhang, L., Ma, Q., & Chen, Q. (ch 2010). The impact of R&D resource input on patent output of various types of colleges and universities. *R&D Management, 22*(3), 103–111. **(translation from Chinese language)**.

Gao, X., Song, W., Peng, X., & Song, X. (2014). Technology transferring performance of Chinese universities: Insights from patent licensing data. *Advances in Applied Sociology, 4*(12), 289–300.

Gephardt, C. (1999). Asia is taking a hard look: University–foreign company relations in China. *Journal of Technology Transfer, 24*(2–3), 247–254.

Guan, J. C., Yam, R. C. M., & Mok, C. K. (2005). Collaboration between industry and research institutes/universities on industrial innovation in Beijing. *China. Technology Analysis & Strategic Management, 17*(3), 339–353.

Guo, D. (ch 2013). A study of the technology transfer system in Chinese universities. *Science Research Management*, *34*(6), 115–121, 160 **(translation from Chinese language)**.

Guo, Q., & Liu, L. (ch 2005). A study of S&T inputs, patent applications and patent management in universities. *R&D Management, 17*(4), 87–93. **(translation from Chinese language)**.

Hayhoe, R. (1989). China’s universities and Western academic models. *Higher Education, 18*(1), 49–85.

He, B., & Fan, S. (ch 2013). The evolution and impact factors of university technology transfer efficiency in China: Based on the method of Bootstrap-DEA and Panel Tobit model. *Science of Science and Management of S. & T., 34*(10), 85–94. **(translation from Chinese language)**.

He, X., Fu, Y., & Sun, J. (ch 2010). Research on countermeasures to stimulate the conversion of S&T achievements of universities. *R&D Management, 22*(6), 128–132. **(translation from Chinese language)**.

He, J., Meng, H., Zhou, L., Wu, Y., & Li, Y. (ch 2007a). Technology transfer of research-oriented university and its countermeasures. *Educational Research, 8*, 15–22. **(translation from Chinese language)**.

He, J., Wu, Y., & Zhou, L. (ch 2007b). A study on the contribution of university technology transfer in Beijing to Beijing’ economic growth. *Studies in Science of Science, 25*(5), 871–876. **(translation from Chinese language)**.

He, W., Zhang, B., Tian, X., & Li, H. (ch 2014). An analysis of the patents of Jinlin University based on innography database. *Information Science*, 32(8), 144–147, 156. **(translation from Chinese language)**.

Hershberg, E., Nabeshima, K., & Yusuf, S. (2007). Opening the ivory tower to business: university–industry linkages and the development of knowledge-intensive clusters in Asian Cities. *World Development, 35*(6), 931–940.

Hong, W. (2008). Decline of the center: the decentralizing process of knowledge transfer of Chinese universities from 1985 to 2004. *Research Policy, 37*(4), 580–595.

Hong, W. (ch 2010). The changing regional pattern of university–industry co-patenting: An analysis based on social network method. *Studies in Science of Science*, *28*(1), 40–46, 150. **(translation from Chinese language)**.

Hong, W., & Su, Y.-S. (2013). The effect of institutional proximity in non-local university–industry collaborations: An analysis based on Chinese patent data. *Research Policy, 42*(2), 454–464.

Hu, E. (ch 2002). A study of the problems and countermeasures in industry–university–institute cooperation. *R&D Management, 14*(1), 54–57. **(translation from Chinese language)**.

Hu, J. (ch 2009). An analysis of technology transfer problems in Chinese universities. *Science and Technology Management Research, 29*(11), 224–225. **(translation from Chinese language)**.

Hu, H. (ch 2010). Incubation, transfer, feedback and alliance: Research on innovative growth path of USOs-Learning from NUCTECH. *China Soft Science, 7*, 58–63. **(translation from Chinese language)**.

Hu, M. C., & Mathews, J. A. (2008). China's national innovative capacity. *Research Policy, 37*(9), 1465–1479.

Hu, G., Zhang, X., Liu, W., & Hu, D. (ch 2014). Local institutes: A new exploration of the transformation mode of S&T achievements in universities. *R&D Management, 26*(3), 122–128. **(translation from Chinese language)**.

Jia, D. (1996). The legislative background and main content of the Law of Promoting scientific and technological achievements. *Keji Chengguo Zongheng*, *5*, 13–17, 43. **(translation from Chinese language)**.

Kaneva, M., & Untura, G. (2014). The knowledge economy in China and public–private partnerships of universities. *European Journal of Economics and Management, 1*(1), 193–211.

Kenney, M., Breznitz, D., & Murphree, M. (2013). Coming back home after the sun rises: Returnee entrepreneurs and growth of high tech industries. *Research Policy, 42*(2), 391–407.

Kenney, M., & Mowery, D. C. (Eds.). (2014). *Public universities and regional growth: Insights from the University of California*. Stanford, CA: Stanford University Press.

Kroll, H., & Liefner, I. (2008). Spin-off enterprises as a means of technology commercialization in a transforming economy: Evidence from three universities in China. *Technovation, 28*(5), 298–313.

Lei, C., & Huang, Y. (ch 2003). A comparison of university technology transfer at home and abroad. *R&D Management, 15*(5), 45–52. **(translation from Chinese language)**.

Lewin, A., Murmann, J., & Kenney, M. (2016). *China's Innovation Challenge: Overcoming the Middle-Income Trap*. Cambridge: Cambridge University Press.

Li, P. (ch 1999). A comparison of the development modes of the Chinese USPs. *Studies in Science of Science, 17*(4), 90–95. **(translation from Chinese language)**.

Li, P. (ch 2002). Research on transformation of high-tech achievements and local governmental management innovation. *Studies in Science of Science, 20*(3), 292–296. **(translation from Chinese language)**.

Li, W. (ch 2003). An analysis of the influencing factors for technology transfer in Chinese universities and national research. *Science of Science and Management of S. & T., 6*, 48–51. **(translation from Chinese language)**.

Li, P. (ch 2006). A comparison between functions of Guangdong and Hong Kong governments in science and technology transformation in universities. *Studies in Science of Science, 24*(6), 890–894. **(translation from Chinese language)**.

Li, S., Han, C., & Yang, H. (ch 2002). The function and position of the USPs. *R&D Management, 14*(4), 77–80. **(translation from Chinese language)**.

Li, J., Ren, L., & Wu, C. (ch 2010). A study of the relationship between R&D expenditure of research institutes, universities and enterprises and patent output. *Science & Technology Progress and Policy, 27*(20), 103–108. **(translation from Chinese language)**.

Li, X., Xuan, Z., & Yang, Y. (ch 2014). A study of the features of Chinese university technology transfer: A comparison study on knowledge flow between China and USA. *Forum on Science and Technology in China*, *12*, 98–102, 113. **(translation from Chinese language)**.

Li, Z., & Zhang, H. (ch 2013). The shaping of the social networks of transplantation with soil in university technology transfer. *Science and Society, 3*(3), 121–135. **(translation from Chinese language)**.

Liang, M. (2012). Chinese patent quality: Running the numbers and possible remedies. *John Marshall Review of Intellectual Property Law, 11*, 478.

Liao, S., & Xu, S. (ch 2009). An analysis of university–enterprise technology transfer efficiency and its influencing factors in China. *Science of Science and Management of S. & T., 11*, 52–56. **(translation from Chinese language)**.

Lin, J., & Zhou, G. (ch 2006). A study of the knowledge transfer mechanism in industry–university collaboration: A case study of the implementation of project management mode in a exploration and design institute. *China Soft Science, 3*, 139–144. **(translation from Chinese language)**.

Liu, Y. (ch 2007). The development and problems of Chinese university technology transfer. *Forum on Science and Technology in China, 3*, 99–104. **(translation from Chinese language)**.

Liu, Z., & Fu, Z. (ch 2010). An analysis of the influencing factors of technology transfer in local colleges and universities. *Scientific Management Research, 28*(3), 26–29. **(translation from Chinese language)**.

Liu, H., & Jiang, Y. (2001). Technology transfer from higher education institutions to industry in China: Nature and implications. *Technovation, 21*(3), 175–188.

Liu, C., & Peng, J. (ch 2004). How to set up a university science park? An empirical study of the science park of Nanjing University. *R&D Management, 16*(4), 101–107. **(translation from Chinese language)**.

Liu, H., & Shi, J. (ch 2009). An empirical study of the relationship between university technology transfer and China's economic growth. *Science and Technology Management Research, 7*, 244–246. **(translation from Chinese language)**.

Liu, X., & White, S. (2001). Comparing innovation systems: A framework and application to China's transitional context. *Research Policy, 30*(7), 1091–1114.

Liu, Y., Zhang, Y., Yang, J., Zhang, J., & Han, X. (ch 2007). Investigation and thinking about the status quo of patent implementation in Chinese universities and colleges. *R&D Management, 19*(1), 112–119. **(translation from Chinese language)**.

Lu, Q. (2000). *China's leap into the information age: Innovation and organization in the computer industry*. Oxford: Oxford University Press.

Lu, J., & Tan, S. (ch 2008). Operational practice of linked organizations for transforming the S&T achievements of universities in Shanghai. *R&D Management, 20*(2), 122–126. **(translation from Chinese language)**.

Lu, J., & Yang, C. (ch 2005). A study of the selection and application of university technology transfer modes. *Science and Technology Management Research, 25*(9), 80–83. **(translation from Chinese language)**.

Luan, C., Zhou, C., & Liu, A. (2010). Patent strategy in Chinese universities: A comparative perspective. *Scientometrics, 84*(1), 53–63.

Lundvall, B.-A. (Ed.). (1992). *National Systems of innovation: Towards a theory of innovation and interactive learning*. London: Pinter.

Lv, C., Meng, H., & He, J. (ch 2005). On the effect of the research university in the national independent innovation system. *Tsinghua Journal of Education, 26*(5), 1–7. **(translation from Chinese language)**.

Ma, Y., Liu, F., & Sun, Y. (ch 2012). Analysis on the network of Chinese university patents cited by the industry: Taking Tsinghua University as an example. *Science Research Management, 33*(6), 92–99. **(translation from Chinese language)**.

Mei, Y., & Meng, X. (ch 2009). An analysis on modes of university technology transfer: Investigation and thinking on technology transfer in Tsinghua University. *Science & Technology Progress and Policy, 26*(24), 1–5. **(translation from Chinese language)**.

Meng, H., He, J., & Lv, C. (ch 2006). Innovation integration at the Tsinghua University Science Park. *Tsinghua Journal of Education, 27*(2), 69–74. **(translation from Chinese language)**.

Min, W., & Ma, W. (ch 1999). The function of the university in the knowledge-based economy age: The practices and prospects for Beijing University. *Research in Educational Development, 27*(2), 65–67. **(translation from Chinese language)**.

Ministry of Education, Science and Technology Development Center. (2010). http://www.cutech.edu.cn/cn/kjcy/xbcytj/2012/05/1331845776580212.htm **(translation from Chinese language).**

Nelson, R. R. (Ed.). (1993). *National innovation systems: A comparative analysis*. Oxford: Oxford University Press.

Nelson, A. J. (2012). Putting university research in context: Assessing alternative measures of production and diffusion at Stanford. *Research Policy, 41*(4), 678–691.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., et al. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research Policy, 42*(2), 423–442.

Piñeiro, C. L., & Hicks, D. (2014). Reception of Spanish sociology by domestic and foreign audiences differs and has consequences for evaluation. *Research Evaluation, 24*(1), 78–89.

Psacharopoulos, G. (1994). Returns to investment in education: A global update. *World Development, 22*(9), 1325–1343.

Psacharopoulos, G., & Patrinos, H. A. (2004). Returns to investment in education: A further update. *Education Economics, 12*(2), 111–134.

Qiu, Q. (ch 2002). Analysis on the property rights arrangement in Chinese university-owned high-tech enterprises. *China Soft Science, 5*, 117–121. **(translation from Chinese language)**.

Qu, Y. (ch 2010). Problems of intellectual property protection in university technology transfer in China and America. *Journal of Beijing Jiaotong University (Social Sciences Edition), 9*(2), 101–105. **(translation from Chinese language)**.

Rao, K., Meng, X., Chen, Q., & Piccaluga, A. (ch 2011). Comparative research on university patent technology transfer between China and Europe. *Soft Science, 25*(10), 22–26. **(translation from Chinese language)**.

Rao, K., Meng, X., & Piccaluga, A. (ch 2012a). The impact of government R&D investments on Chinese university technology transfer contracts: Based on the triple helix theory. *Science of Science and Management of S. & T., 33*(8), 74–81. **(translation from Chinese language)**.

Rao, K., Meng, X., Xu, L., & Piccaluga, A. (ch 2012b). The impact of R&D investments on technology transfer contracts of chinese universities. *Journal of Management Science, 25*(5), 76–84. **(translation from Chinese language)**.

Rao, K., Meng, X., Xu, L., & Piccaluga, A. (ch 2013a). The impact of R&D investments on patent technology transfer activities of local universities: An empirical analysis of provincial panel data. *Management Review, 25*(5), 144–154. **(translation from Chinese language)**.

Rao, K., Meng, X., & Yu, X. (ch 2013b). The impact of S&T human resource factors on Chinese local university patenting-licensing activities. *Forum on Science and Technology in China, 4*, 135–141. **(translation from Chinese language)**.

Rothaermel, F. T., Agung, S. D., & Lin, J. (2007). University entrepreneurship: Taxonomy of the literature. *Industrial and Corporate Change, 16*(4), 691–791.

Shi, D., Xu, H., & Liu, F. (ch 2009). The impact of government's S&T investment on the expenditure and patents of universities. *Science & Technology Progress and Policy, 26*(23), 192–195. **(translation from Chinese language)**.

State Council of China. (ch 2008). The notification of the national intellectual property strategy outline issued by China's State Council. http://www.gov.cn/zwgk/2008-06/10/content_1012269.htm **(translation from Chinese language)**.

State Intellectual Property Office of the P.R.C. (ch 2012).The notification on National Patent Development Strategy (2011–2020) issued by the State Intellectual Property Office of the People's Republic of China. http://www.sipo.gov.cn/ztzl/ywzt/qgzlsyfzzltjgz/noticeps/201311/t20131113_879257.html **(translation from Chinese language).**

Su, D.-J., Al, M., & Sohn, D.-W. (2011). A model to create high-tech start-ups from the academic environment: The case of Peking University (PKU) and Tsinghua University (THU). *African Journal of Business Management, 5*(26), 10821–10833.

Tang, M. F. (2006). A comparative study on the role of National Technology Transfer Centers in different Chinese universities. In *4th Globelics conference in Trivandrum, India.*

U.S. National Science Foundation. (2016). Science and Engineering Indicators 2016.

Van Essen, C. (2007). The development and diversity of science parks in China: Three cases. Master Thesis, Erasmus University (May).

Von Hippel, E. (1988). *The sources of innovation*. New York: Oxford University Press.

Wang, T. (ch 2010). A study of modes of university technology transfer in Xinjiang. *Forum on Science and Technology in China, 1*, 96–100. **(translation from Chinese language)**.

Wang, Y., Huang, J., Chen, Y., Pan, X., & Chen, J. (2013). Have Chinese universities embraced their third mission? New insight from a business perspective. *Scientometrics, 97*(2), 207–222.

Wang, Y., & Lei, H. (ch 2012). University technology transfer and university patent management are a responsibility for engineering education. *Research in Higher Education of Engineering, 6*, 158–162. **(translation from Chinese language)**.

Wang, Y., & Lu, L. (2007). Knowledge transfer through effective university–industry interactions: Empirical experiences from China. *Journal of Technology Management in China, 2*(2), 119–133.

Wang, B., & Ma, J. (2007). Collaborative R&D: Intellectual property rights between Tsinghua University and multinational companies. *Journal of Technology Transfer, 32*(4), 457–474.

Wang, Q., Wu, J., & Shen, Y. (ch 2012). A study of the correlation between quantifiable factors of resources and the technology transfer output of universities of science and engineering. *Science and Technology Management Research, 9*, 81–86. **(translation from Chinese language)**.

Wang, X., Zhang, Y., & Wang, Z. (ch 2004). IPR protection and technology transfer of SJTU. *R&D Management, 16*(2), 110–115. **(translation from Chinese language)**.

Weng, J. (ch 2000). A Comparison of the incentive policies for university technology transfer in America, Japan and China. *Journal of Higher Education, 4*, 98–102. **(translation from Chinese language)**.

Wu, W. (2007). Cultivating research universities and industrial linkages in China: The case of Shanghai. *World Development, 35*(6), 1075–1093.

Wu, W. (2010). Managing and incentivizing research commercialization in Chinese Universities. *Journal of Technology Transfer, 35*(2), 203–224.

Wu, F., & Dong, Z. (ch 2010). The influencing factors of university technology transfer ability and empirical analysis. *Science & Technology Progress and Policy, 27*(10), 137–140. **(translation from Chinese language)**.

Wu, Y., Ge, Z., & Zheng, Y. (ch 2001). Strengthening the patent work in colleges and universities and promoting the development of science and technology: Preliminary research and revelation of patent work in Tsinghua University. *Science of Science and Management of S. & T., 4*, 38–41. **(translation from Chinese language)**.

Wu, J., Zhang, Y., & Shi, Q. (ch 2008). A study on the efficiency of knowledge innovation: An example of patent applications. *R&D Management, 20*(6), 117–121. **(translation from Chinese language)**.

Wu, W., & Zhou, Yu. (2012). The third mission stalled? Universities in China's technological progress. *Journal of Technology Transfer, 37*(6), 812–827.

Xiao, G., & Li, J. (ch 2014). The influence of patent funding policy on university technology transfer: Evidence from Shanghai. *Scientific Management Research, 32*(6), 37–40. **(translation from Chinese language)**.

Xie, K., Zhao, B., Zhang, L., & Wang, X. (ch 2002). A discussion of the industry–university–institute program in universities and its operating mechanism. *Studies in Science of Science, 20*(4), 423–427. **(translation from Chinese language)**.

Xu, C. (ch 2013). Universities' patents, technology transfer and firms' innovation in China: Based on the accumulation innovation. *Science of Science and Management of S. & T., 34*(12), 78–86. **(translation from Chinese language)**.

Xu, Y., & Chen, Z. (ch 2005). Analyzing and designing an information system for achieving the transformation of science and technology in universities based on B/S model. *Studies in Dialectics of Nature, 21*(7), 90–93. **(translation from Chinese language)**.

Xu, K., & Gao, S. (ch 2008). A study of the scientific research inputs and outputs of Chinese universities. *R&D Management, 20*(2), 97–101. **(translation from Chinese language)**.

Xu, J., & Mei, M. (ch 2003). The accelerator of the knowledge economy: The concept and development strategy of Tsinghua University Science Park. *Journal of Tsinghua University (Philosophy and Social Sciences), 18*(4), 89–94. **(translation from Chinese language)**.

Xu, G., Ye, J., & Zou, Y. (ch 2008). Analysis of the influencing factors of knowledge transfer in industry–university collaboration. *Journal of Information, 2*, 87–89. **(translation from Chinese language)**.

Xue, L. (2004). University–market linkages in China: The case of university-affiliated enterprises. Paper presented at the symposium on University, Research Institute and Industry Relations in the U.S., Taiwan and Mainland China, Stanford Project on Regions of Innovation and Entrepreneurship, Palo Alto, CA (September 7–8, 2004) http://iis-db.stanford.edu/evnts/4097/LXue_University-Market_Linkages_in_China.pdf.

Yan, W., & Zhou, F. (ch 2006). A study of a fuzzy evaluation methods for the performance of university technology transfer. *R&D Management, 18*(6), 129–133. **(translation from Chinese language)**.

Yang, Z. (ch 2008). Study of Chinese university patents and science and technology innovation activities. *Library Work and Study, 6*, 90–93. **(translation from Chinese language)**.

Yang, J., & Li, C. (ch 2010). A comparative study of technology transfer at MIT and Tsinghua University. *Forum on Science and Technology in China, 1*, 147–151. **(translation from Chinese language)**.

Yang, T., & Ling, W. (ch 2009). Cointegration and Granger causality analysis of university technology transfer and economic growth in Guangdong province. *Science and Technology Management Research, 11*, 215–217. **(translation from Chinese language)**.

Yang, D., Wang, Q., & Meng, X. (ch 2007). An analysis of the factors influencing Chinese research university spin-off firms. *Studies in Science of Science, 25*(3), 511–517. **(translation from Chinese language)**.

Ye, J., Yang, Y., Han, J., & Wei, L. (ch 2014). Inputs, unobserved factors and university technology transfer: An empirical analysis of China's universities patent data. *Economic Science, 5*, 103–117. **(translation from Chinese language)**.

Yu, X., Qi, W., Li, F., & Tan, M. (ch 2011). Study of the evaluation of the whole process of universities' technology transfer of Chinese provinces: A catastrophe theory perspective. *Forum on Science and Technology in China, 10*, 102–108. **(translation from Chinese language)**.

Yuan, C., Jia, Y., Fang, K., & Liu, Z. (ch 2009). Effects of university type on university knowledge transfer in China: A resource-based view. *Science of Science and Management of S. & T., 30*(7), 134–138. **(translation from Chinese language)**.

Yuan, C., Gao, J., & Sun, H. (ch 2013a). The impact of local government support and regional market uncertainty on the efficiency of university technology transfer: Evidence from chinese "211-project" universities. *R&D Management, 25*(3), 10–17. **(translation from Chinese language)**.

Yuan, C., Sun, H., & Fang, K. (ch 2013b). The effects of institutional change on university knowledge transfer during the transition period: Evidence from the universities mergers in China. *Chinese Journal of Management, 10*(3), 451–457. **(translation from Chinese language)**.

Yuan, C., Sun, H., & Li, X. (ch 2013c). The impact of local government's S. & T. investment intensity and local market technology demand on research university patent output efficiency. *Science & Technology Progress and Policy, 30*(10), 26–30. **(translation from Chinese language)**.

Yuan, C., Sun, H., & Wang, T. (ch 2012a). Study of the relationship between the government support and the efficiency of university knowledge creation and transfer. *Studies in Science of Science, 30*(9), 1397–1404. **(translation from Chinese language)**.

Yuan, C., Zhao, W., & Zhou, L. (ch 2012b). The impact of government support and market uncertainty on university–industry knowledge transfer efficiency. *Science Research Management, 33*(10), 106–113. **(translation from Chinese language)**.

Yusuf, S., & Nabeshima, K. (Eds.). (2007). *How universities promote economic growth*. World Bank Publications.

Zhai, T., & Li, Y. (ch 2012). The path analysis of collaborative management on the transformation of university scientific and technological achievements. *Science & Technology Progress and Policy, 29*(22), 44–47. **(translation from Chinese language)**.

Zhang, A., & Cao, X. (ch 2004). Analysis on scientific and technological achievements transformation in universities and colleges. *Seeker, 10*, 50–51.

Zhang, J., & Liu, W. (ch 2012). Evolution and trend of university technology transfer organization. *Science & Technology Progress and Policy, 29*(6), 147–150. **(translation from Chinese language)**.

Zhang, H., Hu, Z., & Li, Z. (ch 2013a). Empirical measuring the correlation between R&D projects and agreements of university technology transfer: Case study of Chinese 985 Project universities. *Studies in Science of Science*, *31*(4), 495, 537–545. **(translation from Chinese language)**.

Zhang, H., Patton, D., & Kenney, M. (2013b). Building global-class universities: Assessing the impact of the 985 Project. *Research Policy, 42*(3), 765–775.

Zhang, Y., Wu, J., & Shi, Q. (ch 2008). Analysis of the efficiency of university's S&T input and achievement transformation. *Science and Technology Management Research, 8*, 133–135. **(translation from Chinese language)**.

Zhao, W., Xue, T., & Hou, D. (ch 1998). Comparative study of university technology transfer in different countries. *Studies in Foreign Education, 5*, 39–43. **(translation from Chinese language)**.

Zhou, X. (ch 2011). Study on modes of scientific and technological achievements transformation in Chinese universities and colleges. *Journal of Fuzhou University (Philosophy and Social Sciences), 25*(1), 104–107. **(translation from Chinese language)**.

Zhou, Y. (2015). The rapid rise of a research nation. *Nature, 528*(17 December), S170–S173.

Zhou, Y., & Minshall, T. (2014). Building global products and competing in innovation: the role of Chinese university spin-outs and required innovation capabilities. *International Journal of Technology Management, 64*(234), 180–209.

Zhou, Y., Minshall, T., & Hampden-Turner, C. (2010). Building innovation capabilities: An inquiry into the dynamic growth process of university spin-outs in China. *International Journal of Innovation and Technology Management, 7*(3), 273–302.

Zhou, R., Tu, G., & Yu, D. (ch 2013). Structure, behavior and their evolvement of knowledge network of university technology transfer team. *Forum on Science and Technology in China, 11*, 79–84. **(translation from Chinese language)**.

Zhou, F., & Zhu, X. (ch 2007). A study on the resource factors and the performance of university technology transfer. *R&D Management, 19*(5), 87–94. **(translation from Chinese language)**.

Zhu, G., & Frame, J. D. (1987). Technology transfer within China. *Journal of Technology Transfer, 11*(2), 29–42.

Zou, Y., & Zhao, W. (2014). Anatomy of Tsinghua University Science Park in China: institutional evolution and assessment. *Journal of Technology Transfer, 39*(5), 663–674.