Government-driven university-industry linkages in an emerging country: the case of China

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Abstract

Purpose – The purpose of this paper is to analyze and summarize the development of science and technology (S&T) policies in China from a government-driven perspective in chronological order. To develop knowledge-based economy, China enacts a range of S&T policies since "Reform and Open Policy" started in 1978. Furthermore, it investigates the overall effects of these S&T policies on university-industry linkages (UILs).

Design/methodology/approach – This paper conducts an analysis framework of S&T policies in historical sequence to explain how government drives UILs to stimulate technological progress and economic growth in China.

Findings – More than a site for high-quality workforce education and knowledge spread, universities as an important part of national innovation are required to participate in economic activities. Considering that most Chinese universities are national, S&T policies with particular regard to university technology transfer would be more important and essential. This research finds that S&T policies enacted by government have made critical contributions to UILs in economic transition period, such as improving academic faculty, enhancing university–industry collaborations and supporting university spin-off formation. The experiences of China suggest that government should enact more effective S&T policies in the knowledge-based economy era.

Practical implications – First, universities need to educate high-level human resources that are important for economic growth and social development. Second, universities need to engage in R&D activities and enhance their collaboration with industries, such as consulting services, research contracts with industry, patent licensing and other general knowledge commercial mechanisms. Third, universities also can directly transfer commercial knowledge to start up new businesses by itself or in partnership with industrial sectors. Without doubt, a series of S&T policies or programs enacted by China's government to drive entrepreneurship continuously played critical role in the UILs over the past 26 years.

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Originality/value – This paper is a pioneering work on how S&T policies enacted by government drive UILs to stimulate technological progress in transitional China.

Keywords China, Reform and open policy, S&T policies, University-industry linkages

Paper type Research paper

1. Introduction

Recently, a bulk of literature has found that research-intensive universities expand their role in many fields. More than a site for high-quality talents education and knowledge spread, they also make big contributions to technological progresses[1] and economic growth through technology transfer, university-industrial collaboration and even spin-offs creation in the knowledge-based economy era (Rolfo and Finardi, 2014; Sohn and Kenney, 2007; Wu and Zhou, 2012). These contributions can be concluded as university-industry linkages (UILs) which have attracted great attentions of research scholars and policy-makers in recent years. Meanwhile, UILs in turn generate dramatic economic incomes for universities, thereby underpinning the implementation of cutting-edge research and enhancing academic status (Bonardo *et al.*, 2011; Xu and Yu, 2013). More specially, UILs increase the interactions among academic environment, industries and government and, thus, stimulate universities' commercial behaviors that transfer new research results to market practices. In this respect, the primary reasons why UILs become more active and stronger have been broadly investigated from different perspectives.

One key perspective is how the nature and extent of government factors can impact UILs in the developed countries. For instance, the key S&T policy that US universities actively transfer their technologies to market is attributed to the Bayh-Dole Act, which permits universities, non-profit organizations or small business entities to make use of their intellectual properties in preference to the government (Di Gregorio and Shane, 2003; Guerzoni *et al.*, 2014; O'Shea *et al.*, 2005; Tyler III, 2013). Consequently, Bayh-Dole Act dramatically guides universities and their researchers to actively develop and transfer knowledge, new technologies, know-how and other knowledge-based results to market, as well as ensure that practitioners can apply them into new products, processes and services. Compared to the USA, China, as a centralized country, is more potentially influenced by its political elements, such as S&T policies, national S&T projects and national S&T development programs (Chen and Kenney, 2007; Huang *et al.*, 2013; Zhang *et al.*, 2013). Accordingly, it is necessary to offer a systematic framework to enhance our understanding of how Chinese Government drives UILs since "Reform and Open Policy" started in 1978.

2. The Chinese context

It was acknowledged that the planned economy had led to numerous difficulties, such as economic inefficiency, investment failure and social poverty (Chen and Kenney, 2007; Guan and Yam, 2015; Sun, 2010; Wu and Zhou, 2012). Consequently, the leaders of Communist Party of China shifted economic focus to market and designed two stages to implement economic reforms in 1978. In the first stage (from the late 1970s to the early 1980s), China promoted the household contract responsibility system, opened market to foreign investment and permitted entrepreneurs to start-up new businesses, aiming at changing the foundation of planned market and bringing economic vitality. The second stage (from the late 1980s to the early 1990s) involved privatization and contracting out of many state-owned enterprises, price controls and other economic reforms. To this end, a number of government-driven policies or programs were launched during these two stages, such as "Program 863" and "Torch Program", which aim to develop biotechnology, energy, IT, new materials and other high-tech industries (Guan and Yam, 2015; Liu *et al.*, 2011; Su *et al.*, 2013).

As an important part of national/regional innovation systems, universities (particularly research-intensive ones) got a wealth of political supports (often along with favorable policies, financial funding, intellectual assets and other strategic resources) to upgrade their research surroundings and hire high-level researchers for knowledge spillover and R&D activities. Furthermore, some Chinese top universities (such as Peking University and Northeastern University) achieved dramatic successes in terms of UILs (Table I) through active technology transfer[2] (Su and Sohn, 2012). However, a majority of universities still focused on their higher education and knowledge generation rather than the commercialization of R&D results as of the early 1990s.

Since the early 1990s, some research-intensive universities broadened in industries, particularly high-tech industries which might in turn generate much more economic profits for themselves and then underpinned the cutting-edge knowledge generation and R&D activities (Chen and Kenney, 2007; Freitas *et al.*, 2013). For instance, Tsinghua University (THU) continuously founded many university-affiliated enterprises at this period, some of which have become the leading high-tech companies (such as Tongfang and Ziguang) in recent China. Dating to the mid 1990s, Chinese Government proposed some special S&T policies for universities, such as "Project 211" in 1995 and "Project 985" in 1998. As a result, the top research-intensive universities got a wealth of financial and political supports from government and realized dramatic successes in terms of UILs (Zhang *et al.*, 2013). Since 1998, individual inventors who develop patents on the basis of government R&D projects also can obtain a royalty of at most 35 per cent of the license fee, when their patents are transferred to practice. This preferential policy in finance has effectively stimulated the motivation of university professors or staffs toward UILs, leading to an emergence of academic entrepreneurship around 2000s.

Entering 2000s, China achieved the highest economic growth among the newly industrializing economies, with gross domestic product (GDP) growth of over 8 per cent during 2000-2011. However, the rapid economic development was mainly promoted by the amount investment in infrastructure construction rather than by the knowledge-based business. Furthermore, it has led to a lot of social problem, such as higher housing price, too fast urbanization, severe employment pressure, export

Table I. Typical university-affiliated enterprises in high tech industries (unit: million)

Founding year	Firms	Parent university	Core business	Initial capital	Sales in 2012	Net profit in 2012
1986	Founder	PKU	Computer systems, IT peripherals, IT software	4.4	62,376.7	1,487.2
1991	Neusoft	NEU	Energy, IT, biotech, logistics, health	0.03	7,211.9	542.7

Notes: PKU = Peking university; NEU = Northeastern university
Source: A statistical report on China's university-affiliated enterprises in 2012

decrease, etc. To solve such kinds of economic and social problems, an increasing number of researchers have suggested that it is necessary to shift Chinese economy from capital-driven model to knowledge-driven model. For the latter, it was recognized that new technologies will be the most effective driving force to increase the efficiency, productivity and competitiveness of the economy. Under these circumstances, the role of UILs in China's technological progress entered new stage. Since then, a growing number of universities started to present stronger interests in UILs and involved in the development of high-tech industries because forerunners have benefited from their commercial behaviors. In this period, the central government continuously enacted some S&T policies or projects toward the development of knowledge-based economy, such as "Fifteen Years S&T Program", "National Medium and Long-term Talents Strategy" and "Program 111".

3. An evolution of government-driven UILs in China

To enhance understanding of how Chinese government drives the UILs, a majority of S&T policies with particular regard to university technology transfer are reviewed and discussed in chronological order.

3.1 University-affiliated state key laboratories

As the R&D bases of cutting-edge technologies, China's high-level laboratories were widely acknowledged that might have critical effects on technology development and transfer (Chen and Kenney, 2007). From 1984 to 1993, the central government invested 910 million RMB to build 81 state key laboratories, most of which were affiliated with research-intensive universities, such as THU (including the State Key Laboratory of Tribology in 1986), PKU (including the State Key Laboratory of Nuclear Physics and Technology in 1990, the State Key Laboratory of Earth Materials Chemistry and Applications in 1991) and University of Science and Technology Beijing (including the State Key Laboratory for Advanced Metals and Materials in 1991). In 2006, MOST (Ministry of Science and Technology) stated that it would support to find the state key laboratories involved in ocean, aerospace, population health, nuclear, new energy, advanced manufacturing, quantum control, protein, agriculture and rail transit. Consequently, ten state key laboratories were founded in this year, six of which were affiliated with six prestigious universities (namely, Shanghai Jiaotong University, Nanjing University, Beihang University, Ocean University of China, Southwest Jiaotong University and China Agricultural University). These laboratories have become important R&D forces that implement state key projects sponsored by "Program 863", "Torch Program" and other government S&T programs. Besides government-sponsored research projects, university-affiliated state key laboratories also help industrial sectors develop new technologies or provide some technological assistance.

3.2 China Spark Program

Although China has achieved some success in S&T fields in the early 1980s, national innovation systems still lagged far behind Western countries[3]. In 1985, State Scientific and Technological Commission (the predecessor of MOST) suggested the central government to launch high-tech projects to drive local economic growth, particularly to incubate agricultural technology firms and stimulate the application of technologies into agriculture. According to the *China Spark Program Annual Report 2012*, it invested 39.6 billion RMB to support 13,445 projects and yielded output value of 175.194 billion RMB and a profit of 26.498 billion RMB. Furthermore, over 1.58 million jobs were created for society.

From the perspective of university, the *China Spark Program* encouraged relevant universities and their researchers to transfer their new research results to agricultural industries, such as founding rural technology service platforms, agricultural talents education and technology incubators, thus enhancing the linkages between university and agricultural industries (Zhang *et al.*, 2015). Furthermore, this program plays very important role in the emergence of rural entrepreneurship in the process of Chinese urbanization, which has become a hot issue within economic development. In the case of Liaoning Province, Shenyang Agricultural University designed "enterprises + bases + farmers + technology" model according to the *China Spark Program*, aiming at transferring new research results to practice and collaborated with five counties to develop agricultural technology-based industries and provided over 7,100 jobs. However, the major limitation is that only a small number of universities (especially agricultural ones) can benefit from this program, because it mainly focuses on the technological progresses of agricultural industry.

3.3 Program 863

In the early 1980s, four scientists from China Academy of Sciences acknowledged that:

- the weak national R&D capabilities have become the key conundrums that hinder industrial reform and economic development in transitional China; and
- the knowledge-based technologies have become the critical elements that decide national competitive advantage in the global complicated environment.

Thus, they suggested central government that it is critical moment to examine and follow the direction and contents of foreign strategic high-tech development in March, 1986 (Su *et al.*, 2013). Subsequently, the central government enacted "High-tech R&D Program" (often called "Program 863"), aiming at improving the self-innovation capacity and establishing cutting-edge industries. According to the "Program 863", China would invest a wealth of resources to support the development of biotech, aerospace, IT, laser technology, automatic technology, energy, new material and marine technology. Hence, "Program 863" has been considered as a critical state-level S&T program that provides a bulk of resources for research-intensive universities to implement the development of cutting-edge technologies at the early stage of economic transition.

The Web site of "Program 863" reported that 33 billion RMB was invested and 150,000 researchers (from 500 R&D institutes, 300 universities and 1,000 enterprises) participated in this national S&T projects from 1986 to 2005. At this time, it funded 120,000 papers, 8,000 patents and 1,800 national or industrial standards. However, this program mostly followed the trajectory of global technology development and observed S&T changes of developed countries rather than independently developed cutting-edge technologies before the 2000s. To defend the passive situation in high-tech fields, the "Program 863" keenly supported the cutting-edge studies and a growing number of R&D teams from research-intensive universities benefited from these projects entered the 2000s.

For universities, Program 863 is an important political signal that guides the direction of R&D activities and the commercial behavior of new research results. Accordingly, a growing number of research-intensive universities invested a wealth of resources to support researchers to commercialize new research results originated from "Program 863", because it not only can enrich university's R&D funding to underpin the cutting-edge technologies but also can stimulate the commercialization of new research results to create economic profit. For example, in 1995, THU founded national CIMS (Contemporary Integrated Manufacturing Systems) center based on "Program 863" key project, focusing on the *chanxueyan* (university research–industry linkages) of CIMS and its industrialization. In addition, this center implemented a large number of R&D projects with prestigious universities from the USA, Germany, Australia and other developed countries. Furthermore, this center have finished 150 government-sponsored research projects and won numerous prizes, such as five times *National Second Prize for Progress in Science and Technology*, which is the China's highest-level prize in the field of S&T. In the case of PKU, in 1986, Founder Group was established which played catalytic role in transferring research results to market and generate financial income for PKU. As of now, Founder Group has become the most famous university-affiliated enterprise because of its competitive advantage in IT, medicine and other advanced technologies. In 2012, Founder Group brought 61.8 billion RMB to PKU. Roughly speaking, "Program 863" has driven universities to implement and commercialize R&D activities and, therefore, make big contributions to technological progress and economic growth.

3.4 "Torch program"

In 1988, Chinese leader Deng Xiaoping pointed out that "science and technology are the primary productive forces", so that the high-tech industries attracted large of attention from practitioners and policy-makers. Under these circumstances, MOST enacted new national S&T project "Torch Program", which aimed at stimulating the exploitation of technological potential, the transfer of newly developed scientific results, the commercialization of high-tech, the internationalization of high-tech industries and the establishment of high-tech zones. According to the official site of "Torch High Technology Industry Development Center" of MOST, universities and other knowledge-based institutions have benefited from "Torch Program" to improve their R&D capacity as well as enhance the linkages with industries (Table II). In the context of university, "Torch Program" financially or politically supported 94 national university science parks (NUSPs), which incubated 7,369 spin-offs launched by university professors (staffs) or in partnership with outside entrepreneurs in 2012. In addition, these NUSPs hired 132,000 employees and generated 20.67 billion RMB this year.

In sum, as an important part of national innovation systems, universities have been regarded as the primary force to implement "Torch Program", such as undertake the projects of Torch Program, commercialize R&D results, start up new businesses and other UILs.

3.5 Science park: the case of Zhongguancun science park

Besides the state S&T policies mentioned above, Chinese Government also founded the first and yet the largest Science Park, named "Zhongguancun" in May 1988, covering 41

Typologies	Key indicators (in 2012)
National University Science Parks (NUSPs)	(1) 94 NUSPs; (2) 7,369 incubating firms, including 1,787 newly incubated ones in 2012; (3) total income: 20.67 billion RMB; (3) number of employees: 132 thousand
National High-tech Zones (NHTZs)	(1) 105 NHTZs; (2) 63,926 firms; (3) total employees number: 12,695 thousands; (4) total sales: 16,568.99 billion RMB; (4) Net profit: 1,024.32 billion RMB
Technology-Based Incubators (TBIs)	(1) Number of TBIs: 1,239; (2) number of incubating firms: 70,217; (3) total income of incubating firms: 49,583 billion RMB; (4) number of employees of incubating firms: 1,437 thousands
Software Industrial Bases (SIBs)	(1) Number of SIBs: 39; (2) total number of employees: 2,268 thousands; (3) total income: 169,509 Billion RMB; (4) total value of profits and taxes: 24,071 billion RMB; (5) export earnings: 2,738 billion USD

Table II. "Torch program" and its major contributions to S&T in 2012

universities, 206 public research institutions and other enterprise research centers. The main target of Zhongguancun Science Park was to integrate S&T resources of universities, public research institutes and other high-tech organizations; respond to the demands of the emerging new technologies; stimulate the industrialization of new technologies; and develop national competitive advantage (Kenney *et al.*, 2013; Wright *et al.*, 2008). In the early stage, spin-offs from public research institutes and universities were an important driving force that promoted Zhongguancun Science Park into the largest high-tech cluster (Wang and Wang, 1998). In the process of China's technological progress and economic growth, Zhongguancun Science Park has made significant contribution to the development of IT, biotech, pharmacy, green energy tech and other high-tech industries since its establishment, so that it was also called as "Chinese Silicon Valley". Thus, recent observers have credited various variables as critical to the high-tech development of Zhongguancun Science Park, including public financial supports (Su and Sohn, 2012), close proximity to research universities (Chen and Kenney, 2007), cutting-edge technology transfer from universities (Su *et al.*, 2013), abundance of venture capital (Wright, 2007) and returnee entrepreneurs (Kenney *et al.*, 2013). In sum, they have got the same conclusion that universities around Zhongguancun Science Park play indispensable role in the development of this high-tech zone by providing a range of technology licensing, high-quality talents, consulting service, joint research and other UILs. In addition, some universities' researchers also independently or jointly found new firms in Zhongguancun Science Park by using their original ideas or new research results. The success of Zhongguancun Science Park has become the symbol of University Technology Transfer (UTT) from academic research to industrial practice and set an example for other coming Science Parks in China.

Motivated by the experience of Zhongguancun Science Park, some regions also actively founded numerous science parks around universities, such as Shanghai

Zhangjiang high-tech park covering Fudan University, Shanghai Jiao Tong University and other famous universities or research institutes; Wuhan East Lake High-tech Development Zone covering Wuhan university, Huazhong University of Science and Technology, China University of Geosciences and other 55 universities (Huang *et al.*, 2013). Furthermore, an increasing number of high-tech firms are located around these science parks and they collaborate joint R&D activities with nearby universities, thus making big contributions to technological progress and regional economic development.

3.6 University science parks

As the birthplace of academic entrepreneurship, the USA is famous as its well-running university science parks (USPs), such as Stanford Research Park established in 1951, Research Triangle Park established in 1959 and subsequent many others which continuously make big contributions to the establishment of American national innovation systems (Kenney and Von Burg, 1999; Zou and Zhao, 2014). In the USA, USPs have become an essential component of national/regional innovation systems through the cutting-edge knowledge spillover, the transfer of academic research results to industrial practice, joint research contract and other UILs. Recognizing the effect of USPs on technological progress and economic growth[4], in 1989, China's NEU founded the first USP which mainly focused on the R&D of software and automatic technologies. NEU utilized its excellent innovative capacity to underpin technology transfer from academic environment to practice and supply a variety of technical resources for incubating high-tech spin-offs. Furthermore, it brought dramatic financial income for Northeastern University (Pang and Ding, 2012). Being aware of the importance of USP in financial income and practical benefits, more and more research-intensive universities (such as THU, PKU, Nanjing University, and Southeast University) began to found USPs in the 1990s.

Consequently, in 2002, the central government proposed new national project, named "National University Science Parks" (selecting from the existing USPs) which would get more political and financial supports from government. The number of USPs in total was 96 as of 2013 (Table III).

According to the report released by MOST in 2010, 86 state-level university science parks undertook 1,728 projects (including 345 state-level projects); applied 5,603 patents (including 2,333 invention patents); got 2,857 licensed patents (including 872 invention patents); and imported 34 foreign patents. In addition, spin-offs which are incubating in state university science parks transferred 4,606 technologies into industrialization and the total income was up to 22.163 billion RMB.

China's most universities, in particular research-intensive universities, are public and funded by government, which indicates that the growth trajectory of USPs in China is different from that in Western countries (Zou and Zhao, 2013). Hence, USPs maybe a good platform to commercialize university research results and explore UILs which are encouraged by the recent policy-makers in China.

3.7 "Project 211"

In the mid 1990s, the central and local governments at various levels have viewed universities as important engines of economic development and preferred to supply a range of supports for improving their academic level and research capacity (Wu and

Group	Year	No.	Universities
1	2002	23	THU, PKU, Northeastern University, Nanjing University, Fudan University, Sichuan University, Xi'an Jiao Tong University, etc
2	2003	14	Nankai University, Jilin University, Shanghai University, Nanjing University of Science and Technology, Tongji University, etc
3	2004	6	Dalian University of Technology, Lanzhou University, Nanchang University, etc
4	2005	8	University of Science & Technology Beijing, Xiamen University, China University of Petroleum, etc
5	2006	12	China Agricultural University, Sun Yat-Sen University, East China Normal University, North China Electric Power University, etc
6	2008	7	Renmin University of China, Nanjing University of Technology, Harbin University of Science and Technology, etc
7	2009	7	Suzhou University, Huazhong University of Science and Technology, Kunming University of Science and Technology, etc
8	2010	10	Hunan University, Wuhan University, University of Science and Technology Liaoning, etc
9	2013	9	Changchun University of Science and Technology, Shandong University of Science and Technology, Shanghai Ocean University, etc

Source: MOST site www.most.gov.cn/bszn/new/dxk/jgcx/index.htm

Table III. The number of "National university science parks" as of 2013

Zhou, 2012). In 1995, the central government proposed "Project 211" with the intent of raising the research standards of around 100 universities in the twenty-first century, thereby accumulating intellectual resources to underpin the development of high-tech industries. The universities listed in Project 211 set up special offices to coordinate and allocate the financial or political supports from government. In the first phase from 1995 to 2005, 36.826 billion RMB was invested in these universities to strengthen R&D capacity. According to a report published by MOE (Ministry of Education) in 2005, universities listed in "Project 211" had educated over 80 per cent PhD students, 66.7 per cent graduate students, 50 per cent overseas students and 33.3 per cent undergraduate students. In addition, these universities kept 85 per cent state-level faculties, 96 per cent state-level laboratories and received 70 per cent government-sponsored research funding (Su *et al.*, 2013). Accordingly, this project provided a wealth of financial or political support to the top-level universities to strengthen their academics and R&D capacity, thus underpin the development of new knowledge and cutting-edge technologies (Kafouros *et al.*, 2015).

3.8 "Project 985"

Although China enacted a special policy called "Project 211" for universities, the gaps between Chinese universities and those in developed countries still need to be narrowed. In May 1998, the central government enacted "Project 985", which aims to found some world-class universities. As of 2014, 39 research-intensive universities entered this project list and were required to study the advanced university mechanism of developed countries. By providing a wealth of R&D funding, well-educated personnel and political supports, "Project 985" has led Chinese research-intensive universities to get dramatic achievements in the forms of publications and patents that underpin university technology transfer, university-industry collaborations and other UILs (Zhang *et al.*, 2013). In the case of publications, 39 universities published 462,792 papers (11,866.5 per university) from 2002 to 2011, occupying 0.115 per cent of world papers in the same period (Yu *et al.*, 2012). Furthermore, a majority of these publications were relevant to S&T fields that might provide directions or solutions for industrial sectors. In other words, it believes that the universities listed in "Project 985" have stronger R&D ability and achieve more successes in UILs than other Chinese universities.

3.9 State-level university technology transfer centers

Entering the 2000s, China continuously proposed some more special S&T policies for developing university R&D capabilities and driving entrepreneurial behavior (Zou and Zhao, 2013). The data reported by State Economic and Trade Commission (predecessor of Ministry of Commerce) in 2001 showed that:

> […] the configuration of technical resource is very unreasonable; technological progress and economic development is inharmonious; UILs are unidirectional. Furthermore, two-thirds large and medium-sized enterprises do not have R&D institutes, and half of them do not implement R&D activities; on the other hand, the rate of technology transfer is lower than 30 per cent and less than 10 per cent are industrialized.

Accordingly, in November 2001, MOE and State Economic and Trade Commission set up the first group of State-level University Technology Transfer Centers in six universities (namely, THU, Shanghai Jiao Tong University, Xi'an Jiao Tong University, East China University of Science and Technology, Huazhong University of Science and Technology and Sichuan University) which are entrusted to undertake five missions:

(1) develop and promote common technologies;
(2) participate in the establishment of enterprise innovation system;
(3) promote university technology transfer and commercialization;
(4) strengthen international technical innovation collaboration; and
(5) provide various integrated service for enterprises.

In the case of East China University of Science and Technology, the center is constituted of eight departments, namely, office, marketing department, information department, expert consultation department, test platform department, design research department, integrated service department and international collaboration department. The issued patents of this center from 2005 to 2012 were 77, 129, 123, 130, 139, 177, 226 and 332, respectively. Furthermore, it indicates that the State-level University Technology Transfer Center played a critical role in the university-based patents' protection and licensing, thereby making big contributions to China's technological progress in the past decade (Etzkowitz and Göktepe-Hultén, 2010).

3.10 "Program 111"

In 2006, MOE and the State Administration of Foreign Experts Affairs enacted "Program 111". Like the project 985, this program also aims to narrow the gap between Chinese universities and world-class universities in terms of academic faculty, high-level talents, R&D capacity and the linkages with industries. To this end, universities listed in Project 211 or Project 985 were encouraged to bring in 1,000 foreign academic elites from the world's top 100 universities and to found 100 world-class faculties. More specially, MOE and the State Administration of Foreign Experts Affairs provided over 0.6 billion RMB to bring in oversea talents and academic force to found some world-class universities in China from 2006 to 2010. Meanwhile, 69 universities (79 overseas talent-introduction projects) obtained the financial or political support of Program 111 in 2006 and 2007. Policy-makers hope that this program can help Chinese research-intensive universities to improve academic faculties and research capacity by bringing in foreign high-level professors or researchers, thus enhancing the interactions among university, government and industries in the knowledge-based economy era.

3.11 Medium- and long-term talents strategy

Out of question, Chinese high-tech industries have benefited from prior S&T policies or programs. However, continuously developing competitive advantage in the fields of S&T needs to overcome the shortage of talents, because intellectual resources are the base for the cutting-edge knowledge creation and spillover. Furthermore, it will lack over five million high-level talents in the areas of equipment manufacturing, information, biotechnology, new materials, aerospace, finance and accounting, modern transportation, agricultural technology and other key economic fields as of 2020. Accordingly, Chinese government enacted "National Medium-and-Long-Term Talent Strategy" in 2010 (Table IV). The key issue of this program is to find 100 scientists research workshops in high-tech areas; educate younger high-tech entrepreneurs to develop global cutting-edge technologies and strategic emerging industries; attract 2000 high-level returnees to establish new business or carry out R&D activities. In the context of university, this program states that 300 innovation talents bases will be founded in universities, research institutes and high-tech zones. In addition, this program encourages universities to educate and attract an array of researchers to enhance the linkages with industries, such as talents education, technology licensing, university-industry joint research and university spin-offs creation.

Typologies	2008	2015	2020
Total talent resources number (10 thousands)	11,385	15,625	18,025
R&D personals (per 10 thousands)	24.8	33	43
High technical personnel/the skilled personnel personals (%)	24.4	27	28
Major labor age personnel with higher education (%)	9.2	15	20
Investment in human capital/GDP (%)	10.75	13	15
The contribution rate of talent capital (%)	18.9	32	35

Source: The Central People's Government of the People's Republic of China (2011)

Table IV. National medium- and long-term talent strategy from 2010-2020

4. Roles of government S&T policies in UILs

As discussed above, Chinese government have enacted a series of S&T policies or projects to develop its high-tech industries and national competitive advantage. From the perspective of university, policy-makers look forward to enhancing the three roles of UILs. First, universities need to educate high-level human resources that are important for economic growth and social development (Fukugawa, 2013; Lepori *et al.*, 2015). Second, universities need to engage in R&D activities and enhance their collaboration with industries, such as consulting services, research contracts with industry, patent licensing and other general knowledge commercial mechanisms (Landry *et al.*, 2006; O'Kane *et al.*, 2015). Third, universities also can directly transfer commercial knowledge to start up new businesses by itself or in partnership with industrial sectors (Guerrero *et al.*, 2015; O'Shea *et al.*, 2005). Obviously, a range of S&T policies (often in the forms of projects and programs) enacted by Chinese Government to drive entrepreneurship continuously played a critical role in the UILs over the past 26 years.

4.1 Improving academic faculty

As the most important education institutions for high-level talents, universities are required to continuously improve their academic faculties in the knowledge-based economy era. However, it is widely acknowledged that there are big gaps between Chinese universities and those in developed countries in the matter of high-level talents' education (Li *et al.*, 2015; Zhang *et al.*, 2013). In this regard, Chinese government enacted some special programs for universities since mid 1990s. For instance, the main objective of "Project 211" is to primarily support about 100 universities to develop their academic capacities in twenty-first century. And, "Project 985" aims to find some world-class universities to narrow the gaps with those in developed countries. In addition, "Program 111" directly supports some Chinese leading universities to attract foreign scholars who have excellent capacity and rich experiences in academic research in the world-class universities. This program brought in 79 overseas R&D teams for 69 universities in 2006 and 2007. Generally speaking, the central government has made critical contributions to improve academic faculty by providing a wealth of political or financial supports over the past several decades. Furthermore, the improvement of academic faculty is more likely to educate well-trained talents and to generate cutting-edge technologies and, therefore, provides more opportunities for UILs.

4.2 Enhancing university-industry collaborations

As the most important organizations of knowledge generation and spread, universities have become crucial part of national innovation system. US experiences suggest that stronger interactions between university and industry (such as consulting service, joint R&D, research results transfer and other collaborative forms) might make more contributions to the development of high-tech industries, in turn generating financial income which could reduce the stress of government budget (Calzonetti *et al.*, 2012; Colyvas *et al.*, 2002). In this respect, Chinese Government also proposed some S&T policies to guide research universities to establish stronger linkages with high-tech industries (such as electronics, biotech, computer, data communications industries) over the past several decades. For instance, the major reason for MOE and State Economic and Trade Commission to set up the first group of state-level technology transfer centers in six universities in 2002 was to encourage universities to transfer their research results to market. Roughly speaking, it believes that the policy interventions with respect to collaborative research, contract research, consulting service and other forms of UILs are very important in the context of China.

4.3 Supporting university spin-off formation

In addition to improving academic faculty and enhancing collaborations with industry, government also encourages universities to directly commercialize their inventions and formulate spin-offs (Rolfo and Finardi, 2014; Shane and Stuart, 2002). To launch university spin-offs more effectively and successfully, Chinese government inspires research universities to establish science parks by providing financial or political supports since the early 1990s. Consequently, an increasing number of spin-offs are launched through directly commercializing university research results. The emergence of university spin-offs in China indicates that university researchers can be involved in business creation and operation instead of only focusing on talents education and collaboration with industries. Both in developed countries (such as USA, Japan and Italy) and emerging countries (such as China, India and Brazil), it is widely acknowledged that university spin-offs have become important engine to drive regional economic growth through direct knowledge commercialization and entrepreneurship (Huang *et al.*, 2013; Plewa *et al.*, 2013).

In sum, national strategies for developing R&D and innovation capacities to enhance UILs have come to occupy a more important position in Chinese S&T policies since 1980s. Furthermore, university has been viewed as the crucial sector that produces innovations as well as the occasional technological breakthrough and, thus, provides a wealth of business opportunities for entrepreneurs to create economic benefits. In sum, Table V provides a summary of the major S&T policies or programs enacted by government, which might have direct or indirect impacts on UILs.

5. Discussions

In the planned economy period, public research institutes were the main force of R&D activities, while enterprises concentrated on agriculture and manufacturing industries (Chang and Shih, 2004). As a result, the linkages between research institutes and industry were very weaker, so that only little R&D results can be used in enterprises to develop their competitive advantage. In knowledge-based economy, knowledge has replaced physical resources (such as material, labor and capital), becoming important strategic resource that develops sustainable competitiveness in a rapidly changing business environment (Su *et al.*, 2013). In this regard, universities as the knowledge creators and disseminators have grabbed the attentions of scholars, policy-makers and practitioners in recent years.

In response to the emerging importance of university, a range of S&T policies or programs have been enacted since the "Reform and Open Policy' started in 1978. To enhance our understanding of why and how government can directly or indirectly impact the UILs, this study focuses on the evolution of government-driven S&T policies or programs and their roles in UILs over the past 26 years. Our study shows that the main instruments of these policies are money-related, such as providing R&D expenditure, tax preferences and financial subsidies for technology transfer and commercialization. In addition, government also suggests the major directions for UILs.

Table V.
A comparison of the major S&T policies or projects and UILs

Year	Typologies	Key focus	Main effects on UILs
1984	University-affiliated State Key Laboratories	Financially support to found some key laboratories for the development of cutting-edge technologies	Upgrade the software and hardware of university laboratories, thus generating more innovations
1985	China Spark Program	Enhance agricultural R&D capability and transfer new technologies to agriculture	Related universities and their researchers are encouraged to transfer their new research results to agriculture, such as founding rural technology service platforms, agricultural talents education and technology incubators, thus enhancing UILs
1986	"Program 863"	Invest a wealth of resources to support R&D activities of Biotech, Aerospace, IT, Laser Technology, Automatic Technology, Energy, New Material and Marine Technology	Research-intensive universities have got a lot of achievements in terms of papers, patents, university spin-offs (such as Tongfang Group of THU) and other knowledge commercial behaviors
1988	"Torch Program"	Financially or politically drive the development of high tech industries through building suitable environment, national high tech zones, high tech incubation centers	Some universities founded high-tech businesses incubators and platforms to transfer their research results to practice
1988	Zhongguancun Science Park	As the first science park, it aims to integrate S&T resources; respond to the demands of the emerging new technologies; stimulate the industrialization of new technologies	41 universities around this science park were encouraged to actively transfer their research results for the development of high tech industries. In addition, some researchers from those universities also independently or in partnership with industry started up new businesses in this science park
1989	University Science Parks	Following the growth trajectory of USPs in developed countries, Chinese USPs provide an array of service (such as office space, consulting service, venture capital) for business incubating	By 2010, 86 state-level university science parks have undertaken 1,728 projects (including 345 state-level projects); have applied 5,603 patents (including 2,333 invention patents); have got 2,857 licensed patents (including 872 invention patents); imported 34 foreign patents

(*continued*)

Table V.

Year	Typologies	Key focus	Main effects on UILs
1995	Project 211	With the intent of raising the research standards of around 100 universities in the twenty-first century, thereby accumulating intellectual resources to underpin the development of high tech industries	Chinese government continuously provide various financial or political supports for over 100 universities listed in this project, thus developing university key disciplines, education, faculties and strengthening research capacity
1998	Project 985	Found some world-class universities to narrow the gaps with Western countries' universities	Government has invested a wealth of funding to strengthen research capacity and stimulate technology transfer
2001	State-level university technology transfer centers	Through founding some state-level university technology transfer centers to develop R&D capabilities and drive entrepreneurial behavior and provide benchmarking for other universities	These centers have made big contributions to the technology transfer and academic entrepreneurship. In addition, nearly every major research university had technology transfer center by 2013
2006	Program 111	Aims to bring in 1000 foreign academic elites from the world's top 100 universities and found 100 world-class faculties	69 universities (79 overseas talents introduction projects) obtained the financial or political supports by Program 111 in 2006 and 2007
2010	Medium- and Long-term Talents Strategy	Boosts S&T investment relative to GDP to enrich Chinese high-level talents, provide supports for enterprises to implement R&D, and enact protection laws regarding S&T	Government has allocated a large number of sponsored research projects in recent years

5.1 Managerial implications

A wealth of previous literature argued that government S&T policies potentially affect both the pace and direction of UILs through their impact on technology transfer, financial budgets and public service (Guan and Yam, 2015). In this respect, this study might offer some guidance for policy-makers to get more usable ideas and develop more suitable policies regarding how to stimulate UILs in the knowledge-based economy era. In the context of China, government enacted a range of general S&T policies (such as "Program 863", "Torch Program", "China Spark Program" and "Medium-and-Long-term Talents Strategy") and special ones (such as "Project 211", "Project 985" and "Program 111") in the past several decades, which might lead to dramatic successes in UILs. In the future, Chinese Government needs to consistently enact more S&T policies to stimulate UILs. In our opinion, one urgent policy is that government should arrange special budgets for universities to stimulate UILs, because most of Chinese universities lack funding to transfer research results to practice (Su *et al.*, 2013).

In light of the importance of UILs in academic faculty and economic interests for university, we also suggest that university policy-makers should propose different policies toward different staffs. In detail, some policies are required to encourage that university staffs specializing in teaching should concentrate on talents education and knowledge spread, while others with stronger research ability should devote themselves to develop new cutting-edge technologies for industrialization. For the latter, university policy-makers need to develop some policies or programs to exploit the market potential of scientific breakthroughs conducted by them (Guerzoni *et al.*, 2014).

5.2 Limitations and future research

Although it made contributions, this study also has some limitations. First, a key limitation is that we did not exactly examine to what degree government impacts UILs. That major reason is because the political supports from government are abstract and unmeasured. Second, the S&T policies or projects discussed in this study are of national level rather than regional level, though regional governments also proposed numerous S&T policies with respect to UILs.

Meanwhile, we suggest two directions for future research. First, scholars need to evaluate the major problems of existing S&T policies and propose more flexible and effective S&T policies that strengthen the role of UILs in technological progress and economic development. Second, it is necessary to examine the nature and extent of S&T policies' involvement in the UILs, because this work might enhance our understandings of the mechanism of government-driven UILs.

6. Conclusions

As an important part of national innovation system, universities are expected to continuously educate high-level talents, actively collaborate with industries and even launch spin-offs. In this respect, Chinese Government has enacted a range of S&T policies to highlight the importance of universities in the knowledge-based economy era. In other words, S&T policies are widely acknowledged as crucial driving forces for UILs by providing political directions or monetary supports for universities (Motohashi and Yun, 2007; Sternberg, 2014). This study offers a full understanding of how government-driven S&T policies or programs impact Chinese UILs. The growth trajectory of UILs in China is unique, but it might provide useful implications for other emerging countries (such as Brazil, India, Russia and South Africa) to stimulate UILs to drive technological progress and economic growth in the context of globalization.

Notes

1. For example, the idea of nuclear technology was first generated at Columbia University; the originality of Internet technology was discussed by a group of physicists in Switzerland Universities (Nerkar and Shane, 2003) and then was tested by connecting four computers located in UCLA, Stanford University, UCSB, and University of Utah in 1969.
2. In the context of China, university enhances its linkages with industry through two broad categories of mechanism. The first is the university-industry collaborations, such as joint research, consulting service, technology licensing and technical service, which should be the major mechanism of UILs in the developed countries. The second one, maybe the unique mechanism for China, is university-affiliated enterprises that are wholly or partially invested by university and means that university directly participates in business creation and operation (Wu, 2007). As known, some of these university-affiliated enterprises have grown into big companies (e.g. Founder Group, Neusoft, and Tongfang, Table I) and hold an important position in China's high-tech industries.
3. In the context of developed economies, many countries enacted a series of S&T policies that aimed at developing new high-tech results and stimulating the flow of technology among people, enterprises and institutions, thus driving economic growth and advance national competitive advantages. For instance, USA proposed Star Wars Program (also called "Strategic Defense Initiative") in 1983 to improve its technological competitiveness over the Soviet Union and Japan; 17 European countries founded European Research Coordination Agency in 1985 that jointly developing cutting-edge technologies and narrowed the gap between academic research and market applications, thus responding to the challenges from USA and Japan.
4. USPs in China play a critical role in UILs: integrate social resources with university intellectual assets; provide platforms for the commercialization of research results, the incubation of university spin-offs (USOs), the education of academic entrepreneurs and the university-industry collaborations; incubate other high-tech start-ups that are founded by outside entrepreneurs. By providing a range of political supports and professional services, USPs have become important engines for regional growth.

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