Universities/Research Institutes and Regional Innovation Systems: The Cases of Beijing and Shenzhen

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Kun Chen
Graduate Student
Department of Human and Community Development
University of California, Davis
Davis, CA 95616
kchen@ucdavis.edu

Martin Kenney
Professor
Department of Human and Community Development
University of California, Davis
Davis, CA 95616
mfkenney@ucdavis.edu
&
Senior Project Director
Berkeley Roundtable on the International Economy

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In developed nations, it is now widely accepted that universities and public research institutes (URIs) played a significant role in the regional development of high-technology industries. In the U.S., the two most successful clusters of high-technology firms in both the information technologies and biotechnologies are the Boston and San Francisco Bay areas (Kenney and Burg 1999). The success of these two regions can be, at least, partially explained by the presence of global-class universities. Their students often remain in the area and later become entrepreneurs, and the research conducted at these universities often becomes the seed for new firms particularly in biotechnology (Etzkowitz 1999; Hsu and Kenney 2005; Kenney 1986; 2001; Zucker et al. 1998). Not surprisingly, the discussions of high-technology regions has focussed on the developed nations, though recently Bresnahan and Gambardella (2004) edited a book on high-technology regions including an examination of Hsinchu (Saxenian 2004) and a general discussion of India (Arora, Gambardella, and Torrisi 2004). In neither of these was university research a significant contributor to regional growth, though obviously in each case well-trained university graduates were critical inputs. In the last decade, three major technology clusters have emerged in China. This paper examines the role of URIs in the emergence of two of these, Beijing and Shenzhen.

Universities have long been considered important institutions in national innovation systems (NIS) (Lundvall 1992; Nelson 1993). Of course, as an institution the university has a variety of roles including education, public service, research, helping to ameliorate social injustice (e.g., affirmative action), and recently regional economic development. The NIS perspective highlights the fact that nations organize innovation differently. Even as the concept of NISs was introduced, geographers comparing innovation processes in different regions in the same nation discovered that the innovation systems operated differently. For example, Saxenian (1994) argued that the institutions and entrepreneurship of Silicon Valley and Boston differed appreciably, something she attributed to cultural characteristics, rather than path dependent historical outcomes.[1]

Though recognizing the importance of the NIS for understanding how innovation occurred in nations, geographers argued that innovation systems had a strong regional character (Cooke 1992; 2002; Storper 1997). The regional argument fit with research by economists such as Jaffe et al. (1993) and Feldman (1993) who found that patents will cite other patents originating in the same location more frequently than patents outside the location even when controlling for the existing geography of related research activity. This suggested that it might be profitable to consider whether there were regional innovation systems (RIS) that consisted of private and public sector actors interacting to create local arrangements and relationships encouraging innovation (Edquist et al, 2002; Wolfe, 2003; Doloreux 2003). For high-technology clusters, it is generally believed that URIs are central institutions.

The linkage between the NIS and various RISs is often omitted or assumed by those studying regions (Niosi 2005). The NIS is important because it sets the basic parameters for what is possible. For example, in the case of China universities can own profit-making firms, while in the U.S. a university's direct management of a commercial firm would invalidate its tax-exempt status – a line that private and public research

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[1] For a critique of this explanation, see Kenney and Burg (1999). On path dependency, see David (1986) and Arthur (1994).

universities have been unwilling to cross. Thus national laws and decisions set the parameters for the university's role.

China is a particularly interesting case study because the general wisdom holds that URIs are critical for economic development. Much of the literature treats URIs as an endowment. Regions have excellent URIs or they do not. This paper examines the role of URIs in two different Chinese RISs, Beijing and Shenzhen. This is a particularly interesting comparison because Beijing is the Chinese city most endowed with top-quality institutions of higher education, while Shenzhen only twenty years ago had no universities or research institutions. In contrast, Beijing had little in the way of industry, while Shenzhen was the earliest early growth pole of the Chinese economy. Given their different endowments, the development trajectory of the two regions with respect to utilizing URIs diverged significantly.[2] As polar opposites, these two cities can provide insight into the deeply held belief by local officials throughout China that universities are the fount of high-technology development that will lead to prosperity.[3]

This paper reviews the literature on the development of the Chinese university and Chinese NIS. To set the context, this is followed by a brief history of China's NIS from the 1500s to the contemporary period. The next section describes the current level of Chinese technological development and the role of the URIs. After the overview of the current situation, we identify two models of URI regional involvement and illustrate this with case studies of Beijing and Shenzhen. This is followed by a discussion and conclusion.

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[2] On development trajectories, see Dosi (1988).

[3] Throughout this paper we accept the Chinese definition of "high technology," even though only some of the activities would conform to the commonly accepted definitions of high technology in developed

Literature Review

In knowledge economies, URIs are considered vital actors in the creation, acquisition, dissemination, and utilization of knowledge in a national innovation system (Nelson and Rosenberg 1993). Literature broadly defines that the NIS as a network of institutions, policies, and agents supporting and sustaining scientific and technical advance (Nelson and Rosenberg 1993; Porter and Stern 2001; Furman et al. 2002; Crow and Bozeman 1998). Three core actors to an NIS are URIs, industry, and, often government (Etzkowitz 1999; Mowery and Rosenberg 1993).

URI-industry relations include: labor market related linkages, linkages for creation, acquisition and dissemination of knowledge, and linkages to create new enterprises that form the basis of high-tech regions. URIs are the major educational and training institutions within which students and professionals educated and trained gain knowledge and skills, and become part of the labor pool in regional economies (Jaffe 1989). Linkages between URIs and industry also take a variety of forms as joint R&D projects, technology licensing, consulting, internships, and other collaborations between firms and URIs to develop a product or technology (Kodama and Branscomb 1999).

Recent research has shown that URIs can be key elements in RISs because of the geographic spillovers of knowledge both as a human capital provider and technology incubator. More recently, there has been great interest in the role of universities as a source of spin-offs. There is substantial evidence that universities around the world are adopting a policy of encouraging entrepreneurship (Rappert et al.1999; Shane 2004;

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nations. For example, personal computer assembly is considered high technology in China, while few in the U.S. would define it as such.

Goldfarb and Henrekson 2003). Framed in a slightly different way, Etzkowitz et al. (2000) observed that the university as an institution is moving toward a more entrepreneurial paradigm. China developed a policy of encouraging the spin-off of enterprises from its universities, even while they own the spin-offs. In addition, URIs create spin-off activities leading to high-tech enterprises or service-oriented enterprises with contribution to commercialization and industrialization of technological innovation, and meet other needs of URIs. The relationship between the RIS and local URIs can only be understood by placing URIs in a national context. For this reason, the next section begins with a discussion of the historical background within which Chinese URIs have evolved.

Technological Development in China

To understand the Chinese NSI, the historical context is a necessary background. Until approximately the 15th century, China was a global leader in technology. With the development of Western Europe and the rise of capitalism, China increasingly lagged Europe and later the European settler states in the development of new technology, which was followed by the rise of the science-based industries at the end of the 19th Century. The reasons for the decline are not entirely clear, already by the 19th Century China no longer played a significant role in the global economy; nor was it a contributor of new technical or scientific knowledge (Needham 1954; Adas 1989; Mokyr 1992).

It was only in 1895 that Tianjin University (Peiyang University) was established as the first Western-style university.[4] This was followed in quick succession by Xi'an Jiaotong and Shanghai Jiaotong Universities in 1896. Soon every major Chinese city established a university, e.g., Zhejiang University (1897), Peking University (1898), and Nanjing University (1902). Tsinghua University, which was to become China's premier technical university, was established in 1911. Already by 1920 the Chinese university system was concentrated in Beijing and Shanghai. Until the victory of the Communist Revolution in 1949, higher education developed along a Western model that was adapted to the Chinese situation. This development was fitful as invasion, political unrest, and civil strife wracked China. The universities were particularly severely affected by the Japanese invasion (1937-45) and the continuing Civil War (1946-49) that eventually led to the triumph of the Communist Party led by Mao Zedong. Communist victory resulted in a large-scale exodus of many professors appointed by the previous regime.

Ideologically, the Communist Party was committed to education and the use of science and technology for economic development and one of the stars on the Chinese flag represents "intellectuals." Very rapidly, the new government increased its investment in basic education creating a broad educational base. When the Chinese economy opened to overseas investment world this investment in elementary and secondary education provided the relatively well educated population capable of working in factories. As in the earlier Confucian system, a system of examinations was instituted nationally to identify the most capable students that could continue for massively subsidized post-secondary education. This meant that even children from impoverished backgrounds could, in theory, receive higher education. The national system for grooming an elite

[4] The discussion of the development of the Chinese educational system is drawn from Pepper (1996).

begins in the elementary schools and culminates in selection for elite universities. The result has been an adequately educated population and an extremely well-educated elite that has been concentrated by the university system in a few locations. Beijing and Shanghai would be the greatest beneficiaries of this concentration, while Shenzhen was irrelevant.

Upon the establishment of the People's Republic of China in 1949, the Western powers pursued a policy of isolating China; a by-product of this was that the Chinese NIS was also isolated from the Western world. China adopted the Soviet Union's model of comprehensive and specialized universities and a large network of research institutes. In 1978 the Chinese university model was again reformed to one that more resembled that of the U.S. and emphasized comprehensive universities (Pepper 1996; Wang 2000). Universities did undertake research, but their most important priority was pedagogy.

In terms of expenditures, the research institutes were the core of the NIS. The Communist government established an enormous complex of research institutes including the Chinese Academy of Sciences (CAS). Different ministries controlled the research institutes. At the time, the majority of Chinese scientific and technological research was focused on military-related research such as the development of nuclear weapons, satellites, and jet-propulsion technologies. The research projects were centrally planned, and resources were appropriated from the central government.

Prior to the reforms initiated in late 1970's, government planners explicitly accepted the linear model of innovation that Bush (1945) had popularized and assumed that "technological development [follows] naturally and easily from basic and applied research to technological development and eventually to innovation." For them innovation was “an organized collective activity, governed by research laws,” and these beliefs led to an extremely linear and rigid model (Segal 2003). This assumption proved unfounded and few research results were applied to industrial production and, for all intents and purposes, the science and technology (S&T) system was segregated from industry. From the perspective of economic development, researchers in the URIs had few linkages or interactions with industry, and the centralized command system for allocating research efforts, led to a limited scope and range of research activities (Lu 2000).

Whatever forward momentum the S&T system developed in the 1950s and 1960s, it was brought to halt between 1966 and 1976 while the Cultural Revolution roiled the nation, and led to an even greater isolation of the country from the outside world. After the death of the CCP’s Chairman Mao Zedong in 1976, Deng Xiaoping became the Chinese leader. He advocated fundamental reforms in the economy and the NIS system arguing that “science and technology are the chief productive forces” and that China needed to learn from Western nations. As a result, the government began reforming the old systems and embarked upon creating a market-oriented economy, launching the “Open Door Policy”, decentralizing fiscal and managerial control, redefining public and private ownership, and encouraging new linkages between research and production (Segal 2003; Lu 2000).

The establishment and legitimization of private ownership allowed the economy to diversify and small businesses and private companies gradually became more significant. Private firms were permitted to operate on a for-profit basis. The state-owned enterprises also were increasingly forced to compete, but still were inefficient due to their legacy of being in the protected state sector. In conjunction with the development of an internal market orientation, the "Open Door Policy" attracted foreign direct investment (FDI). Foreign MNCs of all types established manufacturing facilities for export and later to serve the domestic market. As Kogut (2004) has pointed out, more generally, these MNCs brought advanced technologies and, as important, management techniques. Eventually, many MNCs, often at the urging of the Chinese government, established R&D centers. Chinese private sector firms often were able to absorb advanced technology from foreign high-technology companies.

Foreign investors concerned about their intellectual property were reluctant to transfer their most sophisticated technologies to China despite government prodding. The Chinese government recognized this problem. Jiang Zeming, the successor to Deng, stated the Chinese position in this way in the National People's Congress, "New ideas are the very soul of national progress and are indispensable to the development of any country. If we do not have our own autonomous ability to create innovation and just depend on technology imports from abroad, we will always be a backward country… …As we continue to learn from others and to import advanced foreign technology, we must remain focused on raising China's ability to do research and development on its own." The government continued to pressure foreign firms to do research in China, but also encouraged Chinese firms to improve their research capacity.

Supporting R&D is also ideologically safe, as the Communist Party has long held that science and technology are critical to economic development. From the mid 1980s onwards, the Chinese government continually tinkered with the S&T system to strengthen Chinese R&D and develop the nation's absorptive capacity (Cohen and

Levinthal 1990). One of the most important reforms to the NIS came in the early 1980's, when government drastically cut URI funding (this was also driven by a desire to lower the cost of supporting the URIs). In order to strengthen linkages between the URIs and enterprises, the government encouraged URI-affiliated enterprises, launched fiscal and legal services for professorial and student start-ups, strengthened patent laws, built new technology industry zones (high-tech zones)/innovation centers/ software industry bases near URIs, provided innovation funds for small technology-based firms, and supported the establishment of university science parks. For URIs, the only option was to search for alternative sources of funds. The most significant of these was the establishment of URI-affiliated firms that were meant to generate profit that the URIs could use to fund their operations.[5]

A number of other reform programs were initiated to encourage the development of high technology by restructuring the innovation system at institutional and organizational levels. The central government also initiated research programs on technologies that small enterprises were not able to undertake through large-scale national efforts. These included the 863 Program/Plan (Baliusan Xiangmu/Jihua) targeting biotechnology, new materials, lasers, energy, information, robotics and space (Segal 2003), and the Torch Program/Plan (Huoju Xiangmu/Jihua), which aimed to develop small non-governmental high-technology enterprises through the creation of a favorable supporting environment, which included legal, fiscal and managerial mechanisms. The commitment of the central government to the further introduction of a market economy was accompanied with a focus on the knowledge base (Leydesdorff and

[5] There is evidence that many of these affiliated firms are not making a profit and might lead to future difficulties for the university owning them (Xue Lan 2005).

Zeng 2001).

Current Situation

During the last two decades, the Chinese economy has grown rapidly while shifting from being a largely agricultural nation to a major industrial power. China now has developed a substantial technological base, though Chinese industry is still dependent upon imports of advanced production equipment, technology in the form of licenses, and uncompensated usage of intellectual property. The preponderance of R&D, both that done by domestic organizations and MNCs, is concentrated in only a few major cities. With the exception of Shenzhen, these are the same cities that have the greatest concentrations of URIs.

During the mid 1980s, the Chinese government concluded that reforming the systems for commercializing S&T was crucial for China's economic development. The most prominent initiative was the Torch Program launched in 1988. It eased regulations, provided support for building facilities to attract foreign high-tech companies, and encouraged the establishment of indigenous high-tech companies in special zones throughout China. Government planners established these high-tech zones in close proximity to URIs with the goal of promoting linkages between researchers and firms. According to *the 2003 Annual Report on China Torch Program*, 53 national high-tech zones had been established since 1991. The main industries in these zones were information technology (IT), biotechnology, new materials, and new energy technologies.[6] As Table 1 indicates, these zones experienced rapid growth. By 2003, the

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[6] Though government statistics treat all the activities in these zones as high technology, it is likely that the preponderance of the activity was assembly of IT devices such as personal computers and cell phones or

national high-tech zones (and state-level science and technology industrial parks) had received RMB[7]155 billion investments in infrastructure and hosted 32,857 companies. The reported annual revenue in 2003 for all of these zones was RMB2,094 billion up from 8.7 billion in 1991, net profit grew from RMB800 million to RMB113 billion, employment grew from 67,000 in 1991 to 589,000 in 2003, and exports increased from RMB100 million to RMB51 billion. There is skepticism about the accuracy of Chinese government but clearly there has been dramatic growth.

Table 1 Statistics for Chinese High-Technology Zones (1991 to 2003, 100 million RMB)

Year	Investment in Infrastructure	Number of Company	Total Revenue	Net Profit	Tax	Export	R&D In Enterprise	Number of Enterprise Patent	R&D Personnel
1991	N/A	2,587	87.3	8	3.9	1.8	N/A	N/A	N/A
1992	N/A	5,569	230.9	23.9	9.9	4.1	15.2	933	67,116
1993	175.7	9,687	563.6	53	21.5	5.4	48	2,111	96,970
1994	216.2	11,748	942.6	73.7	36.4	12.7	64.9	2,470	119,063
1995	181.1	12,980	1,529	107.4	69	29.3	57.1	2,520	129,701
1996	184.9	13,722	2,300.3	140.5	97.7	43	62.4	4,476	124,339
1997	190.8	13,681	3,387.8	206.6	143.3	64.8	95.4	2,933	160,445
1998	272.7	16,097	4,839.6	256.2	220.8	85.3	134	3,317	202,079
1999	367.3	17,498	4,774.8	398.7	338.6	119	230.8	3,584	259,045
2000	442	20,796	9,209.3	597	460	185.8	155.37	4,741	363,234
2001	592	24,293	11,928.4	644.6	640.4	226.6	221.8	5,749	185,607
2002	951.2	28,338	15,326.4	801.1	766.4	329.2	314.5	6,852	526,225
2003	1,549.1	32,857	20,938.7	1,129.2	990	510.1	419.5	NA	589,362

Source: Compiled by authors from the Statistics of China Torch Program Over Fifteen Years of Development and the Annual Reports on China Torch Program, Ministry of Science and Technology

Over the last two decades, R&D investment in China increased rapidly. The Chinese National Bureau of Statistics calculates that in 2003 the total R&D expenditure was RMB154 billion, an increase of 20 percent from 2002. The percentage of GDP invested in R&D grew from .6 percent in 1991 to 1.31 percent in 2003. Universities expended 10.5 percent of total R&D while the RIs spent 25.9 percent. The expenditures

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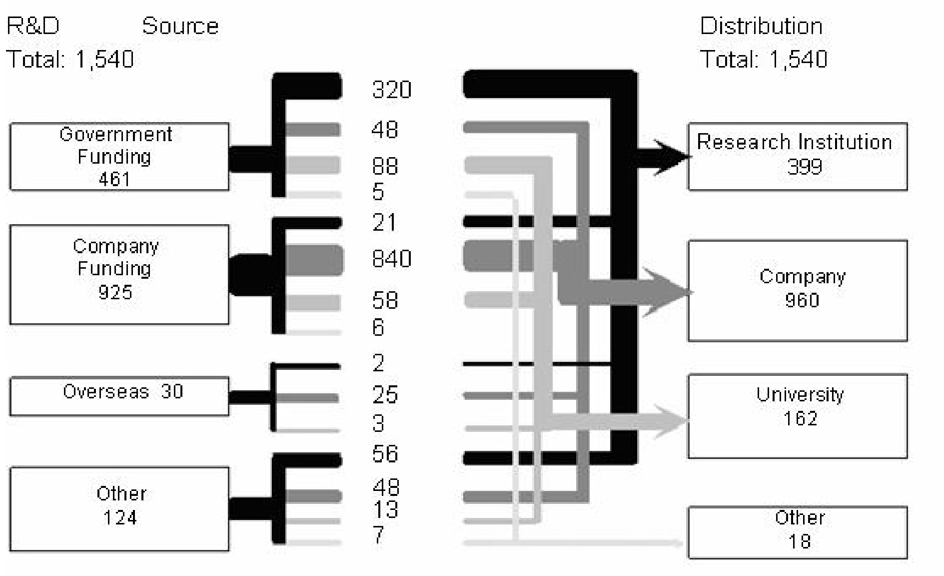
the production of simple pharmaceuticals that would not be considered high technology in the Western sense of the term.

[7] The exchange rate is around RMB￥8.3 to US$1.

by RIs has dropped from 42.8 percent of the total in 1996 to 25.9 percent in 2003, as companies increased their percentage of total spending from 43.3 percent in 1996 to 62.4 percent of the total in 2003 (China Science and Technology Statistics Net 2005 http://www.sts.org.cn). As Figure 1 indicates, more than half of the R&D funding in China is undertaken by the private sector, while the government is the main source of R&D funding for URIs.

Figure 1 R&D Sources and Distributions in China (2003, 100 million RMB)



Source: China Science and Technology Statistics Net. http://www.sts.org.cn

China's innovative capacity has expanded rapidly. In terms of publications, China improved from 15th in terms of publications listed in SCI, EI and ISTP in 1990 to the fifth in 2003 with 93,352 publications listed. From 1949 to 2004 the accumulated total number of patent applications was 354,000, and a total of 190,000 patents had been approved. Table 2 indicates before 2003, foreigners were more than Chinese active in patenting in China. In 2003, for the first time since 1993, there were more Chinese patent applicants than foreign applicants, which suggests that Chinese are becoming more likely to patent. There were 6,895 indigenous duty inventions.[8]

Table 2 Invention Patent Applications by Chinese and Foreigners (1996 to 2002)

	1996	1997	1998	1999	2000	2001	2002
Total	2,976	3,494	4,733	7,637	12,683	16,296	21,473
Chinese	1,383	1,532	1,655	3,097	6,177	5,395	5,868
Duty invention	825	912	954	1,685	2,824	2,614	3,144
University	228	256	243	425	652	579	697
Research Institute	247	316	337	543	910	800	907
Company	187	170	182	462	1,016	1,089	1,461
Organization	163	170	192	255	246	146	79
Non-duty invention	558	620	701	1,412	3,353	2,781	2,724
Foreigner	1,593	1,962	3,078	4,540	6,506	10,901	15,605
Duty invention	1,497	1,889	2,949	4,295	6,222	10,455	15,013
Non-duty invention	96	73	129	245	284	446	592

Source: China Science and Technology Statistics Net. http://www.sts.org.cn

Of the total of 7,800 patent applications approved in 2003 by the Chinese patent office 3,382 were from companies, 130 percent more than 2002, 1,730 were from universities, 150 percent greater than 2002, and 1,677 were from research institutes, 85 percent greater than 2002 (http://www.sipo.gov.cn/sipo/tjxx/default.htm). Particularly noteworthy was that patenting by universities was growing even more rapidly than was industry.

An important component of the Chinese government's effort to strengthen the country's S&T system has been improving the quality of China's URIs (See Table 3). To facilitate this improvement the government has been increasing funding to URIs. For example, the government increased its investment in URIs by 4 percent from 2000 to 2003, even while it decreased its funding to firms by 2 percent (http://www.sts.org.cn/tjbg/zhqk/index.htm). The percentage of government funding in the expenditures by research institutes increased from 53 percent in 1991 to 71 percent in

[8] Duty inventions are those received by an inventor that developed them while being employed by an organization or while using the facilities and resources of an employer.

2003, five times greater in 2003 than it was in 1991. Since 2000, universities have

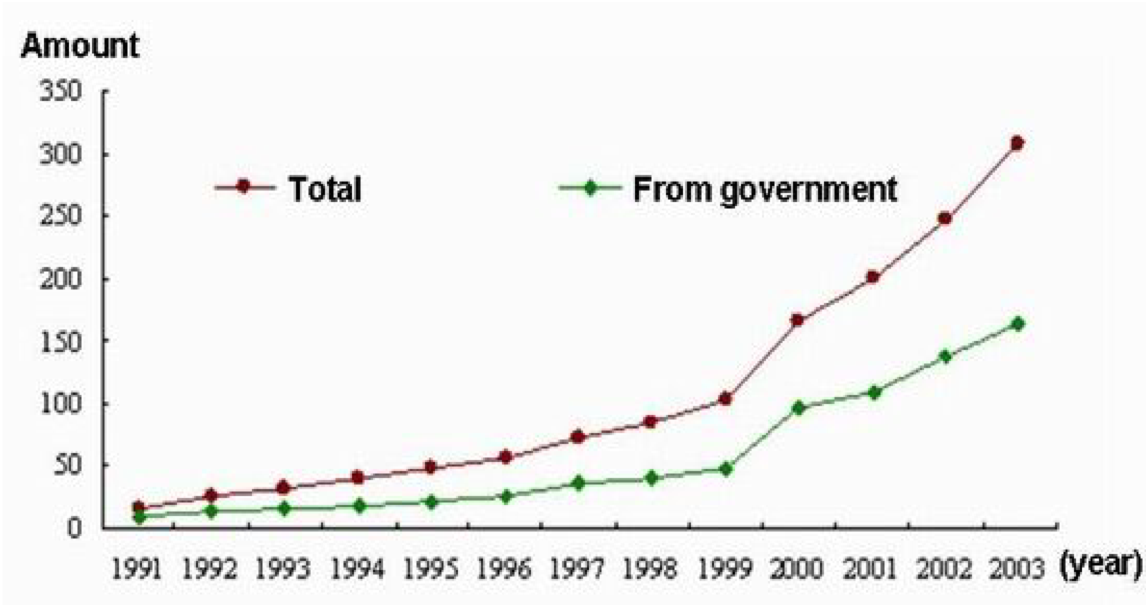
Table 3 R&D Statistics of Government Research Institutes (1991 to 2003, 100 million RMB)

	1991	1994	1996	1998	2000	2001	2002	2003
S&T Expenditure	170.7	308.9	409.1	479.7	495.7	557.9	620.2	681.3
Government Support	93.5	158.2	192.9	244.7	377.4	434.9	498	535
Government/Total (percent)	53.2	48.87	44.24	45.29	67.46	69.47	70.86	71.28
R&D Expenditure	78.8	128.7	172.9	234.3	258	288.5	351.3	399
Basic Research (%)	6.2	8.2	6.5	7.5	9.8	11.6	11.6	11.8
Applied Research (%)	27.4	29.8	27.4	28.1	25.9	27.7	34.5	35.3
Development (%)	66.4	62	66.1	64.4	64.3	60.6	53.9	52.9
R&D/S&T Expenditure (%)	46.16	41.66	42.26	48.84	52.05	51.71	56.64	58.56
R&D Personnel (10 thousand)	27.4	25.7	23	22.7	22.7	20.5	20.6	20.4
R&D/S&T Personnel (%)	34.38	38.88	36.39	38.61	48.09	48.01	49.64	50.25

Source: China Science and Technology Statistics Net. http://www.sts.org.cn

received more than 50 percent of their R&D expenditures from the government (See Figure 2). In 2003, university R&D expenditures were RMB16.23 billion, RMB3.18 billion more than in 2002. In summation, R&D expenditures grew rapidly as the Chinese government pursued its policy of improving research performance of the URIs.

Figure 2 S&T Funding in Universities (1991 to 2003, 100 million RMB)[9]



Source: China Science and Technology Statistics Net. http://www.sts.org.cn

In terms of sheer quantity the output at the URIs has grown steadily. Table 4 shows that publications and patenting increased at research institutes before 1999. The decrease from 1999 to 2001 was due to 25 percent of the research institutes being corporatized and removed from the base. The central research institutes that were corporatized during the restructuring had a total revenue of $34.3 billion and sales income of $21 billion (http://www.sts.org.cn). In 2003, there were 63,600 papers with the first authors from universities listed in SCI, EI and ISTP (http://www.edu.cn, and for 2000 to 2002, see Table 5). Between 1988 and 1999, patent applications ranged between 1,300 and 1,800. Since 2000, there has been a dramatic growth in patent activities in universities. In 2003 universities applied for 10,252 patents, of which 75 percent were invention patent applications. This veritable wave of patent applications continues to grow. In the first six months of 2004, there were 6,250 patent applications from

[9] S&T expenditures refer to R&D expenditure, application expenditure of R&D achievements, and S&T service expenditure including S&T personal service expenditure, S&T fixed asset expenditure, etc.

universities, an increase of 34 percent over the same period in 2003 (http://www.cnipr.com).

Table 4 S&T Achievements in S&T Research Institutes (1997 to 2003)

	Publication	International Publication	Book	Patent Application	Patent Approved	Invention Patent Approved	International Patent
1997	75,363	8,396	1,948	2,249	1,110	457	18
1998	79,395	9,560	2,020	2,356	1,340	526	29
1999	79,350	9,531	2,217	2,488	1,687	669	24
2001	62,611	8,342	1,639	N/A	1,298	617	10
2003	65,000*	10,000*	1,696	4,374	2,010	1,305	13

* Estimates

Source: Compiled by authors from the China Science and Technology Statistics Net. http://www.sts.org.cn

Table 5 Chinese University Publications (2000 to 2003)

	2000	2001	2002	2003
Publication referred by SCI, EI, ISTP	30,839	37,754	48,557	63,672
Publication in Chinese Journals	115,720	132,608	157,984	181,147

Source: China Science and Technology Statistics Net. http://www.sts.org.cn

University-affiliated enterprises have grown rapidly since the mid 1990's (See Table 6 and Table 7). Only 45 percent of these university-affiliated enterprises are in high-technology fields (the definition of high-technology is quite loose), but they produce more than 80 percent of the total revenue. Universities have also established 44 science parks since the first one was established by Northeast University in 1988. According to the speech of Zhou Ji, Minister of Education, at the 2nd University Science Annual Conference in 2003, by the end of 2002, the 44 university science parks had attracted RMB29.7 billion investments, employed 100,000 persons in 1,200 R&D centers, supported 5,500 high-technology companies, incubated 2,300 start-ups of which 920 have graduated, and 29 had been listed on the stock exchange (See Table 8).

Table 6 A Comparison of the Performance of University-Affiliated High-Tech Vs. General Enterprises

(1997 to 2003, 100 million RMB)

Year	Number		Revenue		Profit		Net profit		Tax		Money to University	
	H*	G*	H	G	H	G	H	G	H	G	H	G
1997	2,564	6,634	184.87	295.54	18.2	27.2	15.83	23.22	6.87	12.3	6.84	15.8
1998	2,355	5,928	214.97	315.54	17.7	25.88	15.84	22.62	8.31	13.49	6.58	15
1999	2,137	5,444	267.31	397.03	21.56	30.53	18.04	25.90	10.96	15.68	13.92	15.99
2000	2,097	5,451	368.12	484.55	35.43	45.51	28.03	36.04	18.97	25.42	8.46	16.85
2001	1,993	5,039	452.26	607.48	31.88	48.51	24.29	35.63	20.47	28.8	7.88	18.42
2002	2,216	5,047	539.08	720.08	25.37	45.93	18.63	35.33	25.92	36.28	7.61	17.24
2003	NA	4,839	668.07	826.67	27.61	42.98	14.73	27.95	NA	NA	NA	NA

*H: High-tech spin-offs; G: General spin-offs
Source: Compiled by authors from the Annual Reports on University-Affiliated Enterprises, Ministry of Education

Table 7 University Rank, Income of their Affiliated Firms and Location (1999 and 2003, 100 million RMB)

	1999			2003		
Rank	University	Income	Location	University	Income	Location
1	Peking	87	Beijing	Peking	163.60	Beijing
2	Tsinghua	32.4	Beijing	Tsinghua	144.60	Beijing
3	Harbin Tech	9.5	Harbin	Zhejiang	33.80	Hangzhou
4	Zhejiang	8.8	Hangzhou	Xi'an Jiaotong	25.70	Xi’an
5	Northeast	8.6	Shenyang	Northeast	24.00	Shenyang
6	Shanghai Jiaotong	8.2	Shanghai	Tongji	22.30	Shanghai
7	Petroleum (East China)	7.6	Dongying	Shanghai Jiaotong	19.00	Shanghai
8	Tongji	6.8	Shanghai	Harbin Tech	15.30	Harbin
9	Tianjin	6.4	Tianjin	Petroleum (East China)	13.90	Dongying
10	Nankai	5.9	Tianjin	Fudan	13.60	Shanghai

Source: Compiled by authors from the Center of S&T Development of the Ministry of Education. http://www.cutech.edu.cn, the China Education and Research Network. http://www.edu.cn

Table 8 Statistics of University Science Parks (2002 to 2003)

	2002	2003	Growth Rate (%)
Incubation space (10 thousand square meters)	145	578.4	298.90
Company being incubated	2,411	4,100	70.17.8
Gross Income of Tenant (in 100 million RMB)	15.5	133.5	761.3
Graduated Tenant	720	584	-18.9
Gross income of Graduated Tenant (n 100 million RMB)	7.8	110.1	1,311.5
Incubation Fund (in 100 million RMB)	2	4	100
Employees in Tenant	51,900	70,855	36.5
New Tenant	888	1099	23.8

Source: Statistics on China Torch Program 2003, Ministry of Science and Technology

Two Models for URI Involvement

The previous discussion provided an introduction to the national context for URI-industry linkages. However, local economies have much latitude for creating their own models. Due to the different historical background and the stage of development of Beijing and Shenzhen and their respective URIs, different strategies for forming and cultivating URI-industry linkages evolved. Beijing is the home to China's premier research and educational institutions. The Beijing URIs not only function as human capital providers and core research centers for the entire country, but also have generated spin-offs and established science parks to commercialize their research and technologies. While Beijing utilizes its rich URI resources to encourage high-tech development, Shenzhen, as a young city, is in a different position because only two decades ago, it had no URIs. Initially, its high-tech industrial growth did not rely on local URIs forcing high-technology firms to develop their own R&D capacities. URIs were established later to meet the demand of the rapid high-tech development, and only recently have begun to play a role in the local economy. Figure 3 and Figure 4 provide stylized depictions of the two models of URIs-industry linkages in Beijing and Shenzhen.

Figure 3 URI-Industry Model in Beijing

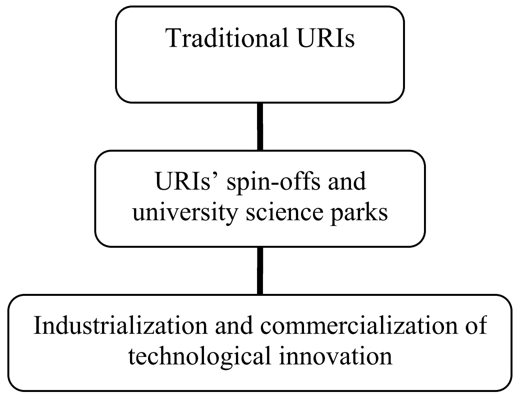
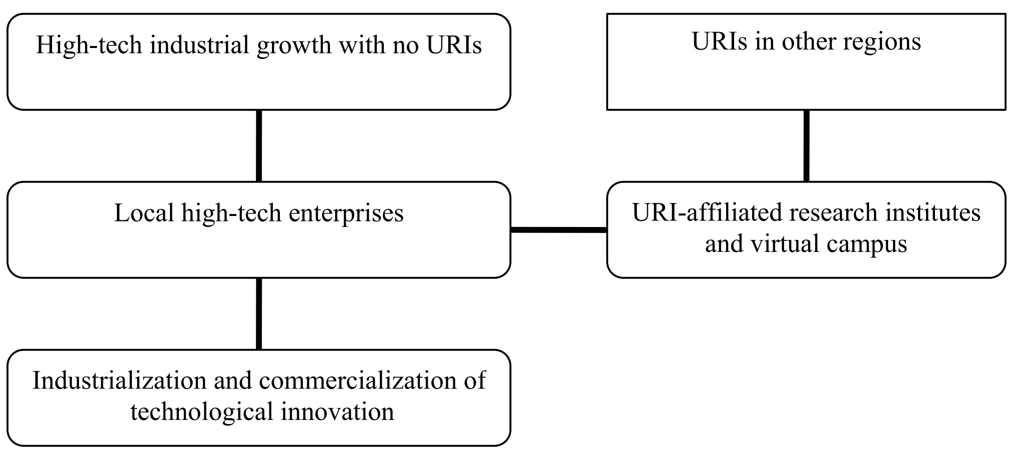


Figure 4 URI-Industry Model in Shenzhen



Beijing

Beijing is the political, educational, and S&T capital of China. In 2003, 71 universities and 371 research institutes were located in Beijing (http://www.bjstats.gov.cn), by far the largest number in any Chinese city. The most prominent of these were the Chinese Academy of Sciences, Peking University, and Tsinghua University, all of which are concentrated in the Haidian District in the Northwest of the city. The Haidian district is the location of the Zhongguancun Science Park (ZGC), one of the earliest and most important concentration of IT-related firms in China. Given a concerted effort that began in the 1980s to move industrial production out of Beijing, high-technology firms have become the primary force for industrial growth in Beijing. As an indicator of the importance of high technology, in 1999 high-technology businesses accounted for 25.4 percent of the city's total industrial value added, and rose to 39.3 percent in 2004 (see Table 9). Given this success, the municipal government has focused its development efforts on encouraging IT, bioengineering and new pharmaceuticals, photo-electromechanical integration, new materials, and environmental protection (Li 2000).

In 2004 Beijing was rated as the top Chinese city in terms of S&T capacity (Chinese Academy of Social Sciences, 2004). In 2000, 25 percent of government S&T funds were allocated to Beijing institutions while 18 percent of all R&D funds were expended in Beijing and 18 percent of all patents were granted to entities located in Beijing (See Table 10 and Table 11). Thirty-three percent of all research institute R&D spending and 20 percent of university R&D spending took place in Beijing (http://www.bjstats.gov.cn). In 2003 total R&D spending in Beijing reached RMB25.63 billion, of which government funding accounted for RMB13.67 billion; Chinese companies, RMB8.42 billion; foreign companies, RMB0.96 billion; and other institutions and organizations, RMB2.57 billion (http://www.bjkw.gov.cn).

Table 9 High-tech Statistics of Beijing (1999 to 2003, 100 million RMB)

Year	GDP of the City	High-tech Industrial Added Value	High-tech Added Value/ Total Industrial Added Value %	High-tech Output Value	High-tech Sales Income	R&D Personnel (ten thousand)	S&T Funding	R&D Funding	Technology Contract Value
1999	2,169.7	165	25.4	589.2	618.8	24	230.4	106	92.2
2000	2,460.5	213.5	28.9	867.6	1,040.7	24	230	139	140.3
2001	2,817.6	263.8	31.2	1,221.5	1,251.9	26.1	305.2	155.7	191
2002	3,130	251.6	28.90	1,165.7	1,121	25	370	180	221.1
2003	3,611.9	314.1	30.9	1,455.4	1,410.6	27.4	457.5	252.8	265.4
2004	4,283.3	377.7	39.3	NA	NA	29	510	300	425

Source: Compiled by authors from the annual statistical reports on economic development in Beijing at the Beijing Statistical Information Net. http://www.bjstats.gov.cn, and Beijing Municipal Science and Technology Commission. http://www.bjkw.gov.cn

Table 10 R&D in Beijing 2000 (100 million RMB)

	R&D Expenditure	Basic Research	Percent	Applied Research	Percent	Development	Percent
Total	139.9	15.6	11.14	38.5	27.57	85.7	61.29
Research Institute	74.7	10.5	14.1	18.8	25.17	45.4	60.73
University	17	3.98	23.38	10	58.55	30.7	18.07
Company	48	1.1	2.21	9.7	20.3	37.2	77.49

Source: Beijing Statistical Information Net. http://www.bjstats.gov.cn

Beijing's success is mirrored in various objective indicators of performance. For example, since 1995 Beijing has received between 17 and 21 percent of total patent approval (See Table 11). Also in terms of URI-industry technology contracts, Beijing captured more than 20 percent of the total contract revenue for the entire nation (See Table 12).

Table 11 Invention Patents Approved by Region (1995 to 2000)

	1995	1996	1997	1998	1999	2000
Beijing	328	246	281	309	573	1,074

Liaoning	131	118	131	131	224	458
Shanghai	72	74	88	97	189	304
Jiangsu	72	98	106	85	167	341
Shandong	84	84	96	91	172	363
Guangdong	56	57	49	77	123	261
Country	1,530	1,383	1,472	1,574	3,097	6,177
Beijing/Country	21.4	17.8	19.1	19.6	18.5	17.4

Source: Beijing Municipal Science and Technology Commission. http://www.bjkw.gov.cn

Table 12 Technology Contract Value in Beijing and in China (1999 to 2003, 100 million RMB)

Year	1999	2000	2001	2002	2003
Country	523.5	650.8	782.5	884.2	1084.7
Beijing	92.2	140.3	191	221.1	265.4
Beijing/Country (%)	17.6	21.6	24.4	25	24.5

Source: Beijing Statistical Information Net. http://www.bjstats.gov.cn

The previous discussion has shown the centrality of Beijing in the Chinese S&T system. In the next two sections, we discuss in greater detail the commercialization of the Beijing URIs. Much of this commercialization is not the commercialization of research results, but rather the transfer of personnel from non-commercial activities such as teaching and research to the commercial sector. For example, many of the early spin-offs simply provided technology services to other firms. Skilled personnel were more significant than research results. Also, nearly all of the technology that was transferred was not what could be considered global-class as was the case in U.S. universities such as MIT and Stanford, but rather was adequate for the Chinese market, which was highly protected and often these spin-offs benefited from government patronage. Despite these caveats, what is significant is that a few of these spin-offs became important Chinese IT firms.

Research Institutes

Beijing is the home to more research institutes than any other Chinese city.

Though the Chinese Academy of Sciences (CAS), which was founded in 1949, has institutes throughout China, the largest and most prestigious ones are located in Beijing. Prior to the reorganizations beginning in late 1970's, CAS was the leading institution for defense-related research on nuclear weapons, satellites, and jet-propulsion technologies. In the 1980s, CAS shifted toward conducting R&D that had greater commercial application. In the process, CAS was corporatized and the number of its institutes was reduced to increase efficiency, better reflect the market, and to encourage its staff to establish new firms (Kondo 2003). Today, approximately 37,000 scientists and engineers work at CAS, as well as more than 20 thousand graduate students and one thousand postdoctoral scholars. In 2003, CAS R&D expenditures reached RMB8.28 billion (http://www.cas.cn). CAS was also the leader in generating both publications and patents.

To encourage and facilitate the transfer of research results to the private sector, the government provided various tax and individual incentives aimed at both high-tech start-ups and researchers, and loosened the regulations regarding the use of public property (Kondo 2003). In response to the economic reforms and the restructuring of the S&T system in the1980's, CAS established a Technology Licensing Office (TLO), and with the local government, established an "S&T Development Center" in Haidian District to facilitate the commercialization of the research at CAS. CAS also formed a venture capital firm, China Science and Technology Promotion and Economic Investment Company, to support CAS staff establishing start-ups enterprises (Kondo 2003). As of 2004, CAS has invested in and spun off more than 400 high-tech enterprises, eight of which have been publicly listed. The gross income of the enterprises CAS invested in reached RMB53.37 billion in 2003, (an increase of 7.8 percent from 2002) and they had a net profit of RMB2.03 billion. The cumulative return to CAS from 1993 to 2002 was RMB690 million (http://www.cas.cn).

One of the most successful companies that emerged from CAS was the Lenovo Group Limited (formerly called the Legend Group). Lenovo was founded by eleven CAS Institute of Computing Technology (ICT) scientists in November 1984 in the Zhongguancun Region with a RMB 200,000 start-up loan from CAS. The founders remained institute employees even as they worked at the firm, and CAS provided technologies, the loan, and office space as well as research facilities. The decision to start Lenovo in ZGC was sparked by a government initiative to reform the national S&T system giving rise to new non-government S&T enterprises (Lu 2000). In 1994, Lenovo was listed on the Hong Kong Stock Exchange, and became the world's fifth largest supplier of computer motherboards and add-on cards (Lazonick 2004). Today, Lenovo is the largest Chinese IT company and since 1996 it has been China's sales leader. Its growth has been nothing short of spectacular.

In 1999, the turnover and net profit of Lenovo were HK$[10]11 billion and HK$0.43 billion respectively. For the year ended March 31, 2004, Lenovo reported a turnover of HK$23.2 billion and net profit of HK$1.05 billion (http://www.lenovo.com). With its 2005 acquisition of IBM's personal computer (PC) business, Lenovo has become the world's third largest PC firm in terms of sales. With the acquisition, Lenovo has moved its headquarter from Beijing to New York and has R&D centers and business operations in Silicon Valley, Hong Kong, Beijing, and Shenzhen. All of its manufacturing is in Southern China and thus, in this way, does not contribute to manufacturing employment in Beijing. Lenovo is the quintessential example of the how Chinese URIs have created firms based on their skilled personnel.

As CAS-affiliated company, Lenovo's success benefits from the economic reforms as well as the institutional and organizational restructuring of China's S&T system that overcame the barriers in the old system. This enterprise model is referred to as "one academy, two systems", "a symbiosis between the system of scientific research and the system of technology commercialization under one organizational roof" (Lu 2000). CAS supported Lenovo with preferential treatment including the full autonomy in managerial decision-making, financial budgeting, employee recruitment, full access to CAS resources, and use of the institute's name in making business deals (Lu 2000). Though CAS owns a controlling interest in Lenovo, Lenovo is independent in conducting business. The benefit for CAS is that Lenovo gives it fixed payments each year. And yet, CAS has a close but, also, vague relationship with Lenovo.

CAS is by far the most successful of the government research institutes in spinning off firms. Moreover, the early success of Lenovo inspired other research institutes and others within CAS to establish spin-off firms. This was particularly important for Beijing because of its endowment of a large concentration of RIs. In effect, the RIs were large concentrations of commercially under-utilized skilled labor power that could be mobilized to participate in for-profit activity when economic liberalization both allowed it and forced it upon the RIs. By providing access to facilities and guaranteeing the salaries of the entrepreneurs, the RIs lowered the risks, thereby performing a function somewhat like that of a venture capitalist in an environment that in the early 1980s could

[10] The exchange rate is around HK$7.8 to US$1.

not have supported true venture capital either ideologically or economically.

Universities

Beijing is the center of the Chinese university education system (See Table 13). In the latest university ranking 20 percent of the top 100 universities of China are located in Beijing (www.china-school.net). Of the eight Chinese universities listed in the top 100 Asian Pacific universities, the top two are Tsinghua University (THU) and Peking University (PKU) (Shanghai Jiaotong University, 2005). Not only are THU and PKU the most prestigious Chinese research universities, they also are the national leaders in commercialization (See Table 7). In 2002 there were 26,038 S&T employees in the universities in ZGC working on 7,450 research projects, which resulted in the transfer of 986 technology products. The local universities were responsible for 47.58 percent of the publications and 36 percent of the invention patents in the region in 2000 (http://www.bjstats.gov.cn).

Table 13 University S&T Statistics in 2000

	S&T Personnel	S&T Funding (100 million)	Research Project	Research Unit	SCI	EI	ISTP
Country	272,914	142.6	89,969	2,093	10,933	10,511	3,950
Beijing	49,990	29.6	13,877	639	2,002	2,954	851
Percent	18.3	20.7	15.4	30.5	18.3	28.1	21.5

Source: Ministry of Education. http://www.moe.edu.cn

Beijing universities have developed close relationships with industry through joint projects, professional consulting, and training. But the most striking relationship is through the spin-off and ownership of for-profit enterprises. In 2000, among 8,278 research projects underway in Beijing universities, 1,540 of them were conducted in cooperation with firms, and another 795 were technology service contracts. At the same time, in order to promote the commercialization of university research results and patent licensing, Beijing universities signed 1,159 technology transfer contracts with industry worth RMB811.95 million. Put simply, Beijing has the most university-affiliated enterprises and they are the largest in terms of sales and profit (See Table 14).

Table 14 University-Affiliated Enterprise Sales Income Rank by Region (1998 to 2002, 100 million RMB)

Year	Rank 1	2	3	4	5
	Beijing	Shanghai	Jiangsu	Sichuan	Liaoning
1998	121.28	38.78	23.99	14	12.91
	Beijing	Shanghai	Jiangsu	Liaoning	Guangdong
1999	146.93	40.23	24.69	18.2	15.98
	Beijing	Shanghai	Jiangsu	Tianjin	Liaoning
2000	200.81	53.82	27.56	26.18	24.21
	Beijing	Shanghai	Tianjin	Jiangsu	Liaoning
2001	261.85	59.71	32.6	32.52	32.46
	Beijing	Shanghai	Jiangsu	Liaoning	Shandong
2002	299.55	76.95	40.07	36.09	33.85

Source: Compiled by authors from the Ministry of Education. http://www.moe.edu.cn and the China Education and Research Net. http://www.edu.cn

The two leading universities in terms of commercialization are THU and PKU. In terms of engineering and science, THU is considered the best Chinese university. Founded in 1911, THU was originally as “Tsinghua Xuetang”, a preparatory school for students being sent by the government to study in the United States. THU began enrolling undergraduates in 1925, and established a research institute in 1929. In response to the Japanese invasion in 1937, THU, PKU and Nankai University were moved south to

Changsha, and then a year later were moved to Kunming. These three universities were then merged to become Southwest Associated University. In 1946, THU returned to Beijing. In the nationwide restructuring of universities and colleges system in 1952, THU was transformed into a polytechnic college focusing on engineering. In the S&T reforms of the late 1970's THU was reorganized into a comprehensive research university, and in 1984 it established the first graduate school in China. Today, THU houses eleven national key research labs, employs over 7,800 faculty and staff, and serves more than 27,000 students (http://www.tsinghua.edu.cn).

As China's premier technical university, it had a strong endowment of personnel and they proved successful in developing commercial products. In terms of R&D funding, number of patents and publications it leads the nation (See Table 15 and Table 16). For example, in 2004 THU had 527 patents approved including 454 invention patents, and ranked first in the nation (http://www.cutech.edu.cn). As was the case with CAS, THU is actively involved in commercialization of inventions by its faculty and staff and in other areas. In 1991 it established a "Science and Technology Development Department" that operates as an internal Technology Licensing Organization (TLO) to promote technology transfer and industrial cooperation. In 2001, THU signed 828 research contracts worth RMB432 million and 534 technology transfer contracts worth RMB234 million (http://www.bjstasts.gov.cn).

Table 15 R&D Funding Sources and Personnel Statistics at THU (1999 to 2001, 100 million RMB, person)

Year	Total R&D Funding	Research Institute	Ministry of Education	Ministry of S&T/ State Development Planning Commission	Industry	Number of Teaching Personnel	Number of R&D Personnel
1999	5.5	0.7	0.23	1.31	2.2	5,751	1,543
2000	7.3	0.61	0.29	1.49	2.13	5,549	2,754

2001	7.24	0.38	0.25	1.12	3.32	5,554	2,746

Source: Compiled by authors from Beijing Statistical Information Net. http://www.bjstats.gov.cn

Table 16 THU S&T Achievement Statistics (1999 to 2003)

Year	Patent Application	Patent Approved	Number of Contract	Contract Revenue (10 thousand)	Total Publication	SCI	EI	ISTP
1999	189	121	341	18,367	7,008	424	576	263
2000	344	135	534	23,500	5,621	598	1,430	372
2001	396	163	534	23,400	5,553	1,054*	1,418	410
2003	N/A	N/A	N/A	N/A	10,296	2,212*	2,584	1,303

*(Internet Edition)

Source: Compiled by authors from the Beijing Statistical Information Net. http://www.bjstats.gov.cn, and the Center of S&D Development of the Ministry of Education. http://www.cutech.edu.cn

In addition to active collaboration with industry through joint projects and technology transfer, THU also has established firms to commercialize its inventions. Chinese institutions of higher education have a long history of establishing university-affiliated enterprises. In 1922, the first university-affiliated firm at THU was established to create internship and apprenticeship opportunities for students. Early on, the firms did not have many market-oriented or commercial activities, yet they did provide services such as managing guest houses and print shops.[11] Since the early 1980's, these enterprises have been required to generate profit for the university. But THU went further establishing Tsinghua Technology Service Company in 1980 to utilize THU personnel to provide technical services to the marketplace. The efforts by THU to generate income led to a veritable avalanche of new firms. By the early 1990's, more than 190 companies had been created by the professors and staff at THU or in partnerships with companies outside the university. Some firms remained small being based in the professor's or researcher's labs, and yet a few companies such as Tsinghua Tongfang and Tsinghua Unisplendour grew sufficiently large to make public stock offerings. By 1993, the revenues generated by THU enterprises had grown to RMB71.46 million per year, and six firms had a net profit above RMB1 million.

As THU's commercial activities grew, management of the disparate firms became more complicated. To manage the growing number of spin-off companies and accelerate the commercialization of technologies, THU built its own university science park as an incubator in 1994 and established Tsinghua University Enterprise Group in 1995. By 2002, the total assets of the Group had grown to RMB17.8 billion, and gross income reached RMB11.4 billion. In 2003, THU's assets were capitalized at RMB22.7 billion – in comparison PKU's assets were worth RMB14.8 billion. The gross income of the university's enterprises had grown rapidly and reached RMB15.22 billion in 2003 and generated RMB537 million in taxes (http://www.cutech.edu.cn). Because of the increasing size and complexity of THU's business operations and the necessity of providing professional management, in 1995 Tsinghua Holding Company (THC) was established to manage various spin-off enterprises and to invest new companies. THC was better able to rationalize the businesses including improving the process of evaluating the provision of capital to spin-offs, the culling of less successful firms, and a standardization in the naming of firms in the THU group. By 2004, the THC had thirty technology-based spin-offs and approximately thirty service-oriented companies such as the university press, hospitals, and logistic companies, three of which are ranked as the top 10 profitable university enterprises in China (China Education and Research Net 2005).

Through the establishment of a science park on campus in 1993, THU encouraged

[11] This was, of course, not unique to China as universities in many nations manage activities such as dormitories and university presses.

linkages between the university and industry. By 2003, the park had grown to 300 thousand square meters, and by the end of 2005 is expected to have 690 thousand square meters of space (Mei 2004). The THU Science Park was one of the earliest university science park in China and received an award as the "Best Science-based Incubator" by the World Incubation Association in 2002. Currently, the science park houses more than 300 different institutes including national research labs; R&D centers for various multinational corporations such as SUN, Proctor & Gamble, and NEC; the headquarters of the university enterprises including Tongfang, Unisplendour and Zhicheng; and various firms in finance services, law and consulting services, and professional and educational training (Mei 2004). Also, the science park serves as an incubator to develop start-ups, many of which are operated by university alumni and by former students who have returned to China from overseas.

In 2001, a professional incubator company, Tsinghua Business Incubator Co. (THBI) was set up in the park to help new start-ups secure financial support, including venture capital from various companies, loans from banks, government funding, and a RMB200 million investment fund for returned students from overseas. In addition, it provides concessions, including free incubation space for the first year, preferential rents for the first two years, introductions to professional consulting services, and assistance in networking with various institutions and organizations. In 2003, THBI incubated seventy start-ups and twenty-seven graduated.

The university spin-off companies help commercialize advanced university research results and produce profits to finance university research and employee's welfare (Kondo 2003). The close organizational tie between the university and the spin-offs integrates postgraduate education into industrial R&D (Lazonick 2004). The spin-off companies provide internship opportunities to students at the university, many of whom are hired directly after graduation. Meanwhile, the companies receive access to S&T resources, university facilities, and the benefit of THU's name when doing business with other enterprises. THU Science Park works to standardize the small-scale university enterprises, provides a platform to enhance the innovative capacity of the university and accelerate the linkages with industry by introducing advanced R&D achievements from overseas, commercializing and marketing high-technology of the university, linking venture capital, human resource, professional business and technology consulting services, and maximizing utilization of physical infrastructure and informational resources.

Beijing with its preeminent endowment of URIs in both number and quality, has benefited enormously from commercialization. THU and CAS are excellent examples of how Chinese URIs have commercialized both some of their research staff and their inventions. Other Beijing universities such as PKU, China Agricultural University (CAU), Beijing University of Posts and Telecommunications (BUPT), and Beijing University of Aeronautics and Astronautics (BUAA) also are encouraging commercialization of their research results. PKU has commercialized a number of its inventions through its spin-offs. Established in 1985, PKU's spin-off, the Founder Group, currently is the largest university enterprise in China with a total revenue of RMB22 billion in 2004. It is dominant in the markets for Chinese-language electronics publishing systems in Asia, the US, and Europe. Founder's professional technology in pictographic-language electronic publishing systems originated in a government-led R&D project which a PKU professor worked on as the chief designer (Lu 2000). Founder not only continues to develop its electronic publishing system, but has entered other businesses such as personal computer assembly.

CAU has spin-offs commercializing transgenic technologies, which generated revenue of over RMB500 million in 2004. BUPT has developed enterprises commercializing computer networking technology and telecommunication software. BUAA owns more than forty spin-offs. Recently, it established a science park in ZGC to incubate start-ups. All of these URIs have affiliated for-profit firms commercializing their particular expertise.

For a city like Beijing, which has been a government city with little industry and a relatively weak commercial tradition, the commercialization of university research has provided an important source of employment and taxes. Municipal officials have recognized that Beijing has a RIS based upon the outputs of URIs in terms of students, spin-offs, and transferred technology. The future of Beijing's RIS will be largely determined by the continuing success in leveraging the knowledge and capabilities of its URIs.

Shenzhen

In 1979, Shenzhen, which is located close to Hong Kong, was a fishing village. It had no indigenous academic resources such as research institutes and universities. In 1980 it was designated as a "special economic zone" by the Central Government and the State Council of Guangdong Province. Established as a platform to experiment with market reforms and to act as a base for the relocation of manufacturing from Hong Kong, it was given the status of free trade zone so that goods could be imported and exported without duty. Multinational firms established manufacturing facilities there to draw upon a vast pool of relatively unskilled but inexpensive labor.

Shenzhen grew rapidly as a center for assembly manufacturing for export. The policy was a massive success and the city grew rapidly. Today, it has become an important economic center (See Table 17). Since 1979, its GDP has grown at an average rate of 30 percent per annum. In recent years, Shenzhen has become one of the top five Chinese cities in terms of GDP. Its GDP per capita was over $7,400 in 2004, which was the highest in China.

The Chinese Academy of Social Sciences (2004) rated Shenzhen as the second most competitive Chinese city trailing only Shanghai. Shenzhen's success is the result of favorable policies, geographic advantages, visionary planning, deliberate development of a strong industrial structure, and an entrepreneurial institutional and organizational framework. These factors allowed Shenzhen to attract talented personnel from throughout China and investment from around the world.

As Shenzhen grew, labor and infrastructure costs inexorably rose. The municipal government recognized that Shenzhen could not remain successful as a center for low-cost assembly – it had to develop an innovation system. In response it developed a strategy of trying to encourage higher technology business activities. In pursuit of this goal it built office parks meant to attract high-technology firms, MNC R&D, and encourage the formation of local high-technology firms. The leading examples of the new firms that are driving the growth of Shenzhen are the communications technology firms, Huawei Technologies and Zhongxing Telecommunications (ZTE).

Table 17 Shenzhen S&T Statistics (2000 to 2004, 100 million RMB)

Year	GDP	High-tech Output Value	Indigenous Technology Value	High-tech Company Number	S&T Funding	S&T Loan	S&T Personnel (ten thousand)	Patent Application	Patent Approved
2000	1,665.24	1,064.45	532.4	212	2.5	3.96	15.89	4,431	2,401
2001	1,954.17	1,321.36	697.96	314	2.8	8.1	17.23	6,033	3,506
2002	2,239.41	1,709.92	954.48	422	3.25	9.7	18.64	7,917	4,496
2003	2,860.51	2,482.79	1,386.64	673	3.18	12.73	57.54	12,361	4,937
2004	3,422.80	3,266.52	1,853.09	943	5.3	13.94	66.34	14,918	7,737

Source: Compiled by authors from the Shenzhen Annual Report on Shenzhen Government Online. http://www.sz.gov.cn

Shenzhen's municipal government recognized the importance of high quality institutions of higher education. Taking a page from its successful attraction of manufacturing firms' branches in an earlier period, it invited URIs from other regions to establish branches in Shenzhen. This was successful, as during the last decade it attracted more than forty URIs to establish graduate school branches and research centers.

The roots of Shenzhen's movement up the value-added ladder can be traced to 1985, when the municipal government and CAS jointly established the Shenzhen Science and Technology Industrial Park. In 1996, Shenzhen established the national-level Shenzhen High-Tech Industrial Park (SHIP), which included the original industrial park (Li 2000). Today SHIP covers an area of 11.5 square kilometers. As with most Chinese industrial parks, there is little apparent specialization as it welcomes firms in computer and parts, very large-scale integrated circuits, network and communications, software, photoelectronics, digital electrical household appliances, biological engineering, new materials, and environmental protection. It also aims to improve traditional industries by making use of high technology and advanced applicable technologies (http://www.ship.gov.cn).

In 2004, value of production in Shenzhen reached RMB245.4 billion, eleven times that of 1996. In contrast to Beijing, 90 percent of the R&D in Shenzhen is conducted by firms, and 80 percent of all R&D funding originates from firms. In 2003, R&D expenditures were RMB7.2 billion -- an increase of 19.8 percent over 2002. The largest high-tech enterprise, Huawei Technologies invested RMB3 billion in R&D. The number of patents has increased annually (See Table 18). Only Beijing and Shanghai had more patents granted than Shenzhen (http://www.szip.org.cn).

Table 18 Patent Statistics of Shenzhen (1997 to 2003)

	Year	1997	1998	1999	2000	2001	2002	2003	Total
Total application		1,440	2,093	3,314	4,431	6,033	7,917	12,361	43,058
Invention Patent	Application	165	233	490	669	1,033	1,846	3,526	8,663
	Approval	13	16	31	1	7	91	276	489
Practical New Patent	Application	486	722	1,169	1,494	1,904	2,522	3,797	14,519
	Approval	410	311	733	750	1,239	1,624	1,879	8,330
Apparent Design Patent	Application	789	1,138	1,655	2,268	3,096	3,549	5,038	19,876
	Approval	837	1,037	1,352	1,650	2,260	2,781	2,782	14,239
Total patent approved		1,260	1,364	2,116	2,401	3,506	4,496	4,937	23,058

Source: Shenzhen Intellectual Property Net. http://www.szip.org.cn

In addition to high-tech companies, URIs play an important role in the development of technological innovation. Prior to the 1980s, Shenzhen had no URIs. Already in the early 1980s, the municipal government recognized that the lack of institutions of higher education and research would become an obstacle to industrial upgrading. In response, Shenzhen University was established in 1983 and a technology-based college, Shenzhen Polytechnic, was established in 1993. The municipal government decided these were not sufficient and in 1996 attracted THU to establish Shenzhen Tsinghua Research Institute in SHIP. Later, PKU, CAS, Chinese Academy of Engineering, and Hong Kong University of Science & Technology also set up research bases in Shenzhen. To increase cooperation with the existing university branches and encourage yet more URIs to come to Shenzhen, the municipal government established the "virtual campus" concept in SHIP in 2000. As an incentive for URIs to establish branches at the University Virtual Campus (UVC), the municipal government offers free office space and infrastructure including furniture, computers, telephones, and computer networks for the first two years. It also provides long-term passes to Hong Kong[12] for staff, transportation, printing, computer server, rooms for meeting and teaching, apartments for staff, and other amenities at highly subsidized prices.

These incentives were so attractive that within five years 43 URIs including five Hong Kong universities and one French university (Centrale Lyonais) located branches at UVC. Eight technology-based incubators are incubating 252 enterprises, and 217 technologies have been transferred. The campus houses seventy-eight research labs and centers including forty-two national key research labs and engineering centers (http://www.ship.gov.cn). In 2000, a university town was created inside SHIP, where THU, PKU, Nankai University, and Harbin Institute of Technology have set up full-time graduate schools. By 2004, more than 50,000 students had studied at UVC and 10,000 students had graduated with a master's or a Ph.D. degree. Over 120 high-tech enterprises

[12] The long-term pass is important because there are still immigration controls that limit who can enter Hong Kong. For persons working in Shenzhen the ability to visit or live in Hong Kong is an important perk.

were established by the universities and more than 100 research projects from the universities were transferred to industry. Despite beginning with no URIs, the local Shenzhen government was able to implement policies for attracting URIs to compensate for its insufficiencies. Today, there an RIS exists in Shenzhen.

Discussion

URIs have been significant contributors to the growth of the Chinese economy. In terms of economic activity, the commercialization of Chinese universities has been an important success. In the case of Beijing, a vibrant RIS built upon the URIs has emerged. CAS, THU, and PKU have been the sources of firms that are now among the largest IT firms in China. For the universities that suffering from budget cuts successful commercialization has provided a new source of funds. Beijing as the leading city in the China's S&T system has developed successful URI-industry linkages, particularly through spin-offs and university science parks. URIs are one of the fundamental driving forces of the establishment and development of high-tech development in Beijing. There is no doubt that high-tech development in Beijing has relied upon the knowledge and human resources of the URIs and their linkages with industry.

Whereas the URIs were extremely important for the development of the Beijing economy, in Shenzhen economic growth occurred prior to the development of institutions of higher education. However, the municipal government recognized the importance of upgrading its economic base and has actively worked to create a higher education infrastructure to assist in that process. Though research is clearly a part of the Shenzhen strategy, there can be little doubt that the university's most important function is to provide for educational upgrading.

It would be no exaggeration to say that the commercialization of Chinese universities is now a significant part of the NIS. Their commercial endeavors have contributed to the upgrading of Chinese industry. Still it is important to recognize that even more important than their role as commercial enterprises, Chinese universities like those in other nations have an even more important role of selecting and educating the workers of tomorrow – a task that is even more vital in the emerging knowledge economy. The elite universities are also important because they have proven to be pathways for the best Chinese students to prepare to go on to foreign universities that provide global-class training.

As in other nations, there has been concern that the commercialization of Chinese URIs will affect research and teaching.[13] There have been reports that some professors are so engrossed in their commercial activities that they exploit their access to institute or university resources and research facilities. There also has been a concern that graduate students are being used as cheap labor with little attention to research quality or pedagogy. These are serious concerns, but of even greater concern may be the involvement of the university and its administrators in the daily operation of commercial enterprises. This might skew university decision-making regarding research funding, faculty hiring and promotion, and even lead to universities making decisions that are in their economic best interest, but are antithetical to the interests of the society as a whole.

The other concern that deserves some attention is that in many nations universities have been important repositories of the humanities, culture, and the arts. Will the commercialized university where departments and laboratories operate as profit centers protect the unprofitable humanities and arts? Creativity and design, which many believe will be as important in global competition as engineering and production, does not stem solely from well-trained engineers, but requires aesthetics and innovation. The other parts of the university are important for cultivating this.

There are operational difficulties, also. Because of the nature of these arrangements, the actual ownership of firms may be unclear. For example, there have been conflicts regarding the remittances the spin-offs should provide to their mother institutions. For example, in the case of the largest university spin-off PKU's Founder Group, the company's first president was fired by PKU because of his unwillingness to increase payments to what the university defined as "reasonable" (Fan 1999). The difficulty here is that university bureaucrats may become too involved in the operation of the firm, thereby harming the firm. There is evidence that URI-affiliated firms under perform similar non-affiliated firms. Based on a study by the Administrative Committee of ZGC and PKU Network Economics Research Center (2004) it was found that from 1995 to 2003 university spin-offs in ZGC had far greater immaterial assets and a greater proportion of personnel with higher education, but some of the spin-offs are underperforming in technology commercialization. These enterprises on average made a net profit of only half that of the non-affiliated companies in ZGC. The university-affiliated spin-offs had exports of only one sixth of those in non-affiliated companies. Underperforming university spin-offs paid less tax and were less productive in patenting than non-affiliated companies. (Lenovo and Founder, etc are still most successful high-

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[13] For discussion of these concerns in relation to U.S. universities, see Bok (2004), Kenney (1986), and Slaughter and Leslie (1997).

tech companies in ZGC.)The report attributes this under performance to a lack of clarity in ownership, ineffective personnel relations, and the lack of a capital management supervisory system.

There is variability in performance and resource distribution among university enterprises. The revenues generated by PKU and THU spin-offs account for more than half of the total revenue generated by all spin-offs. Interestingly enough, PKU and THU also receive much greater research funding from government than universities in other regions. Finally, in cities like Beijing and Shanghai that are undergoing real estate speculation, these university science parks may be more aimed at creating rentable office space than they are at incubating and transferring technology.

Conclusion

The NIS literature initially treated the nation-state as the appropriate unit of analysis for understanding innovation systems. Our study has shown that the national level was important, but there are clear differences in Chinese regions. This also suggests that analyzes that treat China as being a monolithic entity miss the nuance in how China innovates. Our study, which agrees with Segal (2003), shows that Beijing and Shenzhen starting with different endowments developed remarkably different methodologies for developing their technology clusters. Without a doubt, China has built a unique relationship between its universities and industry. Whereas in most nations, some separation between universities and industry has been considered healthy, in China URIs own and operate firms.

Chinese local authorities place great faith in the economic development benefits of URI-developed technology. This is evidenced by the detailed statistics that have been collected to provide evidence of success. In the case of Beijing, the URIs have provided the seeds for a number of significant firms, and some spin-offs have grown to be large businesses. In Shenzhen thus far this has really not been the case.

Because Chinese universities actually own and operate firms, one could argue that they have the closest relationship with the private sector of any universities in the world. In the case of the elite universities, the number of firms owned by the university can be in the hundreds and include everything from high-technology start-ups to low-tech service firms. Some firms having their roots in Chinese URIs such as Lenovo, Tongfang and Founder, are among the largest and most important Chinese high-technology firms. From this perspective, it is safe to say that Chinese policy has had tremendous success in tapping the capabilities of universities and researchers. For other developing nations that have strong URIs, the Chinese model is worthy of study. The direction within which Chinese URI-industry relationships evolve is of significance to China and the world.

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