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

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Summary. — This paper explores the role of universities and research institutes (URIs) in the development of the Chinese economy through a comparison of the development of the Beijing and Shenzhen technology clusters. The two locations, while embedded in the same national innovation system, have exhibited completely different evolutionary trajectories. In the case of Beijing, the URIs have played an extremely important role in the development of largest high technology cluster in China. In contrast, in Shenzhen, which is now the third most important cluster in China, has in the last twenty years policy makers have consciously worked to establish and attract institutions of higher education. We suggest that the Chinese experience, though not without problems, provides an interesting model for other nations with strong URIs.

Key words — China, Beijing, Shenzhen, universities, clusters, research and development

1. INTRODUCTION

It is now widely accepted that universities and public research institutes (URIs) played a substantial role in the development of many high-technology regions in the United States and abroad (Bresnahan & Gambardella, 2004). In the United States, the two most successful clusters of high-technology firms in both the information technologies and biotechnologies are the Boston and San Francisco Bay areas, which are also the locations of the top four universities (Kenney & von Burg, 1999). [1] The presence of global-class universities in these two regions is partially responsible for their success. Their students often remained in the area and eventually became entrepreneurs, and the research conducted at their universities, at times, became the seed for new firms (Kenney, 1986; Shane, 2004; Zucker, Darby, & Brewer, 1998). [2]

The discussions of high-technology regions have focused on developed countries. [3] In the cases of Taiwan (Saxenian, 2004) and India (Arora, Gambardella, & Torrisi, 2004), university research does not appear to have been a significant contributor to regional growth thus far; although in Taiwan the Information Technology Research Institute played an important role in the development of the Hsinchu Technology Park (Noble, 2000). In all of these countries, well-trained university graduates

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were critical inputs. In the last decade, three IT industry-based clusters, Beijing, Shanghai, and Shenzhen, have emerged in China. [4] This paper examines the role of URIs in the development of IT clusters in Beijing and Shenzhen. We will argue that in the case of Beijing, the URIs were critical contributors, while in Shenzhen they made no contribution.

Universities have long been considered important institutions in national innovation systems (NIS) (Lundvall, 1992; Nelson, 1993). Over the decades the university has been delegated a variety of roles in addition to education and research; these include public service, improving national competitiveness, helping to ameliorate social injustice (e.g., affirmative action), and regional economic development. The NIS perspective highlights the fact that countries organize innovation differently. Not unexpectedly, the role of universities in each NIS differs significantly. The NIS perspective has been criticized by scholars who have asserted that innovation processes in industries and regions differ even within the countries. [5] 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 and different industry foci. [6]

Though recognizing the importance of the NIS for understanding how innovation occurred in countries, geographers argued that innovation systems had a strong regional character (Cooke, 1992, 2001; Storper, 1997). The regional argument fits with the findings of economists such as Jaffe, Trajtenberg, and Henderson (1993) and Feldman (1993) that inventors 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 suggests 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 (Doloreux, 2003; Edquist, 2004; Wolfe, 2003).

The linkages between the NIS and various RISs are 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 China universities can own profit-making firms, while in the United States a university's direct ownership of a commercial firm would invalidate its tax-exempt status—a line that private and public research universities have been unwilling to cross. Thus, national laws and decisions provide the parameters for the actions of organizations such as universities.

The literature treats URIs as an endowment. Regions have excellent URIs or they do not. Beijing and Shenzhen are interesting because Beijing is the Chinese city most endowed with top-quality universities and research institutes (URIs), while Shenzhen only 20 years ago had no URIs, yet it has experienced significant high-technology growth. As an illustration, after Beijing and Shanghai, Shenzhen firms are the recipients of the greatest amount of technology-oriented venture capital (Zero-2-IPO, 2005). In contrast, Beijing had little in the way of industry, while Shenzhen was the earliest growth pole in the new export-oriented Chinese economy. Given their different endowments, the development trajectory of the two regions with respect to utilizing URIs diverged significantly. [7] 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.

When discussing Chinese growth and statistics, it is important to note that governmental statistics are often deceptive because officials are under pressure to meet targets and plans, therefore there is a tendency to minimize the negative and maximize the positive. The Chinese definition of "high technology" is very broad and only some of the activities would conform to the commonly accepted definitions of high technology in developed countries. In China, personal computer assembly is considered "high technology", while few in the United States would define it as such. Because firms considered to be in high technology receive tax and the other benefits, there are ulterior motives for declaring oneself to be a high technology firm. In the case of Chinese technology parks, Cao (2004) in a withering analysis finds that the government, though emphasizing innovation, has in practice been more interested in simple quantitative statistics such as rates of growth, numbers of firms, and value of exports. In the case of Chinese patent statistics, it is generally accepted that many of them are of dubious merit, and also an increasing number of them are filed by foreign firms seeking protection in China, and thus are not Chinese in origin. Where possible we use data from other sources, however often Chinese government data is all that is available. Though the number and quality of what is counted is suspect, it is likely that the trends do represent an underlying reality.

2. LITERATURE REVIEW

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

URI–industry relations are myriad and can include: labor market related linkages, linkages for creation, acquisition, and dissemination of knowledge, and linkages to create new enterprises. URIs are the major educational and training institutions where 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 such as joint R&D projects, technology licensing, consulting, internships, and other collaborations between firms and URIs to develop a product or technology (Kodama & Branscomb, 1999).

Recent research has shown that URIs can be key elements in RISs because of the geographic spillovers of knowledge both through their roles as a human capital provider and as a 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 (Goldfarb & Henrekson, 2003; Rappert, Webster, & Charles, 1999; Shane, 2004). Framed in a slightly different way, Etzkowitz, Wester, Gebhardt, and Terra (2000) observed that the university as an institution is moving toward a more entrepreneurial paradigm. Despite the importance of universities in the local development plans, the relationship between the RIS and local URIs should be understood in a national context. For this reason, the next section begins with a discussion of the historical background within which the Chinese URIs evolved.

3. THE CHINESE CONTEXT

Until approximately the 15th century, China was the global technology leader. With the rise of Western Europe, China increasingly lagged behind Europe and later the European settler states, particularly the United States, in the development of new technology and economic growth. The reasons for China's decline are not certain, however 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 (Adas, 1989; Mokyr, 1992; Needham, 1954).

In 1895, China established its first Western-style university in Tianjin. This was followed in quick succession by Xi'an Jiaotong and Shanghai Jiaotong Universities in 1896. Soon every major Chinese city established a university, for example Zhejiang University (1897), Peking University (1898), and Nanjing University (1902). Tsinghua University, which became China's premier technical university, was established in 1911. By 1920, though most major cities had universities, the Chinese university system was concentrated in Beijing and Shanghai. The universities were severely affected by the Japanese invasion (1937–45) and the ensuing Civil War (1946–49).

In 1949, the Communist Party led by Mao Zedong was victorious. The victory resulted in a mass exodus of many professors appointed by the previous regime, which eroded the capabilities of tertiary level institutions. However, the new government increased its investment in basic education creating a broad educational base. As in the earlier Confucian system, examinations were instituted nationally to identify the most capable students that could continue for completely subsidized post-secondary education. The result has been an adequately educated population and a well-educated elite that has been concentrated by the university system in a few locations. Beijing and Shanghai were the beneficiaries of this concentration, while Shenzhen, at least through the late 1970s, was irrelevant.

Upon the establishment of the People's Republic of China in 1949, 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 United States and emphasized comprehensive universities (Pepper, 1996; Wang, 2000). Universities did undertake research, but their most important priority was pedagogy.

Prior to the reforms initiated in late 1970s, government planners considered that innovation was "an organized collective activity, governed by research laws," and these beliefs led to an extremely linear and rigid model (Segal, 2003). This conceptualization proved to be ineffective as few research results were applied to industrial production. For all intents and purposes, the science and technology (S&T) system was isolated 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 was brought to halt during 1966–76, while the Cultural Revolution roiled the country, and led to an even greater isolation of the country from the outside world. After the death of 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 began 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 (Lu, 2000; Segal, 2003).

The establishment and legitimization of private ownership allowed the economy to diversify, and small businesses and private companies gradually became more significant. Concurrently, the state-owned enterprises were increasingly pressed to compete in the marketplace. In conjunction with the development of an internal market orientation, the "Open Door Policy" attracted foreign direct investment (FDI). Foreign firms established manufacturing facilities for export and later to serve the domestic market. The government pressured foreign firms to do research in China, while encouraging Chinese firms to improve their research capacity. Chinese private sector firms were able to "absorb" advanced technology from foreign firms. From the mid-1980s onward, the Chinese government continually adjusted the S&T system to strengthen Chinese R&D and develop the country's absorptive capacity (Cohen & Levinthal, 1990).

One of the most important reforms to the NIS came in the early 1980s, when the government driven by a desire to lower the cost of supporting the URIs drastically cut their funding. 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. The government encouraged greater linkages between the URIs by encouraging URI-affiliated enterprises, establishing fiscal and legal services for professorial and student start-ups, strengthening patent laws (from what they were previously), building new technology industry zones (high-tech zones)/innovation centers/software industry bases near URIs, providing innovation funds for small technology-based firms, and supporting the establishment of university science parks. Recognizing the need to promote technological progress, the central government also initiated large-scale national research programs on technologies (Kondo, 2003; Leydesdorff & Zeng, 2001). These included the 863 Program/Plan (Baliusan Xiangmu/Jihua) targeting biotechnology, new materials, lasers, energy, information, and robotics and space (Segal, 2003).

The other 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. These high-tech zones were built 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 high-tech zones had been established since 1991 (Wu, 2004). These zones have experienced rapid growth, though as Cao (2004) points out, much of this growth has been in product assembly and thus does not represent Western notions of high technology. By 2003, the national high-tech zones (and state-level science and technology industrial parks) had received RMB155 billion [8] investments in infrastructure and hosted 32,857 companies. The total reported annual revenue in 2003 for 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. In terms of research output, these Zones increased their number of Chinese patents from 933 in 1992 to nearly 7,000 in 2002. The R&D personnel increased from approximately 67,000 to over 589,000 in 2003 (Zhang, 2004; Zhao, 2002, 2003a, 2003b). Though the statistics and definitions are suspect, there can be little doubt about the growth of economic activity within the zones.

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% from 2002. The percentage of GDP invested in R&D grew from 0.6% in 1991 to 1.31% in 2003. Universities expended 10.5% of total R&D, while the RIs spent 25.9%. The expenditures by RIs decreased from 42.8% of the total in 1996 to 25.9% in 2003, as companies increased their percentage of total spending from 43.3% in 1996 to 62.4% of the total in 2003 (China Science & Technology Statistics Net, 2005). 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. It is also important to note that research institutions receive approximately $2\frac{1}{2}$ times more funds than do universities.

China's scientific capacity is expanding 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 (China Science & Technology Statistics Net, 2005). Though still at a very low base, the cumulative number of US patents granted to Chinese inventors in China totaled 3,521 US patents, however the annual rate had increased from 294 in 2000 to 597 in 2004. [9]

Improving research at China's URIs is an important component of the national S&T strategy. To facilitate this improvement the government has been increasing URI funding. For example, allocations to the URIs increased by 4% from 2000 to 2003 (China Science & Technology Statistics Net, 2005). The percentage of government funding in the expenditures of research institutes increased from 53% in 1991 to 71% in 2003, in absolute terms it was five times greater in 2003 than it was in 1991 (see Table 1). Moreover, the research component has increased while the development component has decreased, which is largely a result of the corporatization of many research institutes that had commercial goals and the reorientation of the remaining RIs to research. The effect of this corporatization is responsible for the decrease in the number of R&D personnel in 2001.

The universities also experienced a change from the 1980s when their budgets were cut.

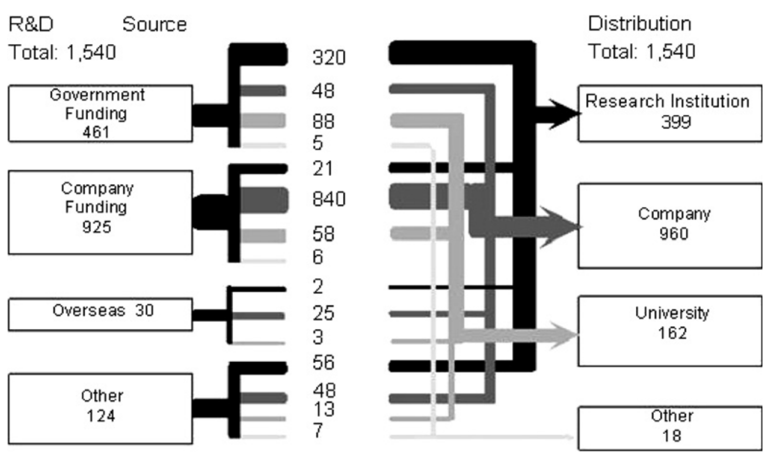

Figure 1. *R&D sources and distributions in China (2003, 100 million RMB). Source: China Science and Technology Statistics Net (2005).*

Table 1. *R&D statistics of government research institutes (1991–2003, 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 (%)	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 personnel (10,000)	27.4	25.7	23	22.7	22.7	20.5	20.6	20.4

Source: China Science and Technology Statistics Net (2005).

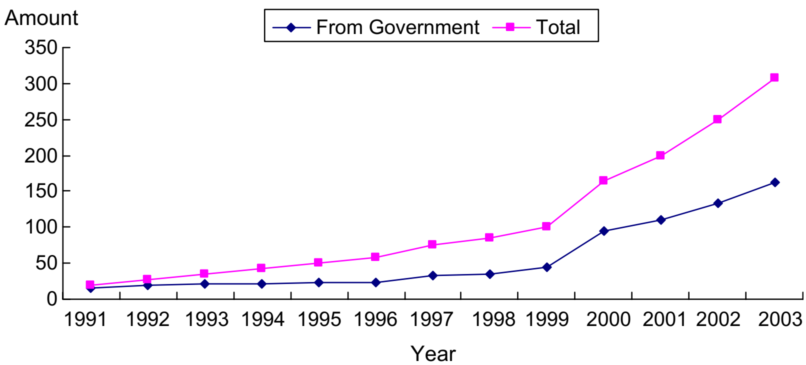

Figure 2. *S&T funding in universities (1991–2003, 100 million RMB). S&T expenditures refer to R&D expenditure, application expenditure of R&D achievements, and S&T service expenditure including S&T personal service expenditure, S&T fixed asset expenditure, etc. Source: China Science and Technology Statistics Net (2005).*

Since 2000, universities received more than 50% 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 (China Science & Technology Statistics Net, 2005). Thus, R&D expenditures grew rapidly as the Chinese government pursued its policy of improving research performance in the universities.

In terms of sheer quantity, the output at the URIs has grown steadily. Prior to 1999, publications and patenting had already begun increasing (see Table 2), then decreased from 1999 to 2001 due to 25% of the RIs being

Table 2. *S&T achievements in S&T research institutes (1997–2003)*

	International publications	Patent application	Patent approved	Invention patents approved	International patent
1997	8,396	2,249	1,110	457	18
1998	9,560	2,356	1,340	526	29
1999	9,531	2,488	1,687	669	24
2001	8,342	N/A	1,298	617	10
2003	10,000[a]	4,374	2,010	1,305	13

Source: Compiled by authors from the China Science and Technology Statistics Net (2005).
[a] Estimates.

corporatized and removed from the base. The RIs that were corporatized during the restructuring had a total revenue of $34.3 billion and sales income of $21 billion (China Science & Technology Statistics Net, 2005).

The universities also have become more active. In 2003, there were 63,600 papers with the first authors from universities listed in SCI, EI, and ISTP. Since 2000, there has been a dramatic growth in patents granted to university inventors. During 1988–99, Chinese patents approved ranged between 1,300 and 1,800. In 2003, universities applied for 10,252 Chinese patents. This veritable wave of patent applications continues to grow. In the first six months of 2004, there were 6,250 Chinese patent applications from universities, an increase of 34% over the same period in 2003 (China Intellectual Property Net, 2005.). The fact that the number of foreign patents is not increasing suggests that the output of high quality research remains roughly unchanged (Chinese Science and Technology Statistics Net, 2005).

(a) *URI enterprises*

The unique feature of the Chinese NIS is the URI-owned enterprises. Regardless of one's opinion of this strategy, and there are critics, they have grown rapidly. The total revenues of the URI-affiliated enterprises has grown dramatically (Table 3). The literature typically focuses on three URI-related firms, Lenovo, Founder, and Stone Group. However, there are many more. For example, Datang Telecommunications Technology, a spin-off of the Ministry of Post and Telecommunications research arm the Chinese Academy of Telecommunications Technology, Datang employs 4,000 persons and in 2004 had annual revenues of approximately $300 million (Hoover's, 2005). As of 1999, 15 firms from 13 different universities had listed on various Chinese stock markets (Xue, 2005). This had increased to 29 firms in 2003 (Song, 2005). The total annual revenues of Beijing and Tsinghua University affiliated firms are nearing $2 billion each. Though only 45% of all URI-affiliated enterprises are in high-technology fields (again the definition of high technology is quite loose), the URI-firms in high technology produce more than 80% of the total revenue (Ministry of Education, 2005).

In Beijing and Shanghai, local authorities have established industrial parks affiliated with local universities. For example, the Zhongguancun area of Beijing, which is in close proximity to CAS, and Beijing and Tsinghua Universities, is recognized as the largest concentration of Chinese and MNC R&D facilities in China (Cao, 2004; Zedtwitz, 2004; Zhou, 2005). In total, by the end of 2002, the 44 university-established 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 (Zhou, 2003). Despite these successes, in 2007 there were press reports suggesting that some universities might go bankrupt because of the losses their affiliated firms were suffering. In other words, the strategy of having universities operate for-profit firms was having potentially negative consequences.

Table 3. *University rank, revenue 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 (2005), the China Education and Research Network (2005).

The university's role in the Chinese NIS has evolved dramatically over the last two decades. Local governments throughout China believe that universities and their affiliated technology parks are important pillars of economic development. In the next section, we examine the role of URIs in Beijing and Shenzhen.

4. TWO MODELS FOR URI INVOLVEMENT IN LOCAL ECONOMIC DEVELOPMENT

The deregulation of the Chinese economy also included a significant devolution of decision-making to local jurisdictions and organizations, thereby providing 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. 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. 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, and its industrial growth did not rely on local URIs. Shenzhen firms developed their own internal R&D capacities utilizing foreign technology and attracted educated Chinese from around the country. 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. Figures 3 and 4 provide stylized depictions of the URI–industry linkages in Beijing and Shenzhen.

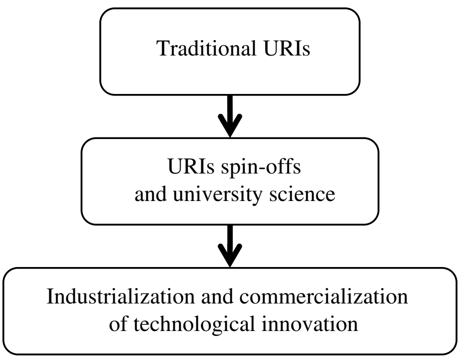

Figure 3. *URI-industry model in Beijing.*

5. BEIJING

Beijing is the political, educational, and S&T capital of China. In 2003, 71 universities and 371 research institutes were located in Beijing Beijing Statistical Information Net, 2005, by far the largest concentration in any Chinese city. The most prominent of these were the Chinese Academy of Sciences, Peking University, and Tsinghua University, all of which are located in the Haidian District. The Haidian district is the location of the Zhongguancun Science Park (ZGC), 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

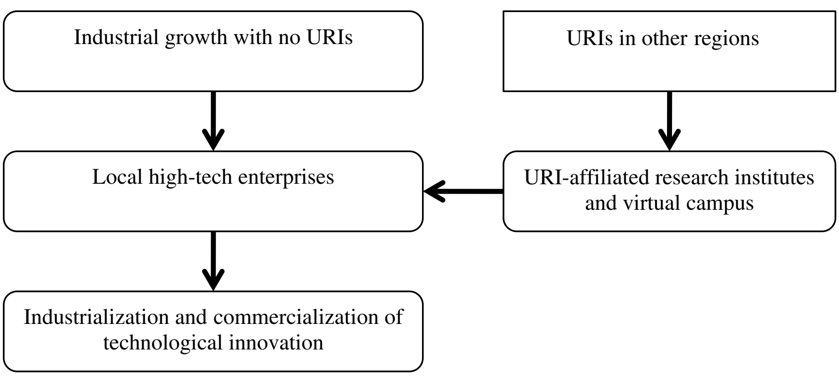

Figure 4. *URI-industry model in Shenzhen.*

a primary force for economic growth in Beijing. As an indicator of the importance of high technology, in 1999 high-technology businesses accounted for 25.4% of the city's total industrial value added, and rose to 39.3% in 2004 (Beijing Statistical Information Net, 2005). Given this success, the municipal government has focused on encouraging further growth (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% of government S&T funds were allocated to Beijing institutions while 18% of all R&D funds were expended in Beijing and 18% of all patents were granted to entities located in Beijing (Beijing Statistical Information Net, 2005). Thirty-three percent of all research institute R&D spending and 20% of university R&D spending took place in Beijing. 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 (Beijing Statistical Information Net, 2005).

Beijing's success is mirrored in various objective indicators of performance. For example, since 1995 Beijing has received between 17% and 21% of total patent approvals (see Table 4). In terms of URI-industry technology contracts, Beijing's URIs captured more than 20% of the total contract revenue for the entire country (see Table 5).

However, the commercialization of the Beijing URIs 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. The technology being transferred was not comparable to that generated by US universities such as MIT and Stanford, but rather was adequate for the Chinese market. Despite these caveats, what is significant is that a few spin-offs became important Chinese IT firms, and Lenovo has managed to become a global player.

(a) *Research institutes*

Beijing is 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 are located in Beijing. In the 1980s, CAS shifted from defense-related research toward conducting R&D that had greater commercial application. In the process, CAS was corporatized and the

Table 4. *Invention patents approved by region (1995–2000)*

	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 (2005).

Table 5. *Technology contract value in Beijing and in China (1999–2003, 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 (2005).

number of institutes was reduced to increase efficiency, better reflect the market, and to encourage its staff to establish new firms (Kondo, 2003). In 2005, CAS employed approximately 37,000 scientists and engineer, more than 20,000 graduate students, and 1,000 postdoctoral scholars. In 2003, CAS expended RMB8.28 billion on R&D (http://www.cas.cn) and was China's leading URI in terms of publications and patents.

In response to the economic reforms and the restructuring of the S&T system in the 1980s, 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 CAS research. CAS also formed a venture capital firm, China Science and Technology Promotion and Economic Investment Company, to support CAS staff establishing start-ups (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. In 2003, the gross revenue of the CAS affiliated enterprises was RMB53.37 billion and they had a net profit of RMB2.03 billion (Chinese Academy of Sciences, 2005). The most successful company to emerge 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 (Lazonick, 2004; Lu, 2000). Today, Lenovo is the largest Chinese IT company, and since 1996 it has been China's sales leader. In 2004, Lenovo reported a turnover of HK$23.2 billion and net profit of HK$1.05 billion (Lenovo, 2006). 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.

As a CAS-affiliated company, Lenovo benefited from the economic reforms as well as the institutional and organizational restructuring of China's S&T system. This enterprise model is known as "one academy, two systems" and is "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 allowing 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, Lenovo enjoys substantial autonomy. The benefit for CAS is from the fixed sum of earnings that Lenovo transfers to CAS each year.

CAS is by far the most successful of the government research institutes in spinning off firms. But Datang shows that there are other cases. In effect, the RIs were large concentrations of commercially under-utilized skilled labor power. By providing access to facilities and guaranteeing the salaries of the entrepreneurs, the RIs lowered the risks, thereby performing a function like that of a venture capitalist in an environment that in the early 1980s could not have supported true venture capital either ideologically or economically.

(b) *Universities*

Beijing is the center of the Chinese university education system. In the latest university ranking 20% of the top 100 universities of China are located in Beijing (Shanghai Jiaotong University, 2005). 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 3). In 2002, there were 26,038 S&T employees in the universities. The local universities were responsible for 47.58% of the publications and 36% of all Chinese patents allocated to entities in Beijing in 2000 (Beijing Statistical Information Net, 2005).

Beijing universities have developed close relationships with industry through joint projects, professional consulting, and training. 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. 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

Table 6. *University-affiliated enterprise sales income rank by region (1998–2002, 100 million RMB)*

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

Source: Compiled by authors from the Ministry of Education (2005) and the China Education and Research Network (2005).

million. But the most striking relationship is through spin-offs and the ownership of for-profit enterprises. Put simply, Beijing has the most university-affiliated enterprises and they are the largest in terms of sales and profit (see Table 6).

The two leading universities in terms of commercialization are THU and PKU. As China's premier technical university, THU has a strong endowment of personnel. In 2005, THU housed 11 national key research labs, employed over 7,800 faculty and staff, and served more than 27,000 students (Tsinghua University, 2005). In terms of R&D funding, it leads the country in the number of patents and publications (see Table 7). In total, in 2001 THU expended RMB 724 million on research, of which RMB 323 million was from the private sector; the remainder was largely from the government sector (Beijing Statistical Information Net, 2005). For example, in 2004 THU had 527 patents approved and ranked first in the country (Center of S&T Development Ministry of Education, 2005). As was the case with CAS, THU is actively involved in commercializing faculty and staff inventions. In 1991, it established 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 (Beijing Statistical Information Net, 2005).

In addition to active collaboration with industry through joint projects and technology transfer, THU established firms to commercialize its inventions. 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. [10] Since the early 1980s, these enterprises have been required to generate profits. In 1980, THU established Tsinghua Technology Service Company to utilize THU personnel to provide technical services to the marketplace. By the early 1990s, 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 and were based in the professor's

Table 7. *THU S&T achievement statistics (1999–2003)*

Year	Patent application	Patent approved	Number of contract	Contract revenue (10 thousand)
1999	189	121	341	18,367
2000	344	135	534	23,500
2001	396	163	534	23,400
2003	N/A	N/A	N/A	N/A

Internet Edition.
Source: Compiled by authors from the Beijing Statistical Information Net (2005) and the Center of S&D Development of the Ministry of Education (2005).

or researcher's labs. However, there were other affiliated firms such as Tsinghua Tongfang and Tsinghua Unisplendour that grew sufficiently large to make public stock offerings.

As THU's commercial activities grew, management of the disparate firms became more complicated. To assist 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 revenues grew rapidly reaching RMB15.22 billion in 2003 (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 in 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 30 technology-based spin-offs and approximately 30 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 & Research Network, 2005).

Through the establishment of a science park on campus in 1993, THU encouraged 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). Currently, the science park houses more than 300 different institutes including national research labs; R&D centers for various multinational corporations such as Sun Microsystems, Proctor & Gamble, and NEC; the headquarters of the university enterprises including Tongfang, Unisplendour and Zhicheng; and various firms in financial, law and consulting services, and professional and educational training (Mei, 2004). The space utilization has prompted some to conclude that these science parks are, in some measure, real estate development schemes. The science park also serves as an incubator to develop start-ups, many of which are operated by university alumni and 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 startups secure financial support, including venture capital from various companies, loans from banks, government funding, and a RMB200 million investment fund for returning 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 70 start-ups and 27 graduated.

The university spin-off companies help commercialize 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.

Beijing with its preeminent endowment of URIs in both number and quality has benefited from commercialization. THU and CAS are 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 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. Beijing municipal officials have decided that future growth is dependent upon training and retaining the talented students coming to Beijing to study.

6. SHENZHEN

In 1979, Shenzhen, which is located close to Hong Kong, was a fishing village and had no local academic institutions. 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 manufacturing for export. The policy was a massive success and the city grew rapidly. Since 1979, its GDP has grown at an average rate of 30% per annum. Today, Shenzhen is an important economic center (see Table 8). 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.

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. The Chinese Academy of Social Sciences (2005) rated Shenzhen as the second most competitive Chinese city trailing only Shanghai. 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 devised a strategy to encourage higher technology business activities. In pursuit of this goal, the municipal government has built office parks to attract high-technology firms, MNC R&D, and encourage the entry of local high-technology firms. The leading examples of the new firms driving the growth of Shenzhen are the communications technology firms, Huawei Technologies and Zhongxing Telecommunications (ZTE). However, many smaller technology-based firms have also appeared.

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) (Li, 2000). In 2005, SHIP encompassed an area of 11.5 km^2. As

Table 8. *Shenzhen S&T statistics (2000–04, 100 million RMB)*

Year	GDP	High-tech output value	Indigenous technology value	High-tech company number	S&T funding	S&T personnel (10,000)	Patent approvals
2000	1,665.24	1,064.45	532.4	212	2.5	15.89	2,401
2001	1,954.17	1,321.36	697.96	314	2.8	17.23	3,506
2002	2,239.41	1,709.92	954.48	422	3.25	18.64	4,496
2003	2,860.51	2,482.79	1,386.64	673	3.18	57.54	4,937
2004	3,422.80	3,266.52	1,853.09	943	5.3	66.34	7,737

Source: Compiled by authors from the Shenzhen Annual Reports on Shenzhen Government Online (2005).

with most Chinese industrial parks, there is little apparent specialization as it welcomes firms from nearly every industry and it also aims to improve traditional industries by making use of high technology and advanced applicable technologies (Shenzhen Industrial Park Net, 2005).

In 2004, the value of production in Shenzhen reached RMB245.4 billion, 11 times that of 1996. In contrast to Beijing, 90% of the R&D in Shenzhen is conducted by firms, and 80% of all R&D funding originates from firms. In 2003, R&D expenditures were RMB7.2 billion—an increase of 19.8% over 2002. The largest high-tech enterprise, Huawei Technologies invested RMB3 billion in R&D. The number of patents has increased annually (see Table 8). Only Beijing and Shanghai had more Chinese patents granted than Shenzhen. Moreover, the growth in patenting was stunning. The applications, for example, grew from 1,440 in 1997 to 12,361 in 2003 (Shenzhen Intellectual Property Net, 2005).

Shenzhen had a different growth trajectory and concomitant model by which universities were meant to contribute to the cities development (see Figure 3). Already, in the early 1980s, the municipal government believed 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, in 1993. In the 1990s, the municipal government decided that these were not sufficient and embarked upon a strategy of attracting URIs to the area. Its first success was convincing 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 [11] 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 78 research labs and centers including 42 national key research labs and engineering centers (Shenzhen Industrial Park Net, 2005). In 2000, a university town was created within 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 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 to attract URIs.

In the case of Shenzhen, it was economic success that drove the development of a higher education infrastructure. In return, the establishment of numerous educational facilities make Shenzhen more attractive as a destination for educated Chinese because of the ability to pursue higher degrees from prestigious URIs locally. Thus the relocated URI branches may operate as an attraction and retention strategy for highly trained engineers and scientists. Whether the educational institutions are making Shenzhen a research center is not yet certain. What is certain is that Shenzhen is being transformed from a low-cost production center into a location for undertaking higher value-added activity. The addition of university branch campuses can only contribute to that process, and over time these branch campuses may also be improved.

7. DISCUSSION

URIs have been significant contributors to the growth of the Chinese economy. In terms of economic activity, the commercialization of Chinese universities and their personnel has made an impact on a few of the leading universities in the major cities. In the case of Beijing, a 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 suffering from budget cuts successful commercialization is seen as a 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 forces in the establishment and development of technology-based firms in Beijing. For economic growth, Beijing has relied upon the knowledge and human resources in the URIs.

Whereas the URIs have contributed to the development of the Beijing economy, in Shenzhen economic growth occurred prior to the development of institutions of higher education. However, the municipal government realizing the importance of upgrading its economic base is actively working to create a higher education infrastructure to contribute to 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.

Chinese universities like those in other countries have a role of selecting and educating the workers of tomorrow—a task that will become even more vital in the emerging knowledge economy. The elite universities are critical 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 countries, there has been concern that the commercialization of Chinese URIs will affect research and teaching. [12] There are 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 is concern that students are being used as cheap labor with little attention to research quality or pedagogy. These are serious, but, perhaps, 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.

In many countries, URIs have been important repositories of the humanities, culture, and the arts. Will the commercialized Chinese URIs where departments and laboratories operate as profit centers protect the unprofitable humanities and arts? Creativity and design, which many believe is as important in global competition as engineering and production, does not stem solely from well-trained engineers, but requires aesthetics and innovation. Will these be abandoned in the university that operates more like a profit making firm than as an institution in the pursuit of knowledge and pedagogy?

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 levels that the university felt were "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 under-performing in technology commercialization. These enterprises on average made a net profit equal to only half that of the non-affiliated companies in ZGC. The university-affiliated spin-offs had exports which were only one-sixth of those in nonaffiliated companies. Underperforming university spin-offs paid less tax and were less productive in patenting than nonaffiliated companies. Lenovo and Founder, etc. are still the most successful firms in ZGC. The report attributes this under performance to a lack of clarity in ownership, ineffective personnel relations, and the lack of capital and management supervisory systems.

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, the building of university science parks may have also been aimed as much at creating rentable office space as they were toward incubating and transferring technology.

8. 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 analysis treating China as being a monolithic entity misses the nuance in how China innovates. Our study, which confirms Segal (2003) findings regarding the importance of local officials in developing the evolutionary trajectories of their regions, shows that Beijing and Shenzhen, starting with different endowments, established remarkably different methodologies for developing their technology clusters. Without a doubt, China has built a unique relationship between its URIs and industry. In most countries, 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 URIs were not the origins of significant spin-offs, the source of successful firms such as Huawei and ZTE are quite different.

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, Dongfang and Founder, are among the largest and most important Chinese technology firms. From this perspective, Chinese policy has had tremendous success in tapping the capabilities of universities and researchers. For other developing countries that have strong URIs, the Chinese model is worthy of study. The direction which Chinese URI–industry relationships evolve is of significance to China and the world.

NOTES

1. There is an enormous literature on Silicon Valley and Boston. Some work compares the two regions (Fleming *et al.*, 2004, Kenney & von Burg, 1999; Saxenian, 1994) particularly in biotechnology (Powell, Koput, Bowie, & Smith-Doerr, 2002; Zhang & Patel, 2005).

2. For a discussion of the roots of venture capital in the United States, see Etzkowitz (1999) and Hsu and Kenney (2005).

3. An important exception is Bresnahan and Gambardella (2004).

4. Definitions of high-technology are always difficult. In China high technology industries these include almost anything in the IT and software industries and includes quite routine work such as PC assembly. There is no way of separating these out, and we believe a credible argument can be made that even assembling such electronics items can over time lead to greater value-added creation as the cases of Japan, Korea, and Taiwan have demonstrated.

5. On industry differences, see differences between biotechnology and IT in Kenney and Patton (2005).

6. For a critique of this explanation, see Kenney and von Burg (1999). For partial corroboration of Kenney and Burg, see Fleming *et al.* (2004) who finds that "simple characterizations of Boston secrecy and autarky vs. Silicon Valley cooperation and interdependence fail to reflect the tension between managers and engineers on both coasts." On path dependency, see David (1986) and Arthur (1994).

7. On development trajectories, see Dosi (1988).

8. The exchange rate is around RMB8.3 to US$1.

9. It is impossible to assess the quality of these patents. Also, we do not know whether these were granted to MNCs operating in China or indigenous Chinese organizations. If China is similar to Japan, Korea, and Taiwan, then it is likely that their patents will improve over time.

10. This was not unique to China as universities in many countries manage activities such as dormitories and university presses.

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

12. For discussion of these concerns in relation to US universities, see Bok (2004), Kenney (1986), and Slaughter and Leslie (1997).

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