Regional specialization in China's biopharmaceutical industry

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Abstract

Purpose – The purpose of this paper is to explore patterns as well as determinants of regional specialisation in China's biopharmaceutical industry. It identifies and characterizes different types of enterprises engaged in the biopharmaceutical sector in terms of their business organisation and regional set up.

Design/methodology/approach – Based on data compilations not yet employed in academic analysis as well as personal interviews in China, structural determinants and driving forces of development are analysed against the background of the innovation systems literature.

Findings – The geography of innovation in China's biopharmaceutical industry is determined by both, government policy and the strategic location decisions of entrepreneurs. While local-government support of firm clustering has contributed to a dispersion of industrial activity throughout China, the firms" networks are spanning clusters. Effectively, domestic firms are turning into multi-regional companies locating activities such as R&D and manufacturing at different clusters.

Originality/value – The paper adds to the literature in so far as it throws light on an until now under-researched field of China's innovation system. It identifies the concept of multi-regionalism among domestic non-state enterprises as an important parameter for understanding success and regional distribution of the industry.

Keywords China, Pharmaceuticals industry, Regional development, Government policy

Paper type Research paper

1. Introduction

Late-comer economies such as China have to master the art of catching-up growth in order to copy and gradually emulate the development patterns of more advanced economies. In a decade-long process they slowly, step-by-step reduce the development gap and the technological distance separating them from their peers. However, Zeno's paradox seems to stand at the end of most of these development processes: Achilles cannot outrun the tortoise and to late-coming economies it seems as if the leading economies can never be surpassed, but always remain one step ahead. In order to surpass this "final frontier", late-comer economies have to depart from the catching-up development model and establish autonomously created technological progress and change as the primary source of their economic development. And only by venturing into technological "terra incognita" and the establishment of technological leadership in an area, where no other national science system and/or multinational corporation has already staked its claims, can a late-developing economy really become independent of its peers and eventually "outrun the tortoise".

As the increasing returns associated with learning and experience provide first movers in dynamic industries with a head start which is often enough sufficient to leave subsequent competitors permanently behind, late-comer economies must focus on new technological trajectories. Such new, unexplored scientific paths may open up

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"windows of opportunity" because at early stages of an emerging trajectory the knowledge and capital required to compete successfully are still manageable (Perez and Soete, 1988). The recent advances in nanotechnologies and biotechnology have been widely viewed as providing such opportunities for the establishment of technological leadership ahead of the established lead-economies (Niosi and Reid, 2007). Accordingly, several developing countries, most notably China and India, have set out to seize their chances. Since the late 1980s, the Chinese government has focused its efforts on promoting the economy's innovation capacity in a narrow set of high-technology fields. One of these fields featuring prominently in the national development strategy is biotechnology, a cross-cutting technology which can be employed, among others, in the pharmaceutical, agricultural and energy industries. Among the potential users, China's central government, however, seems to target the pharmaceutical industry and agriculture in particular (Yu, 2007).

The importance attributed to this field of research is also mirrored in the Medium to Long-term program on Technological and Scientific Development (2006-2020). This centrepiece of China's modern innovation strategy contains several passages that demonstrate the central government's determination to catapult China's health-related biotechnology to the top of the global research activities (Cao *et al.*, 2006). In particular, biotechnology is listed first among the frontier technologies targeted, and two of the four science mega projects enumerated in the "Program" – protein research and growth and reproduction science – are directly related to health biotech.

Despite this strong government emphasis, English-language studies on China's biopharmaceutical industry are surprisingly limited. Most of them are emanating from market research organizations such as BioPlan, Pharma China or Business Monitor International, which supply information on general market developments and on key players in the industry. Academic contributions predominately remain within the field of biotechnological research *per se* and are intended to keep fellow researchers up to date with the latest developments in China. Hence, this second set of studies mainly focuses on the description of scientific results and breakthroughs in drug development, while mentioning industrial dynamics only in passing (Hu *et al.*, 2006). Notably, Chen *et al.* (2007) and Yu (2007) go a step further by integrating their account of biotechnology research into its regulatory and international context.

Scholars interested in economic development and innovation have so far remained reticent or have discussed only very particular issues. Thomas (2009) and Salter (2009), for example, deal with the problems of China's pharmaceutical industry related to IPR protection, respectively, the venture capital industry. Other authors have portrayed outstanding Chinese research institutes in this field such as the Shanghai Institutes of Biological Sciences (e.g. OECD, 2008). To our knowledge the first systematic analysis of China's biopharmaceutical industry has been provided by Frew *et al.* (2008)[1]. Their discussion is based on an in-depth investigation of the product and patent portfolios, financial backgrounds as well as collaborations and alliances of 22 Chinese biopharmaceutical companies. Yet their knowledgeable account fails to embed the firm-level analysis into the development and structure of the whole industry. Hence, it is difficult to derive a more general picture of China's biopharmaceutical industry. In particular, China's geography of innovation, which has been analyzed in scholarly contributions on other Chinese industries (OECD, 2008; Segal, 2003; Sigurdson, 2005), has been missed out. Prevezer and Tang (2006) examine the three biotechnology clusters in Beijing, Shanghai, and Shenzhen. Unfortunately, their selection of the clusters merely rests on a number of enterprises, which they attained through searching incomplete and possibly biased internet databases. Moreover, due to the omission of output indicators, their discussion of the relative importance of regions and of enterprise types within these regions may turn out to be highly deceptive.

Against this background, the present contribution seeks to supplement the previous research by systematically examining the regional patterns and determinants of specialization within this industrial sector. In order to do so, we make use of a unique data source, the Annual Statistical Report on Pharmaceuticals in China (MIIT, 2009), which offers a wealth of information on regional differences in industrial structure with regard to the biopharmaceutical industry. To our knowledge, this report has not yet been employed systematically in relevant research. In addition we base our discussion on the comprehensive firm directory provided by BioPlan (2008), and explorative interviews conducted in Shanghai and Beijing in February 2010.

The discussion opens with a theory-driven discussion of spatial patterns in sectoral systems of innovation (SI) (Section 2). In particular, the role of government policy in the geographical distribution of production and innovation will be emphasized. These insights provide the basis for the subsequent analysis of China's government policies affecting the productivity and geography of China's biopharmaceutical system. Before China's innovation policy is discussed in Section 4, an overview will be given on China's pharmaceutical industry with a particular focus on the biopharmaceutical market segment (Section 3). As government policies merely provide a framework for the strategic action of a broad range of actors, the location strategies of four types of entrepreneurs and firms, which are important for the development of China's biopharmaceutical industry, will be analyzed in Section 5. Section 6 concludes.

2. Spatial dimensions of sectoral systems of innovation in China

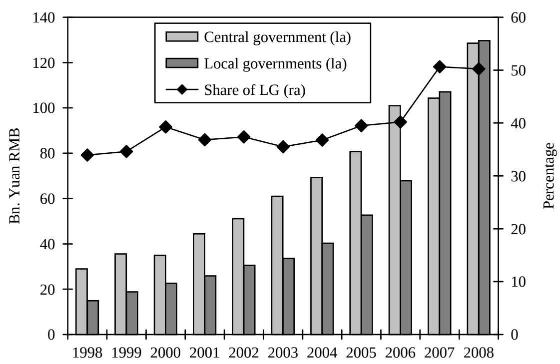
In recent years, it has become widely accepted that in investigations of economic development more holistic approaches have to be employed in order to catch a maximum of relevant factors and processes (Lundvall, 2007). Among others[2], the SI approach has been particularly influential as it has proven useful for analyzing the processes of learning and innovation as the most important drivers of economic development. Innovation is understood as a rule-based interactive process between several actors. Accordingly, SI contain a set of organizations, e.g. firms, government (agencies) and universities, and institutions, i.e. rules such as laws, social norms, and routines, which give rise to certain forms and structures of interaction between (and within) these organizations.

In general, two ways have been used to delimit the boundaries of SIs: geographical and sectoral[3]. Sectoral systems focus on a specific knowledge base that is inherent to a technological domain (Malerba, 2005). As knowledge and technologies change, the product line-ups of a specific sector adapt consequently. In the pharmaceutical industry, the biopharmaceutical segment was made possible due to new technologies such as recombinant DNA technology and hybridoma technology, which facilitate the production of recombinant proteins, respectively, monoclonal antibodies (mAbs). The creation and diffusion of these new scientific knowledge bases and technological opportunities is the outcome of interactions between firms and other actors including universities, laboratories, and hospitals and the institutional framework that enable or disable knowledge exchange. In this sense, a spatial dimension is evident as formal institutions (law and regulations) and policies are usually geographically confined. Most of the SI literature focuses on this geographical dimension. Cooke *et al.* (1997) identify three dimensions that are important for a given region's innovative capacity: the financial, learning, and "productive" cultural dimension. In principle, all of these dimensions can be brought to play by spontaneous processes leading to a spatial clustering of a complementary set of actors. But even if so, states play a significant role in reinforcing or arresting development trajectories through their impact on either of the three dimensions. The national system of innovation (NIS) perspective is based on the acknowledgment of the state's role in economic development (cp. Freeman, 1995). The NIS approach predicts that industrial organization differs between countries and that these differences account for the various countries' differential ability to participate and shape technological trajectories.

As such institutional approaches, sectoral and spatial SIs do not exclude each other but are complementary. In fact, the sectoral perspective requires a spatial dimension but leaves room for the interplay of institutional hierarchies. As Malerba (2005) claims, local, national and global dimensions usually coexist in a given sector. The national level does not necessarily have to dominate the other levels. In China, historical reasons have rendered the sub-national level a decisive force in institutional change and industrial growth. Two phases of political decentralization related to the Great Leap (1958-1960) and the Cultural Revolution (1966-1976) have given local governments ample opportunities to influence local development paths already in the pre-reform era. As a consequence, most provinces had established a fledgling pharmaceutical sector during the early 1970s. In 1976, there were about 2,600 mostly small-scale pharmaceutical plants scattered around the country (CPEMA, 2009). The subsequent reform process initiated at the turn of the 1980s sanctioned and even broadened the devolution of authority (Qian, 2000). Effectively, China evolved into a quasi-federal state with a complex division of labour and authority between the central and the local governments. The fiscal reform of the 1980s has provided local governments with additional sources of income that can be utilized in order to advance the local economy. Accordingly, the function of local governments shows prominently in government expenditure on science and technology (Figure 1).

The importance of both, national and local levels of the Chinese state would imply that regional differences in pharmaceutical sector development are at least partly due to

	Central gover	local governm	share of LG (ra)
1998	28.97	14.89	33.9%
1999	35.56	18.83	34.6%
2000	34.96	22.6	39.3%
2001	44.43	25.89	36.8%
2002	51.12	30.5	37.4%
2003	60.99	33.56	35.5%
2004	69.24	40.29	36.8%
2005	80.78	52.71	39.5%
2006	100.97	67.88	40.2%
2007	104.3	107.05	50.7%
2008	128.52	129.66	50.2%



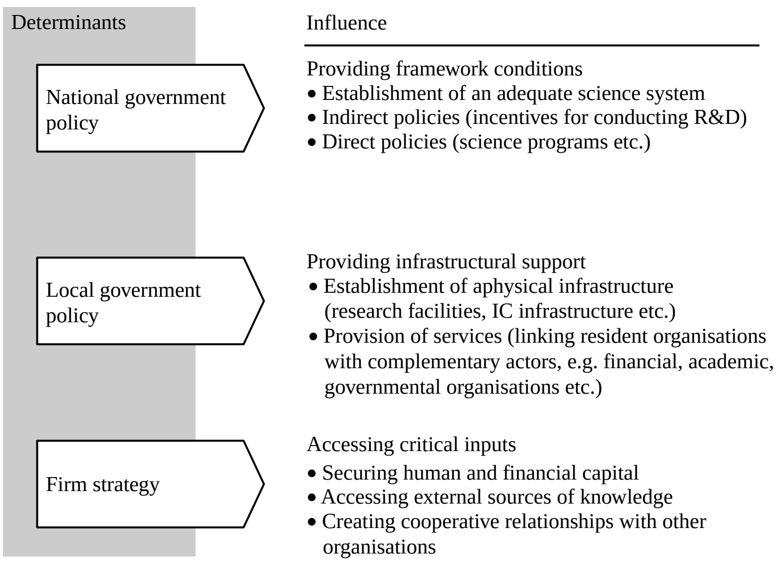
Sources: NBS and MOST (2009); own illustration

Figure 1.
Government expenditure for science and technology, 1998-2008

idiosyncratic local institutions and policies. Therefore, our expectation is, that an analysis of sub-national dynamics can improve our understanding of how innovation works in China. Sectoral studies with a local perspective have been already undertaken by, e.g. Segal (2003) with respect to the computer industry and Thun (2006) regarding the automobile sector. However, the focus on administrative boundaries has led both authors to put a strong emphasis on government strategies, which easily gives an impression of localities as being self-contained systems. Yet as will be shown in subsequent sections, in recent years individual biopharmaceutical firms have been creating interrelationships that span Chinese regions and even reach across the national border. We therefore add a firm-level analysis based on a number of case studies in order to investigate how different sets of firms have utilized local environments to create and adapt value creating network structures. The main determinants of the spatial organisation of China's industries, which we have singled out for further investigation, are shown in Figure 2. In the following, we first provide a short overview of China's pharmaceutical industry. Then, we will turn to each of these factors.

3. General overview of China's pharmaceutical industry

During its first three decades of existence, the People's Republic of China was quite successful in substituting imports of most essential Western pharmaceuticals by domestically manufactured drugs (Shen, 2008). Moreover, a number of medical schools had been successfully instituted at leading universities. A number of research institutes, particularly those of the prestigious Chinese Academy of Sciences (CAS), have achieved major scientific breakthroughs (Yu, 2007; Kühner, 1986). Such achievements, however, remained scarce throughout the period. More importantly, the vertical central planning system hampered the development of the sector as user-producer interactions were notoriously absent. The established organizations were strongly specialized in



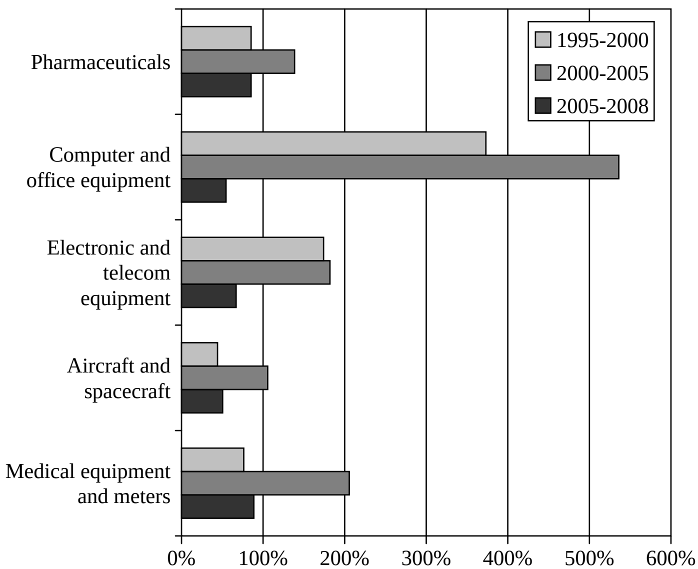
Source: Own illustration

Figure 2. Main determinants of the Geography of Industrial Organisation

functions like R&D or manufacturing, while exchange between them was organized by yet other bureaucratic organizations specialized in procurement and distribution (Liu and White, 2001). This system was complicated by the concurrence of national and local organizations that served these very functions. It was only when this centrally planned division of labour was overcome in the 1980s through the permission of decentralized market interaction – which also included direct science-industry linkages – that industrial development really took off. Likewise, the commitment to establish a market economy in the early 1990s was instrumental in exposing China's innovation system to foreign knowledge.

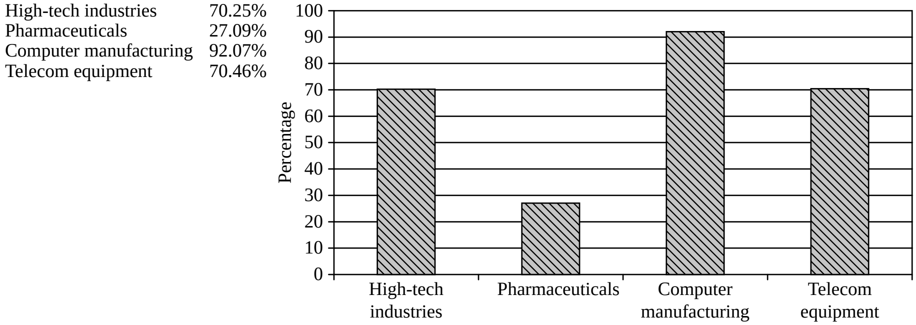
Growth in industrial output has been rapid throughout the last two decades. This also applies to those five industrial sectors that are classified by the OECD as high-tech and that are given the status of "pillar" industries by the Chinese central government. Notably, growth has been uneven between these sectors. Although the pharmaceutical industry enjoyed an eight-fold increase in output value between 1995 and 2008, it has been clearly lagging behind the computer industry (Figure 3). Several reasons may account for this difference in relative performance. Arguably, the most important of them is that the computer industry has been strongly penetrated by foreign direct investment (Figure 4). As has been discussed extensively in the literature, most of the output growth of the latter industry is due to the large-scale relocation of Taiwanese production networks to locations such as Dongguan in Guangdong province and

	Medical equipment and meters	Aircraft and spacecraft	Electronic and telecom equipment	Computer and office equipment	Pharmaceuticals
1995-2000	76.28%	44.10%	174.17%	373.10%	85.32%
2000-2005	205.61%	105.69%	181.99%	536.09%	138.61%
2005-2008	88.68%	50.41%	66.90%	54.62%	85.27%



Sources: NBS *et al*. (2009); own illustration

Figure 3.
Output growth in China's high-tech industries, 1995-2008

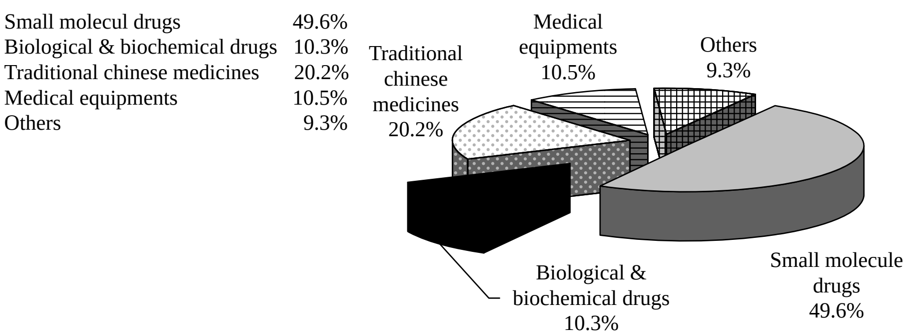


Sources: NBS *et al*. (2009); own illustration

Figure 4.
FIEs' share in high-tech industrial output in percent, 2008

Kunshan in Jiangsu province[4]. In comparison, the pharmaceutical industry has attracted substantially less FDI. Despite acceleration in recent years, the share of foreign-invested enterprises (FIEs) in gross pharmaceutical output has increased only from 19.6 percent in 1995 to 27.1 percent in 2008. Since 2005, however, the growth of both, the computer and telecom sectors appear to slow down, while the pharmaceutical and (even more so) the medical equipment sector have accelerated. Apparently, the leading role in the growth of China's pharmaceutical sector has been taken up by domestic manufacturers and – in contrast to other industries – not foreign investors. All this indicates different drivers and patterns of growth and development governing these sectors.

Growth has been particularly strong in biological and biochemical products. This segment includes genetically engineered drugs (recombinant proteins), mAbs, vaccines, and also blood products. The biopharmaceutical industry took off in the late 1980s, when China's State Food and Drug Administration approved the first indigenous genetically engineered drug, a recombinant alpha interferon against hepatitis B and C. But although growth has been rapid since the late 1990s, the segment is still small and accounted for merely 10.3 percent of China's whole pharmaceutical sector in 2008, up from 7.9 percent in 2005 (Figure 5). Much of this growth is due to a rapid expansion in biogenerics, while novel (non-generic) products have so far accounted for no more than an estimated single-digit percentage of sales. The loss of patent protection for many products in recent years has rendered this



Source: Adapted from CPEMA (2009)

Figure 5.
China's pharmaceutical industry by output value of market segment, 2008

choice a viable option to enter the industry. Technological barriers are rather low as simple and mature expression systems are available to manufacture generics (Hu *et al.*, 2006). However, due to the low entry barriers, competition is also very strong for most generic products.

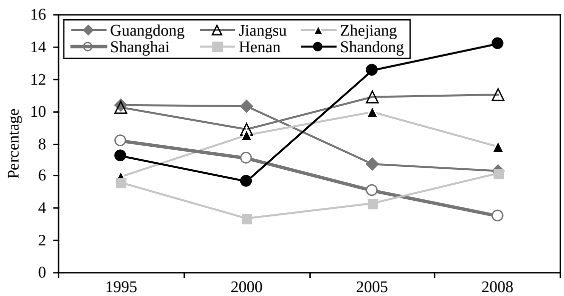
Despite several efforts of the Chinese government to rationalize (i.e. promote consolidation in order to create greater economies of scope and scale) the highly fragmented economic structure, entry in the sector has been strong. In 2008, there were more than 5,200 firms, 750 of which were doing biological and biochemical drugs (CPEMA, 2009). Most of these enterprises were small-scale operations. Among the 750 firms in the bio segment, all but three were SMEs.

At the beginning of the reform era, the Chinese pharmaceutical industry was highly fragmented and scattered around the country. This has basically remained a major characteristic of China's modern pharmaceutical industry as many provinces have copied central policies and declared the national pillar industry "pharmaceuticals" as a local "pillar" industry, as well. As a result, the Maoist feature of duplicated industry structures allowing for a high degree of local autonomy but also foregoing the rents of large-scale production and intensive interregional competition has been perpetuated in the reform era. However, the various provinces are different in importance with regard to gross industrial output, and their relative positioning has changed dramatically over time. As it appears, firms in some provinces have expanded faster, or seen from a different perspective, some provinces have managed to attract and nurture more enterprises than others. Most notably, Shandong province has vastly increased its share of gross pharmaceutical output to more than 14 percent of the national total in 2008 (Figure 6). This surge in output appears to be concomitant to the acceleration of biopharmaceutical development in the province. Indeed, Shandong's share in total national output is even larger in this segment (Table I). In turn, potential leaders in the high-tech industries, in general, such as Beijing, Shanghai, and Guangdong have seen their output shares decrease. Guangdong province, as it turns out today, is relatively stronger in small molecules (i.e. chemical drugs) than in biopharmaceuticals.

4. China's innovation policies and the biopharmaceutical industry

The Chinese state has supported the development of the biopharmaceutical industry with a set of direct and indirect policy initiatives (Kroll *et al.*, 2010). In principle, China's innovation policy can be divided into two phases: The first phase started with the 1985 "Decision on the Reform of the S&T Management System". On the one hand,

	1995	2000	2005	2008
Guangdong	10.40%	10.33%	6.75%	6.34%
Jiangsu	10.29%	8.93%	10.94%	11.08%
Zhejiang	5.93%	8.53%	9.95%	7.81%
Shanghai	8.21%	7.13%	5.11%	3.53%
Henan	5.61%	3.37%	4.33%	6.20%
Shandong	7.28%	5.67%	12.59%	14.22%



Sources: NBS *et al.* (2009); own illustration

Figure 6.
Changes in the provincial share of China's gross pharmaceutical output, 1995-2008

Province	Biopharmaceutical industry Gross output (million RMB)	Share in total output (%)	Rank	Pharmaceutical industry Share in total output (%)	Rank
Shandong	17,589	20.2	1	14.2	1
Jilin	11,136	12.8	2	4.4	8
Jiangsu	8,119	9.3	3	11.1	2
Henan	7,826	9.0	4	6.2	5
Zhejiang	6,152	7.1	5	7.8	3
Guangdong	5,060	5.8	6	6.3	4
Shanghai	4,534	5.2	7	3.5	10
Beijing	3,965	4.6	8	3.4	13
Liaoning	3,862	4.4	9	3.4	11
Sichuan	2,725	3.1	10	5.4	6

Sources: MIIT (2009); NBS and MOST (2009)

Table I. Provincial shares in gross biopharmaceutical output, 2008

major policy programs were launched, in particular the National High-Technology R&D Program ("863 Program") established in 1986. In conjunction with funds to improve R&D facilities, the 863 program has been devised to provide funding for research in a limited set of high-tech areas. On the other hand, the "Decision" put an emphasis on forging links between the public research institutes and industrial enterprises. By means of cutting government funding, public research institutes were forced to sell their technologies and services to enterprises, i.e. to the state-owned enterprises (SOEs), which dominated the economy at that time. Yet due to a lack of a complementary institutional framework, "technology markets" did not get off the ground but developed more than disappointingly.

The failure rested on the fact that most actors were still of the unwavering conviction that scientific research and its innovations constituted a public good. As a result enterprises often showed a habit of not paying royalties. At the same time, however, SOEs were often neither willing, nor did they have the innovative capacity to implement R&D projects. Given this constellation, public research institutes and universities rather opted to commercialize their home-grown technologies themselves (Eun *et al.*, 2006). Central and local governments, in turn, responded to the emergence of such academic spin-offs in a very accommodative manner and launched the Torch Program, designed to provide a suitable infrastructure and institutional support for the development of such technology-intensive enterprise start-ups.

The second phase started a decade later with the "Decision on accelerating the progress in S&T". At that time, the limits of the strong bias against basic research which had resulted from the structural overemphasis on commercial usability of innovation became evident. Although the Natural Science Foundation of China had already been founded in 1986, basic research was rather neglected until the mid-1990s. Only in 1997, the National Basic Research Program ("973 Program") was launched in order to strengthen basic research. Moreover, two programs, the 211 program and the 985 program, were initiated in 1995 and 1998, respectively, to give substantial financial support to a small number of excellent research universities. The CAS Knowledge Innovation Program introduced in 1998 was providing similar support for the CAS.

Among other high-tech sectors, these "big science" programs outlined above, i.e. the 863 and 973 programs, are targeting China's biotech sector. As documented in Table II, expenditures on both programs have prioritized health S&T. Interestingly, the funds have been spent quite unequally among the different provinces. In 2006, the last year when the regional distribution of 863 projects was published, Beijing accounted for more than one-third while Shanghai attracted another eighth of all 863 projects (Figure 7). This regional bias, however, does not come as a surprise as China's major academic R&D institutions are located in these metropolises. Although more recent numbers are not published, it is therefore safe to conclude that the regional differences persist.

While enterprise R&D has been strongly increasing in recent years, most of the more advanced research is done by academia, particularly by the institutes of the CAS and major universities. This also applies for the 863 program: Almost 84 percent of the projects are implemented by academia, whereas enterprises account for merely 15 percent. The same picture emerges on the output side. Patents are predominately emanating from Shanghai and Beijing (Figure 8), which is due to their comparative strength in academic research. Among the patent applicants, universities such as Shanghai Fudan University, Shanghai Jiaotong University, and Tsinghua University in Beijing as well as both cities' CAS research institutes are particularly active in the field of biotechnology. Patenting by domestic firms is on the rise in recent years, but there are still no firms among the most prolific patentees (NDRC and CSBT, 2008).

Apparently, a new division of labour between academia and industry is currently forged by the central government with academia intended to be mainly involved in basic

Table II.
Top 5 expenditure-categories on key government programs for S&T, 2006-2008

863 Program Field	Share (%)	973 Program Field	Share (%)
Biotech & Pharmaceuticals	17.9	Human & Health Science	18.4
Information Technologies	13.7	Interdisciplinary Research	16.0
Energy Technologies	12.4	Materials Science	14.3
Materials Technologies	9.8	Environmental Science	14.1
Maritime Technologies	8.8	Agricultural Science	13.0

Note: Due to yearly fluctuations, a three-year average was calculated
Sources: MOST (2007); NBS and MOST (2009)

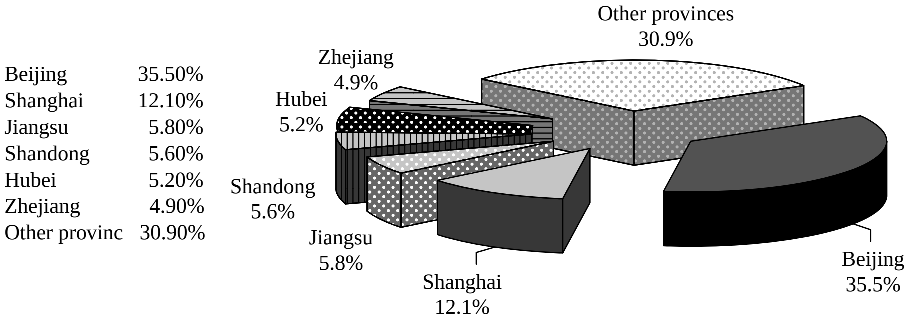
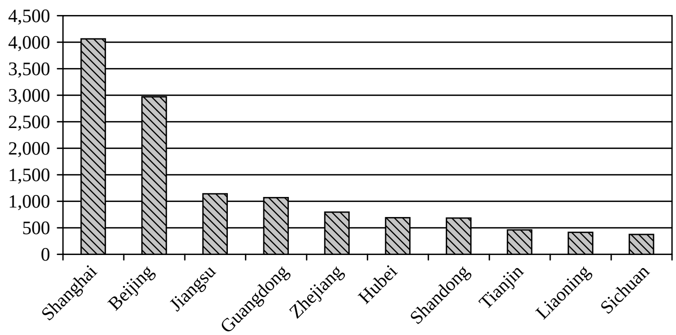


Figure 7.
Regional share of projects of the 863 program, 2006

Sources: MOST (2007); own illustration and applied basic research, while enterprises are supposed to take over the commercially relevant R&D activities. As government is advocating an "enterprise-centred" innovation system since the about turn of the century (Liu and Lundin, 2009), government policies have gradually shifted from direct policies, i.e. the large-scale programs, to indirect policies, i.e. institutional framework conditions trying to nudge enterprise behaviour in specific directions by means of specific sets of incentives and disincentives. This shift has been concurrent to a re-evaluation of the former focus on large-scale "national champions" (Ernst and Naughton, 2008). In addition to establishing the Innovation Fund for Technology-based SMEs in 1999, the constitution was amended to increase the security of private property rights. The "big science" programs were supplemented by tax incentives for R&D, government procurement policies for innovative products and a move to better protect intellectual property rights. In October 2009, the third amendments to the patent law took effect. The amendments do not only clarify issues concerning the patentability of designs, but also with respect to genetic resources (Cheng, 2009), which is directly relevant for the biotechnology sector.

Efforts have also been undertaken to improve the framework for the venture capital industry. In recent years, two new exit mechanisms have been introduced: In 2004, an SME board was launched in Shenzhen and in October 2009, the ChiNext, a Nasdaq-style growth board likewise located at the Shenzhen Stock Exchange, was opened. Initially, 28 companies are traded on the ChiNext, four of them pharmaceutical companies (cf. Mitchell and Fu, 2010). Overall, China's large banking sector and capital markets are however not yet prepared to supply SMEs with finance. As an idiosyncrasy of the Chinese system, local governments have stepped into provide start-up and growth capital (White *et al.*, 2005). The Torch Program mentioned above serves as a platform to extend all sorts of preferential policies to targeted firms, with differences between localities. Whereas the 863 and 973 programs are largely managed by the central government, the Torch Program is handled by local governments that keep on intervening directly to support economic and corporate development in their localities. The Torch Program is set up as an infrastructure program supporting technology-intensive firms through the establishment of industrial zones and incubating facilities. The centrepiece of the program are the "high and new technology industry development parks". Until recently, 56 of them have been sanctioned by the central government as national-level parks, while about 120 local-level parks exist. Within these parks, some specialized incubating facilities have been established. Among them, 62 national-level university parks are

Shanghai	4,061
Beijing	2,970
Jiangsu	1,140
Guangdong	1,069
Zhejiang	795
Hubei	692
Shandong	684
Tianjin	461
Liaoning	413
Sichuan	376



Source: Adapted from NDRC and CSBT (2008)

Figure 8.
Domestic applications for invention patents in the field of biotechnology, 1997-2006

catering to academic spin-offs. Some other parks have targeted returnees, i.e. Chinese professionals with academic and work experience abroad, which are willing to establish an enterprise in China. Moreover, specialized industrial bases have been set up under the Torch Program, which are supposed to support industrial clustering. Almost 30 of these bases are targeting the pharmaceutical industry, most of which are located in Jiangsu province and Shandong province (Table III).

5. Strategic location decision and regional specialization

The Chinese state's innovation policies constitute an important part in the environment governing the development of the biopharmaceutical industry. Arguably, these policies have made a reasonably strong contribution to strengthening domestic health biotech R&D and to commercializing research results. Government policy has also sought to influence the spatial structure of China's biopharmaceutical industry. In fact, one of the key ideas behind the Torch Program was and still is the stimulation of cluster synergies and the realization of positive network externalities. The devolution of regulatory authority over the local economy and command over sizable budgets have provided local governments with the means to foster industries within their jurisdictions. Given this constellation and the fact that government intervention into industry development is particularly strong in China, research on regional innovation systems has usually concentrated on local government policies and initiatives (e.g. OECD, 2008). However, firm clusters are not only the outcome of purposeful government action but are also determined by a broad range of other determinants

	Number of tenants	Industrial output value (million RMB)	Exports (million USD)
Jiangsu Province			
China Torch Program "Three Medicine" Industrial Base of Changzhou City's Xinbei District	89	9,400	248
China Torch Program Advanced Medicine Industrial Base of Lianyungang	24	7,682	26
China Torch Program Biological Medicine Industrial Base of Qidong (Nantong)	21	4,286	31
China Torch Program Medicine Industrial Base of Taizhou (Jiangsu)	202	19,530	660
China Torch Program Wuzhong Medicine Industrial Base (Suzhou)	20	5,307	158
China Torch Program Pukou Biological Medicine Industrial Base of Nanjing	21	1,502	0.5
Shandong Province			
China Torch Program Biology Engineering and Advanced Medicine Industrial Base of Jinan	80	2,988	21
China Torch Program Biology Industrial Base of Jining	35	9,289	47
China Torch Program Biology Industrial Base of Yucheng (Dezhou)	25	2,735	20
China Torch Program Biological Medicine Industrial Base of Zibo	42	12,302	298

Source: Torch (2009)

Table III.
Torch Program drug manufacturing parks at Jiangsu and Shandong in 2008

and decisions made by decentral actors that are involved in enterprise formation. The strategic location decision these actors make are a decisive factor for understanding the spatial dimension of production and innovation in China. Thus, we now turn to the micro level of China's industry evolution in order to better appreciate the determinants of the spatial distribution of biopharmaceutical companies over the country. We distinguish between four types of firms: state-owned business groups, FIEs, returnee enterprises and domestic non-state enterprises.

State-owned business groups

When reforms started in the early 1980s, China had already established a basic structure of pharmaceutical plants and pharmaceutical research institutes. The location of plants and institutes resulted from the decisions of the central planning authorities guided by temporally varying political (and military) considerations. For example, the launch of the "third front" in the mid-1960s aiming at establishing a complete industrial base in China's hinterland contributed to a geographical dispersion of the initial sectoral system. During the 1980s, the central government started to encourage the formation of business groups with the objective of emulating Japan's and Korea's development model (Keister, 2009). Existing enterprises were connected under a state holding structure but this was not accompanied by a relocation of plants. In many cases, this group structure was existing on paper only, but in other cases relatively frequent in-group trade and financial interactions emerged. A notable problem, due to the strong specialization of the pre-reform era, the plants had a very limited innovative capacity, which hampered the reform of SOEs. One way to solve the problem was seen in merging public R&D institutes with SOEs, but this approach largely failed (Gu, 1999).

As the biopharmaceutical sector emerged rather recently, the state-owned groups populating this segment have not had the problems the traditional SOEs faced. The most important group, the China National Biotec Group (CNBG),[5] is one of a new-style type of SOEs that has emerged particularly since the late 1990s. When many industry-specific ministries were abolished in 1998, the research institutes formerly subordinated to these ministries were to a large extent transformed into enterprises. In 1999, the first badge of 242 research institutes started this peculiar transformation process followed by institutes of other ministries and local governments (Sigurdson, 2005). The CNBG anticipated these transformations. Its predecessor, the China National Biological Product Corporation was formed in 1989 following the corporatization of seven research institutes subordinate to the Ministry of Health. These institutes for biological products are spread all over the country, being located in Changchun (Jilin province), Chengdu (Sichuan province), Lanzhou (Gansu province), Shanghai, Beijing, and Wuhan (Hubei province). In addition, two biopharmaceutical manufacturers have been integrated into the group at a later stage: Beijing Tiantan Biological Products, established in 1998 by the Beijing Institute of Biological Products, and Chengdu Rongsheng Pharmceuticals, established in 1997 by the Chengdu Institute of Biological Products (BioPlan, 2008). CNBG, headquartered in Beijing, is the leading manufacturer of vaccines and blood products.

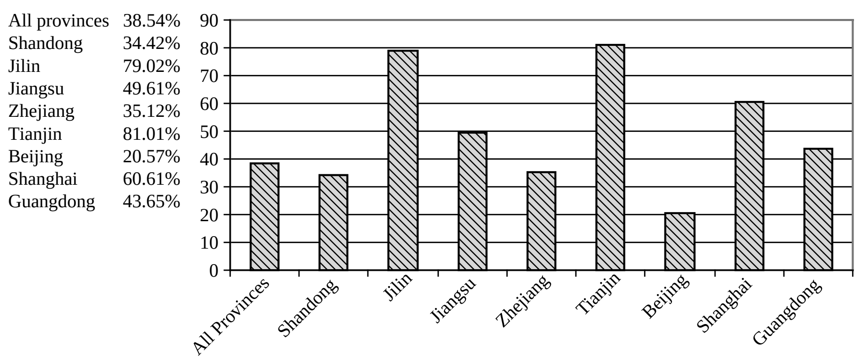
Due to the dispersion of institutes-turned-companies, some provinces have been put on the map of China's biopharmaceutical industry, although they feature no start-up community or cluster initiatives. An example in case is the Lanzhou Institute of

Biological Products, which accounts for more than 90 percent of Gansu's sales revenues in this market segment.

Foreign-invested enterprises

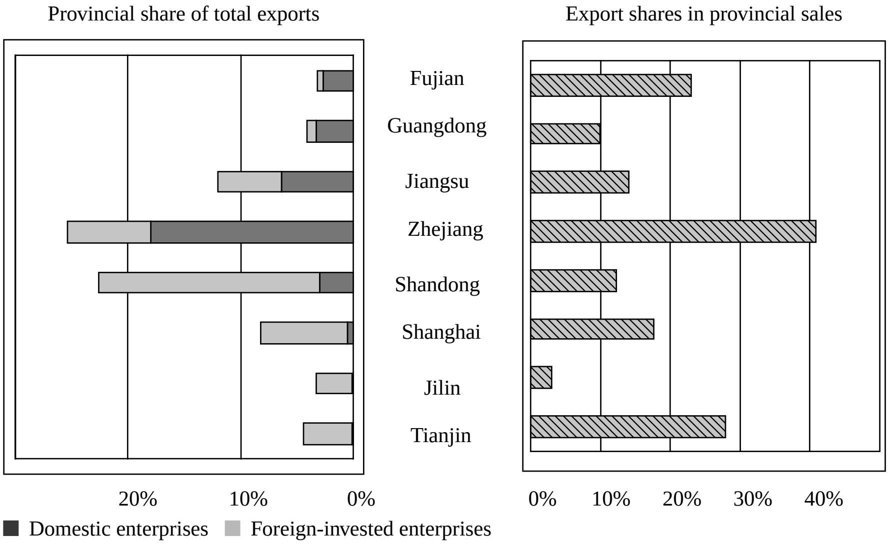
One of the key features of China's high-tech industries is the high share of FIEs in domestic market and export sales revenue. But, although FIEs are also playing a role in the pharmaceutical industry, industry penetration by FIEs was until recently not nearly as high as, for example, in the computer industry (Figure 4). This also applies for the biopharmaceutical segment, even though the share of FIEs is more than ten percentage points higher than for the whole industry (Figure 9). Unsurprisingly, FIEs have not spread evenly across the country. The majority of gross output in Jilin, Tianjin, and Shanghai is produced by FIEs. In Shandong and Jiangsu the share is lower but this is due to the strong performance of domestic manufacturers. In absolute terms, the output of FIEs in Shandong is higher than that of the FIEs in the three provinces listed above combined.

During the 1980s and 1990s, China has attracted FDI on a large-scale by establishing an export-processing regime (Naughton, 2007). In particular, the strong performance of China's computer industry has been due to the integration into Asian production networks. This integration was made possible by the relocation of component suppliers from Greater China, most importantly Taiwan, to the mainland. As a consequence, foreign trade surged with FIEs being responsible for almost all exports (Gaulier *et al.*, 2007). In the biopharmaceutical industry, however, different development patterns apply. Exports have not been the main driver of the biopharmaceutical industry. In 2008, exports accounted for just 10 percent of total sales revenue. They were also not the main reason for FDI in this industry as merely 16 percent of FIEs' sales are due to foreign trade. Altogether, FDI into this industry has been lagging behind that in other high-tech industries, and foreign investors appear to mainly target the post-WTO domestic market. But there are some notable geographical differences. In those provinces, where FDI is particularly strong such as Jilin, Tianjin, Shandong, and Shanghai, FIEs are dominating exports (Figure 10). In Jiangsu and especially in Zhejiang the absolute value of FIE exports is high, but the main exporters are domestic companies. Most surprisingly, the exporting powerhouse, Guangdong province, contributes rather weakly to China's pharmaceutical exports. And most of these exports are done by



Sources: MIIT (2009); own illustration

Figure 9.
FIEs' share of provincial biopharmaceutical output, 2008



Sources: MIIT (2009); own illustration

Figure 10.
Export performance of selected provinces, 2008

domestic manufacturers. Since the province's FIEs contribute more than 40 percent of provincial pharmaceutical output value, these companies are obviously focusing on the domestic market and not on exports.

Besides manufacturing, FIEs may also be attracted to conduct other activities in China. Indeed, in recent years many multinational companies have set up R&D establishments in China. Xue and Liang (2008) show on the basis of the Business Week 1000 that most of the autonomous R&D centres are located in Beijing and Shanghai, while foreign corporate R&D centres in other provinces are usually attached to manufacturing activities. In the pharmaceutical industry, Shanghai was particularly successful in attracting foreign R&D centres. While multinationals such as Novo Nordisk have established an R&D centre in Beijing, most of the newly established autonomous institutes, including those of Astra Zeneca, Glaxo Smith Kline, and Eli Lilly are situated in Shanghai's Zhangjiang science park. The operations of the multinationals are clearly regionally specialized. Novo Nordisk has its R&D centre in Beijing and its manufacturing base in neighbouring Tianjin; Eli Lilly opened its R&D centre in Shanghai, while keeping its manufacturing operations in Suzhou (Jiangsu province). Notably, Shanghai differs to most other cities, including Beijing, in that the city has attracted both, foreign R&D and manufacturing.

But on the whole, the division of labour is that Shanghai, and to some extent Beijing, is attracting research-intensive foreign activities, while other provinces act as manufacturing bases. This has several advantages: In Beijing and Shanghai are the major research institutes and universities that provide both, high-skilled labour and access to domestic R&D output. Eli Lilly, for example, works closely with domestic contracted research organizations in Shanghai (Jia, 2009). In turn, most of the manufacturing takes place in the direct surrounding of Beijing, i.e. Tianjin, and of Shanghai, i.e. the cities in Jiangsu bordering Shanghai, where land and labour is less expensive.

Returnee enterprises

In recent years, the phenomenon of return migration has gained increased attention. Significant numbers of Chinese (and Indian) entrepreneurs with extended study and work experience in developed countries, in particular the USA, have returned to their home countries to improve the research landscape or start an own company. These highly skilled individuals keep contact to their former host country and effectively span networks (Saxenian, 2005). China's biopharmaceutical industry has vastly gained from this return migration and local governments have been competing to provide the best incentive packages designed to lure these companies to locate in their parks.

Examples of returnee enterprises abound, including WuXi AppTech (formerly Wuxi PharmaTech) located in a city of Jiangsu province near Shanghai, which is an outsourcing firm that assumes laboratory and manufacturing services for leading pharmaceutical companies such as Merck. Shandong Simcere Medgenn Bio-pharmaceutical, which was founded by a returnee with a PhD degree from the Department of Molecular and Cell Biology at the University of California at Berkeley, has pioneered a recombinant protein against non-small-cell lung cancer. ACON Laboratories, a diagnostic company founded by a returnee from the US, is one of China's top pharmaceutical companies with respect to revenues. As it is focusing on the international markets, it is one of the companies that explain the excelling export performance of Zhejiang province.

As it appears, returnee enterprises are usually not established in Beijing and Shanghai but rather in provinces such as Jiangsu, Zhejiang, and Shandong. Despite their relatively strong R&D performance, they rather locate in areas that are also targeted by foreign multinationals as manufacturing bases. This may be due to the fact that many returnee enterprises are more focused on international relationships (Frew *et al.*, 2008). This approach is different to that of leading multinationals, which decide to locate their more R&D-intensive operations in the major municipalities in order to tap the local knowledge base.

Domestic non-state enterprises

The types of firms covered so far have powerful relationships to potent actors and access to financial resources. As has been pointed out, China's banking sector is strongly geared towards financing SOEs (Lardy, 1998; Huang, 2003). At the same time, Chinese subsidiaries of multinational firms have sufficient financial support from their parent company to expand into the Chinese market. In turn, some of the more successful returnee firms have international ties that help in accessing sources of capital. Foreign venture capitalists have especially targeted these returnee enterprises. Recently, they have also been targeted by local governments that want to expand the economy within their jurisdiction.

Domestic non-state SME, private or not, in comparison have much less access to financial resources. In order to compensate for this disadvantage, however, many of these companies have started to shop around the country in order to access local governmental sources of capital. As a result the picture of a large numbers of small-scale enterprises scattered around the country, which suggests a highly fragmented structure, is misleading. In reality many of these enterprises are, in fact, interrelated and constitute multi-regional enterprises striving to tap as many local sources of finance as possible. A representative firm is Shanghai Fudan-Zhangjiang Bio-Pharmaceutical. The company was established in 1996 by six teachers from Fudan University.

In the development of the firm, the Shanghai government was instrumental. In fact, Zhangjiang High-tech Park, which is managed by the municipal government, is one of the major shareholders of the joint-stock company. Following a strategy similar to the one of multinationals like Eli Lilly, the company has established a manufacturing firm in Taizhou (Jiangsu province). In lieu for this location decision, the Taizhou government has invested strongly into Fudan-Zhangjiang's manufacturing firm. Other companies have followed similar strategies. In fact, in our interviews, most respondents have stated that local governments have been quite generous in supporting the development of their firms or their subsidiaries. Hence, one of the major reasons why some provinces have increased their share of total pharmaceutical output value appears to be that they have provided the best conditions for this type of firms, in particular with regard to finance.

The parks, which have been established by local governments, have by some authors been viewed as a waste of resources, because a technology-intensive industry like the biopharmaceutical industry needs adequate R&D, which is not given in many localities outside Beijing and Shanghai (Jia *et al.*, 2003). While this cannot be denied in some instances, critics have failed to see the increasingly complex and value creating relations between enterprises from different regions. While a decade ago, firms usually remained within the confines of their locality, the recent improvement of property rights delineation and protection has rendered multi-regional enterprise groups a viable option. In their expansion, small local firms have turned into highly capacitated multi-regional enterprises – for reasons that differ from those of their foreign counterparts. As banks are still inefficient in their fund allocation and domestic stock markets immature, the financial support extended by local governments via park administrations and government venture capital funds has been extremely useful in the expansion of an indigenous industry.

6. Conclusion

In recent years, a number of biopharmaceutical companies with high potential have emerged in China. These companies have proven their ability to innovate sophisticated drugs based on biotechnology. Indeed, the first enterprise worldwide that put a gene therapy drug on the market, was SiBiono Genetech, a Chinese company. Yet although China appears to catch up in this market segment, our knowledge of this industry remains very limited. We understand this contribution as an exploratory exercise designed to shed some additional light on the structural build-up and especially the specific regional parameters shaping China's biopharmaceutical industry.

Based on the information compiled, we have outlined China's geography of innovation. As a result of both, government policy and the strategic location decision of economic actors, several firm agglomerations have developed in China. As it appears, a regional division of labour is gradually emerging. Beijing and, even more importantly, Shanghai is turning into an internationalized hub for advanced R&D, while the provinces surrounding these municipalities have attracted manufacturing activities of both, foreign and domestic enterprises. This division of labour is driven in particular by the financing needs of enterprises. As China's capital markets are still rather immature, local governments have taken over an important role as venture capitalists. As these governments cannot provide a substitute for private venture funding, the development of the industry will be hampered as long as China does not manage to establish a proper capital market. Moreover, as governments have biased incentives, venture financing may lead to a geographical dispersion of the industry that is not viable in the long run.

The problem of geographical dispersion may, however, be not as problematic as is often portrayed in the literature. Many of the impulses for enterprise formation and expansion in China actually originate from Shanghai or Beijing. It is the firms and research organizations of these cities, which are responsible for a large number of enterprise start-ups not only in these two cities, but all over China. Therefore, it does not suffice to look at the institutional and infrastructural environment of an individual cluster in order to evaluate a firm's support for innovative activities. In China, there appears to exist two diametrical tendencies: On the one hand, we can see firm clustering in a number of localities. But on the other hand, these firms' networks are interregional. The interactions across clusters constitute a highly interesting development that requires further research.

In any case, it seems as if the Chinese Achilles is learning how to solve Zeno's paradox and outrun the tortoise – not yet, but probably soon.

Notes

1. There has been an earlier analysis provided by Liu and Lundin (2007). But their paper has remained at a preliminary stage.
2. Other approaches include Whitley's (1999) "national business systems", Amable's (2003) "social SI and production", and Porter's (1990) "industrial clusters".
3. A third way to identify boundaries would be in terms of particular technologies (Carlsson *et al.*, 2002). However, this approach appears rather challenging, because most technologies are used in different industrial sectors featuring quite distinctive organizational processes.
4. See Gaulier *et al.* (2007) and Yang (2009). Indigenous enterprises made an appearance in the international markets as well, including Legend/Lenovo in the computer industry, and Huawei in the telecom equipment sector. Zhou (2008) and Ernst and Naughton (2008) have argued convincingly that these enterprises profited from the influx of FDI.
5. In September 2009, the State Assets Supervision and Administrative Commission, which exercises the property rights of the state, announced that CNBG will be merged with China National Pharmaceutical Group (Sinopharm), an old-style SOE (Business Forum China 6/09). Whatever the reasons, CNBG will cease to exist, but this will not decisively change the organization of the subordinate enterprises.

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