Anatomy of cluster development in China: the case of Health Biotech Clusters

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Received 12 September 2011
Revised 28 October 2011
Accepted 5 December 2011

Anatomy of cluster development in China: the case of Health Biotech Clusters

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Abstract

Purpose – The purpose of this paper is to analyze the dynamics of China's health biotech clusters from an interregional perspective. By treating clustering as the result of firms' localization choices, the paper examines whether and why different types of firms agglomerate in the various locations.

Design/methodology/approach – The paper employs a demographic approach that is inspired by the 2006 work of Romanelli and Feldman on cluster development in the USA. It categorizes China's clusters based on differences in the degree of policy support and the nature of the science base. Then, it draws a sample of 75 of China's most visible firms and analyses them in terms of entrepreneurial origin, their location and, if applicable, the location of their subsidiaries. By matching types of firms with types of clusters, the paper highlights some characteristics of China's regional development.

Findings – Studies on China's high-tech agglomerations unanimously complain about a lack of "creative buzz" compared to the vibrant clusters of for example, the Bay Area in the USA. The analysis indicates that the lack of a creative culture is associated with the anatomy of cluster development. China's clusters grow to a significant extent by attracting enterprise subsidiaries to their sites. The authors argue that these particular cluster anatomies are founded on China's capital market. As the capital market is not prepared to provide pre-revenue firms with sufficient funds, firms have to earn revenue quickly in order to ensure their viability. Therefore, they concentrate on building up manufacturing capacity and exploiting given technologies. The main point is that local governments as major providers of financial support are instrumental in this process. The establishment of manufacturing subsidiaries in various locations rests on the rationale of collecting funds. This leads to the conclusion that national capital markets either reinforce or inhibit clustering depending on how much it allows the mobility of financial capital. Local government funds do not travel far. This has an impact on the firms' localization decisions and their business strategies, which, in turn, affects the "culture" inside the clusters.

Research limitations/implications – This argument is based on a limited number of interviews conducted by the authors or other researchers. In order to corroborate the link between the capital market and local development trajectories, more evidence needs to be collected via interview surveys and other means to extract financial information.

Originality/value – Unlike other research on Chinese clusters, this paper offers an interregional perspective based on a demographic approach. The argument is original in linking regional cluster dynamics with the national institutional set-up.

Keywords China, Health biotechnology, Cluster, Demography, Business models, Venture capital

Paper type Research paper

Journal of Science and Technology Policy in China
Vol. 3 No. 2, 2012
pp. 124-144

1758-552X
DOI 10.1108/17585521211256982

1. Introduction

Researchers with diverse disciplinary backgrounds have identified industrial clustering, the co-localization of related firms and institutions, as a fundamental cause of regional differences in prosperity and welfare (Krugman, 1991; Storper, 1992; Cooke *et al.*, 1997; Porter, 1998; Breschi and Malerba, 2001). Despite removals of trade barriers and major reductions in transportation and communication costs, local environments are considered as a continuing source of competitiveness for individual firms. Empirical studies on health biotechnology clusters have shown that research universities, local access to venture capital, adequate infrastructure and support services as well as active social networks are key success factors (Chiaroni and Chiesa, 2006). Many of these attributes can in principle be manipulated by industrial policy and, indeed, the various approaches have been very appreciated by policymakers around the world. As a consequence, countless science parks, industrial bases, technopoles, etc. have sprung up to provide the environment thought to be conducive to the development of selected industries.

During the past decades, industrial agglomerations have also emerged all over China. While most of them focus on low-tech industrial sectors (Wang and Tong, 2005), technology-intensive sectors are particularly encouraged and supported by the Chinese Government as the utilization of new technologies – such as biotechnology – promises to provide "windows of opportunity" to enter markets or market segments still devoid of strong incumbent firms (Perez and Soete, 1988). Currently, there are about 50 national-level pharmaceutical and biotechnology industrial bases scattered around the country. A growing body of literature has targeted these and other science-based clusters as an object of inquiry. Both kinds of studies, those with and without a sectoral focus, usually draw the conclusion that China's parks miss the "creative buzz" resulting from strong regional firm interaction (Cao, 2004; Sutherland, 2005; Wilsdon and Keeley, 2007; Su and Hung, 2009). By analysing the prevalent structures of China's clusters and comparing their main characteristics with those of model clusters, these studies are instructive in that they point to some structural deficiencies. We argue, however, that a more dynamic analysis can significantly enhance the evaluation of China's cluster development and the formulation of policy recommendations. This is because, first of all, the Bay Area ("Silicon Valley") model that currently provides the general benchmark for policy design and the evaluation of cluster success is based on the characteristics of a rather mature cluster. That is, the features of that model, which are extensively worked out in the literature, were not present when the cluster emerged (Feldman and Braunerhjelm, 2006). It is thus difficult to compare China's still nascent agglomerations with the ideal. Second, empirical studies demonstrate that clusters can feature quite different structures in the sense of cluster-internal and external linkages (Markusen, 1996). The diversity of cluster organization hints at the possibility that historical dynamics prevent clusters (like other kinds of organizations, cf. Aoki (2010)) from converging towards identical structures.

The purpose of the present paper is to contribute to an understanding of the dynamics of China's health biotech cluster development. In order to capture the historical processes, our starting point is the idea that cluster expansion is driven by the establishment of new firms and that local dynamics (and prevalent structures) depend on what type of firms are established and what type of business strategies are pursued. By employing an interregional perspective, clustering is basically treated as the result of firms' localization choices. This perspective provides the rationale for our empirical analysis. Concerning types of firms our investigation is informed by Elaine Romanelli's and Maryann Feldman's pioneering work on the anatomy of cluster development in the USA. Their demographic approach seeks to trace "the organizational and geographic origins of entrepreneurs and firms who populate an industry cluster" (Romanelli and Feldman, 2006, p. 87). Accordingly, we examine whether and why certain types of firms agglomerate in particular locations in China. Our approach will be shown to be instrumental in identifying patterns of cluster development and linkages to the macro-institutional environment that are neglected in the aforementioned studies on China's science-based clusters. In particular, we highlight the impact of China's capital market on the firms' localization decisions, their business strategies and, in turn, the "culture" inside the clusters.

The paper is organized into four further chapters: in Section 2, we explain the theoretical foundations of our demographic approach. The theoretical chapter is followed in Section 3 by an analysis of China's cluster development. We categorize China's clusters based on differences in the degree of policy support and the nature of the science base. Then, we draw a sample of 75 of China's most visible firms and analyse them in terms of entrepreneurial origin, their location and, if applicable, the location of their subsidiaries. By matching types of firms with types of clusters, we highlight some characteristics of China's regional development. In Section 4, we analyse the findings in the light of previously published interview surveys of China's health biotech sector and our own interviews. On that basis, we develop our argument that cluster anatomies are closely linked to the prevailing institutional and structural set-up of the (venture) capital market. We argue that this relationship holds not only for China, but for other economies as well. Section 5 concludes.

2. Theoretical foundations of cluster formation

2.1 The use of co-location

Despite ongoing globalization, industrial activities remain concentrated in a few regions. Geographic proximity apparently offers advantages that render co-location of firms attractive. Alfred Marshall already identified three types of positive externalities that individual firms enjoy when they are co-located with a sufficiently large amount of other firms performing complementary and even rivalling activities: a pooled skilled labour market, opportunities for product specialization and knowledge spillovers (Krugman, 1991).

Basically, agglomeration economies can be rationalized as conferring informational advantages that increase the opportunity sets for suppliers and potential users of specialized inputs. With regard to labour markets, suppliers of human capital (skilled workers) are attracted to the enterprise cluster as they are able to choose from a larger number of employment opportunities. Employers, in turn, profit from the larger and more diverse pool of potential employees. This is particularly helpful for small enterprises that have not yet managed to gain a reputation and scale that catches the attention of potential employees. Small enterprises can more easily find staff because the existence of further employment opportunities in the region reduces the risk of any employee with regard to accepting a position in a fledgling firm. Indeed, a vibrant cluster distinguishes itself by workers identifying themselves with a region such as Silicon Valley or Hollywood instead of a particular firm. In principle, a similar logic also applies to specialized suppliers and users of services and of intermediate products as well as suppliers of early-stage financial capital, if the latter's monitoring of investee firms requires them to reside in geographical proximity (Gompers and Lerner, 2001). In other words, clustering is driven by a shared belief among (ignorant) agents that the opportunities (the likelihood of "meeting" or "learning") at a given location are larger than those in other locations.

Besides private inputs, clustering of firms also has advantages in attracting public investments (Henderson, 1986). The more firms of a given industry agglomerate in a location the more the industry is recognized as vital to increasing the tax revenue of the government (and thus the region's welfare). This renders it more likely that (local) governments devise preferential policies and invest into an infrastructure adequate to the further development of the industry[1]. To put it succinctly, the likelihood of meeting an industry-friendly government rises with the number of resident firms.

In vibrant clusters, the beliefs of firms and entrepreneurs get reinforced as their access to inputs such as human and financial capital, intermediary products and services as well as technologies affords them a competitive advantage over rivals from other regions. Access, in turn, is a knowledge-intensive affair. The literature has identified two different kinds of processes in which geographical proximity can play an important role. On the one hand, the nature of knowledge may render frequent face-to-face (or firm-to-firm) interaction necessary. The more "tacit" specific kinds of knowledge are, the more its diffusion hinges on personal contact and interactive learning (Jensen *et al.*, 2007). On the other hand, the governance of exchange relationships – most importantly, the exchange of knowledge – may be facilitated through interaction in local networks, in which misconduct becomes readily known and punished by the community. In this sense, localized networks provide a hybrid mode of governance between market and hierarchy (Williamson, 1991). However, none of these processes need to be necessarily localized. While geographic proximity facilitates information searches and task coordination, location may matter more for certain types of activities and industrial sectors than others (Feldman, 1999). As to science-based industries like biotechnology and pharmaceuticals, much of the new knowledge created is codified so that the general problem particularly concerns the interpretation of the "code"[2]. Knowledge diffuses in "epistemic communities", whose members share the prior related knowledge (the "absorptive capacity", cf. Cohen and Levinthal (1990)) needed to understand new ideas. By the same token, inter-firm networks usually extend beyond a region. In fact, several authors have pointed out that cluster-external linkages are important for a firm's competitiveness (Orsenigo, 2006). Malmberg and Power (2005) again find little evidence in their review of the empirical cluster literature that firms are tightly interconnected within clusters. Hence, while in the first case "cognitive" proximity appears to trump geographical proximity, in the latter case it is organizational proximity that matters (Boschma, 2005).

As it appears, knowledge spillovers are more informal in nature and often a by-product of social dynamics, in particular local labour market dynamics (Breschi and Lissoni, 2001; Malmberg and Power, 2005). In effect, we may argue that while clustering is based on the perceived likelihood of meeting related people and firms, the knowledge gained through actual meetings – opportunities, shared perceptions, routines and values – accounts for the advantage of residing in a particular cluster (Malmberg and Maskell, 2006). This kind of knowledge is less concrete, less deliberate and more subtle than, for example, explicit technical knowledge and is substantially predicated on the societal background (Gertler, 2003). Most of all, the types of organizations residing or getting established in a region enable or restrict the opportunities for different kinds of knowledge exchange. Organizations differ in their range of activities and, therefore, their need for (local and extra-local) interaction with other organizations. They may have different needs for particular input markets. Hence, we can expect that local firm demography has a decisive impact on the "cultural" beliefs that account for particular characteristics of a given cluster.

2.2 The dynamics of clustering

While increasing returns to agglomeration reinforce the advantages of particular locations over others, a basic problem consists of triggering a virtuous clustering cycle. If we assume, for a moment, that input endowments and psychological attitudes towards entrepreneurship are equally distributed across space, then there need to be local events that set regions apart. Chiaroni and Chiesa (2006) have identified two generic forms of cluster creation in biotechnology. One of them are spontaneous clusters where clustering is started by an initial upswing of entrepreneurship based on some chance events. A second method that has been employed in order to raise the saliency of a region is to trigger clustering through planned government action. According to this approach, an agency is established (e.g. a science park administration), which proactively promotes the development of a local industry. In principle, both of these forms – spontaneous and policy driven clusters – can, but do not have to, generate a virtuous cycle. As Feldman and Braunerhjelm (2006) argue, the genesis of a cluster does not tell what happens in following phases of a cluster's life cycle.

If the initial firms are able to grow into viable enterprises, a second phase sets in. As a stylized process, the following phase is described by Feldman *et al.* (2005, p. 133) in this way:

> Having the experience and example of the initial start-ups, the successful cluster becomes self-sustaining: entrepreneurs attract physical and human capital to the area, public and private networks are built up to support and facilitate the ventures, relevant infrastructure is created through public and private initiatives and services grow to feed these companies.

There is a noteworthy point in this description: in order for clusters to expand, inputs to the sector have to increase by means of production within and/or attraction of inputs from outside the cluster. This, in turn, implies that national factor markets play a role in local dynamics. Hence, while the competitive advantage of a region is based on internal organization, the internal dynamics and the extent of local variation is limited by national institutions such as the capital and labour market.

As Romanelli and Feldman (2006) show with regard to health biotech clusters in the USA, regions develop in idiosyncratic ways through the establishment of particular firms. In line with their approach we can distinguish between following types of firms that, at the time of their establishment, display different types of organization in the sense of firm-internal and -external input linkages:

- *Start-ups or spin-offs from a university or public research institute.* Academic spin-offs represent one of the main forms of science-industry linkages. In science-based industries, these firms play an important intermediary role in the diffusion of scientific knowledge (Stuart *et al.*, 2007).

- *Start-ups or spin-offs from existing enterprises.* Industrial spin-offs concern new enterprises formed by employees of existing enterprises. Thus, they can be viewed as "second-generation entrepreneurship" (Romanelli and Feldman, 2006). According to previous studies of this phenomenon, these spin-offs often pursue business strategies that are related to the ones of the parent firms, but without posing a substantial threat to their parents (Klepper, 2001). With regard to biotechnology, the highly successful cluster of San Diego in the USA has been described as an outstanding example of how this second-generation entrepreneurship can propel a region's cluster development (Casper, 2007). In fact, Romanelli and Feldman (2006) have singled out this phenomenon as the most decisive factor that differentiates vibrant regions from those staying behind.
- *Subsidiaries of enterprises.* The establishment of subsidiaries usually trails the successful take-off of a regional cluster. Enterprises from other regions and/or sectors are lured into the cluster following their belief about opportunities to tap particular local assets. Above all, the localization decisions of multinational enterprises (MNEs) are important. On principle, their investments are input (human and financial capital, knowledge) seeking, market seeking or efficiency seeking (Dunning, 1998). With regard to biotechnology, European MNEs have predominately entered regions in the USA in order to tap local knowledge.
- *Wholesale re-locations of existing firms.* As an effect of the salience of a region, enterprises re-locate to the cluster in order to enjoy the more favourite environment. Like subsidiaries, the firms' decisions reinforce the divergence of regional expansion trajectories.

Altogether, several regions may spawn a number of related enterprises. However, the locations, which are at the risk of becoming a cluster, differ in their internal dynamics. On the one hand, there exists a demonstration effect. Successful spin-offs fire the imagination of would-be entrepreneurs and, possibly, that of venture capitalists. Particular types of firms attract similar endeavours thus forming an idiosyncratic development trajectory. One of the examples is the San Diego cluster mentioned above. Another vivid example is Romanelli and Feldman's (2006) discussion of the New York region, where most of the expansion is due to subsidiaries and relocations, while indigenous start-up activity already ceased very early in the cluster's life cycle. On the other hand, the organizations that exist at a certain point of time provide opportunities for further entrepreneurship. These opportunities, however, differ across clusters according to the business strategies local firms pursue. Business strategies differ with regard to the integration or specialization of activities of the supply chain, product portfolios and the firms' readiness for cooperation and knowledge exchange with other organizations. Depending on the business strategies and respective organizational forms, local opportunities for specialization and the diffusion of knowledge diverge. As a consequence of the dynamics at the first and second stage of a cluster's life cycle, the time of entry into the third (maturation) stage and the structure of clusters at that stage should therefore differ substantially between clusters. Below, we examine the first two stages in the development of China's clusters in health biotechnology.

3. Sketches of China's health biotech cluster development

3.1 Cluster genesis

Since the early 1990s, China has spawned numerous agglomerations related to the pharmaceutical and biotechnology sector. Several policy programmes were launched to support local cluster development. Among them, the Torch Programme initiated in 1988 by the Ministry of Science and Technology (MOST) concerns the establishment of high-tech development zones (science parks) and industrial bases[3]. The currently 67 national-level science parks are set up with the intention to promote science-industry linkages – in particular, by means of academic spin-offs (Gu, 1999). Torch Programme industrial bases, 28 of which are targeting the pharmaceutical sector, predominately serve to upgrade local manufacturing capabilities (Torch and MOST, 2010). Apart from MOST, another important agency – the National Development and Reform Commission (NDRC), which is charged with devising strategic plans and supporting the development of "strategic" industrial sectors – has started another programme in 2005. NDRC has approved 23 national biotechnology industrial bases, which are usually located within the science parks mentioned above. Because several cities feature more than one industrial base, the present number of cities involved amounts to about 40 (Figure 1).

The possibility to identify regional clusters via government-sponsored parks already indicates that the Chinese government is deeply involved in the development of regional industry. Hence, biotechnology clusters in China can be considered to be essentially policy driven (Prevezer and Tang, 2006; Prevezer, 2008; Su and Hung, 2009). Focusing on Beijing, Shanghai and Shenzhen, Prevezer and Tang (2006) yet detect local differences in the role of government. Arguably, differences can be traced back to the origin of China's health biotech clusters. In order to analyse these varieties, we start our

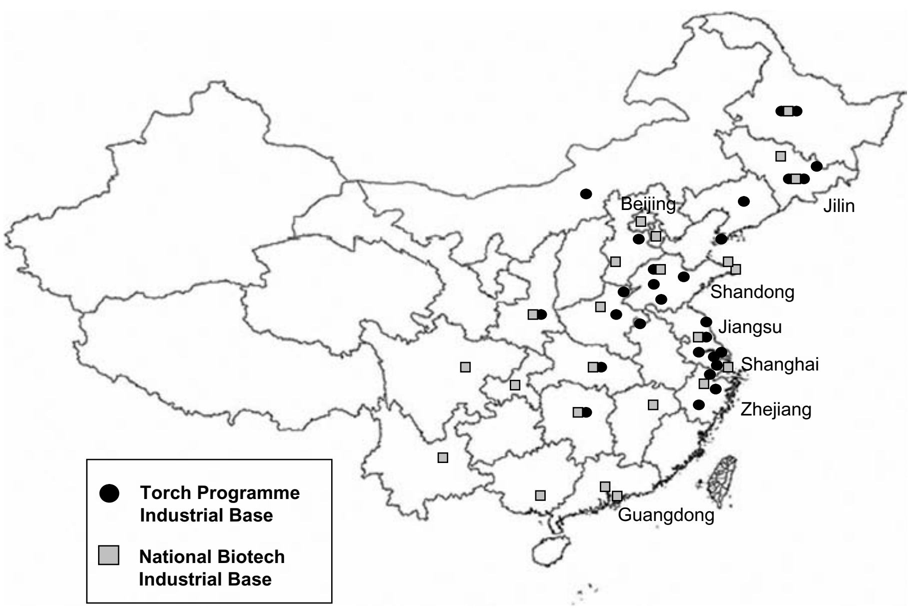

Figure 1.

analysis by examining the types of policy support provided in the different localities. We look at those 19 cities that feature firms from the enterprise sample being introduced more systematically in the next section. All of these localities have developed a pharmaceutical and biotechnology sector, albeit to a differing degree.

As can be seen from Table I, the cities can be tentatively grouped into seven categories. Whereas cities in the first four categories maintain national-level science parks, those in the latter three categories do not feature parks especially targeting high-tech sectors such as the one that is the focus of the present paper. In those latter cities, specialized policy support is given on the basis of endogenous developments. For example, Xinxiang (Henan Province) is home to a well-known Chinese pharmaceutical company, Hualan Bio. The company was established in 1992 by an entrepreneur who had worked at a public research institute of the Ministry of Health before he returned to his hometown (BioPlan, 2008). When the Torch Programme industrial base was launched in 2010, the policy programme provided acknowledgment to the local development taking place based on Hualan's success. Other localities have a longer history with regard to the pharmaceutical industry. Tonghua, for example, is situated at the foot of Jilin Province's Changbai Mountains, which host a wealth of flora that can be used in traditional Chinese medicines. Until 1980, eight factories had been established there to exploit these natural resources. When the reform process started in the 1980s, these first companies' technicians began to establish their own private firms or contracted out one of the previously state-owned enterprises (Liu, 2009). The dynamics in Tonghua therefore resemble those of many low-tech clusters elsewhere in China (most of all, in Zhejiang Province, cf. Wang and Tong (2005)). Tonghua is one of the two cities (the other one being Dezhou in Shandong Province) that has a biotech base not located in a national-level science park.

Compared to the development of the biopharmaceutical industry in advanced economies, one of the distinguishing characteristics of China's localities at the first stage of the cluster life cycle is the nature of their science base. The general expectation would be to find clusters of a knowledge-based industry in science centres, localities with a reasonably strong science base (Audretsch and Stephan, 1996; Zucker *et al.*, 1998). However, as the examples pointed out above suggest, this is not necessarily the case in China. Many of China's health biotech clusters are not situated in localities with a

	Science park	Biotech base	Torch base	Other zones	Cities
1	•	•	•		Xi'an*, Harbin*
2	•	•			Beijing*, Shanghai*, Tianjin*, Changchun*, Hangzhou*, Chengdu*, Chongqing*, Guangzhou*, Shenzhen, Shijiazhuang, Yantai
3	•		•		Dalian*, Jinan*, Suzhou (+ Wuzhong)
4	•				Shenyang*, Hefei*, Xiamen*, Fuzhou, Zhuhai, Zhongshan (Suzhou)
5		•	•		Tonghua
6			•		Xinxiang (Wuzhong)
7				•	Xuzhou, Tai'an, Changzhi, Dongyang

Note: Science centres are signified by a "*"

Table I.
Differences between health biotech clusters

strong science base. In order to explicate this point more clearly, we need to identify China's science centres. Although China possesses a large number of academic institutions, there exist major qualitative differences between them (Kroll *et al.*, 2010). The 39 most prestigious universities are included in the 985 Project of the Ministry of Education. These universities are situated in 20 cities, which also happen to be the home of virtually all institutes of the Chinese Academy of Sciences (CAS)[4]. Therefore, it appears reasonable to refer to those cities as China's science centres. All of these science centres – which are marked in Table I by a "*" – can be subsumed under one of the first four categories.

We can also recognize that every of the first four categories also feature cities that are not science centres according to our classification. This also applies for the first category, because a complete examination of all relevant cities would show that Taizhou (Jiangsu Province) is the third member of the first category. In particular, the special economic zones Shenzhen and Zhuhai stand out as they do not correspond to the notion of science centres. While Shenzhen, for example, has made great endeavours to remedy the lack of academic institutions (for example, by establishing a "virtual university", cf. Walcott (2003)), the city's main strength still is its comparatively conducive regulatory environment. Nonetheless, Shenzhen was among the first cities with a national-level science park. Interestingly, Shenzhen has also originated China's first modern health biotech company – Shenzhen Kexing – merely ten years after the original fishing village started its economic rise. The enterprise was established to commercialize technology derived from research institutes from science centres, especially Beijing.

In summary, we can group the cities along two dimensions: the sophistication of the science base and the degree of policy support. The latter appears to be a particularly distinguishing factor in cities with a lower science base, the periphery. While in some peripheral cities, most notably Shenzhen, the development of high-tech sectors has followed policy incentives, in other cities, especially Tonghua, policy support has increased in lieu with endogenous developments.

3.2 Cluster demography

Cluster development implies above all a quantitative expansion of firms of a given industrial sector. As we have pointed out in Section 2, this development may differ according to the type of firms that agglomerate in a particular location. In order to analyse the development of China's health biotech clusters, we draw upon a sample of 75 of the most highly visible biopharmaceutical manufacturing enterprises[5]. The construction of the sample is explained in the Appendix. Due to our selection criterion, the featured enterprises are comparatively mature. They were established between 1981 and 2007 with the median enterprise being founded in 1994. Our sample includes firms from the cities named in Table I. Since the firm types explained in the preceding chapter are defined on the basis of linkages among firms (industrial spin-offs, enterprise subsidiaries) and between firms and academia (academic spin-offs), we have excluded those firms, which we have recognized as subsidiaries of other domestic firms, from the sample. That is, in contrast to academic and industrial spin-offs, we examine subsidiaries – even renowned ones such as Shandong Kexing – implicitly by associating these with their parent firms. Therefore, our analysis actually covers a higher number of enterprises.

The main attributes of the featured enterprises are shown in Table II. As would be expected for a science-based sector, the firms are not evenly distributed between

Number of surveyed enterprises	75
Location	
Science centres	55
Only Beijing and Shanghai	28
Periphery	20
Only Shenzhen	7
Type of enterprises	
Academic spin-offs	27
Established at a different location	7
Returnee enterprises	14
Enterprises with returnees in management	19
Domestic subsidiaries	
Firms with subsidiaries	36
With subsidiaries at a different location	25
Academic spin-offs with subsidiaries	15
With subsidiaries at a different location	10
Returnee enterprises with subsidiaries	5
With subsidiaries at a different location	4
Number of firms having acquired other firms	11
Number of firms having established new firms	34

Table II. Main attributes of the firm sample

science centres and the periphery. Given the emphasis of the literature on Beijing, Shanghai and Shenzhen, the high number of enterprises from those cities – almost half of the sample – appears to be unsurprising as well. Nonetheless, 40 firms originate from other cities. This suggests that too narrow a focus on those three locations will do injustice to China's overall sectoral development trajectory (Conlé and Taube, 2010). Another expected result is that more than one-third of the companies in the sample can be categorized as academic spin-offs. In the Chinese context, two kinds of academic spin-offs can be distinguished. The first kind has been dubbed by an earlier paper of Eun *et al.* (2006) as "spin-arounds" as these firms have remained tightly connected to their parent institute. Especially the institutes of the CAS have spawned such enterprises (Suttmeier *et al.*, 2006), some of which – e.g. BioSino, a spin-off of the CAS Institute of Biophysics – are active in the pharmaceutical sector. In the second type, the parent institute or university is however only marginally involved. In this case, the technology and/or the entrepreneur comes from the academic institution. Yet while the parent research institutes/universities may in some cases be still present in the names of these enterprises, actual cooperation is limited (or even absent). An interesting fact is that seven academic spin-offs from our sample are not established at the location of the parent institution. Whereas all of the remaining 20 spin-offs are situated in the science centres, five of these seven firms were established in the periphery, four of them in Guangdong Province's special economic zones. Although spin-offs of the second type often remain nearby their parent institutions, these spin-offs also appear to be attracted to particular locations (Walcott, 2003).

As we have reported above, Romanelli and Feldman (2006) find that in the case of the USA industrial spin-offs provide a major explanation for the differential success of a region's sectoral expansion. When we look to China, it is interesting to note that we have – until now – found no evidence for domestic industrial spin-offs. This observation excludes Tonghua whose cluster development is based on such spin-off activity.

But even there this type of enterprises appears to be mainly a characteristic of the first phase of that location's cluster life cycle, when the state-owned sector of the planned-economy period was abandoned. Nonetheless, there exists a particular kind of industrial spin-offs in China if we consider migration into China's clusters from outside the country. This concerns the recent proliferation of returnee enterprises, firms that are established by Chinese scientists returning from extended work and study stays in other countries. Many of these returnees have gained experience through their work in pharmaceutical and health biotech companies in advanced countries, especially in the USA. Chinese Government policy has targeted these entrepreneurs by offering preferential treatment (Kroll *et al.*, 2010). In our sample, 14 enterprises can be considered to be returnee enterprises, while internationally experienced scientists have joined the management of (at least) five more firms. Earlier studies (Sternberg and Müller, 2005; Chen *et al.*, 2011) have focused on the major research hubs – especially Shanghai – to explore this phenomenon. However, the returnee enterprises in our sample are distributed quite equally among nine cities, virtually all of which have a national biotech base.

While we do not have enough information to trace the specific historical development paths of China's biotech clusters, our analysis indicates that their trajectories are highly contingent on the establishment of firms by entrepreneurs from outside the locality. This is most obvious in the case of Shenzhen. Five of Shenzhen's seven featured companies are either academic spin-offs or returnee enterprises attracted to the city. While Shenzhen is unique in this regard, the more common strategy is apparently to support the establishment of firm subsidiaries. From a legal point of view, most of the returnee enterprises are, in fact, subsidiaries because the returned entrepreneurs usually establish a company in the USA (or a tax haven) first and then set up a "foreign-invested" enterprise in China (Sternberg and Müller, 2005). Moreover, pharmaceutical multinationals have increased their investments strongly in the wake of China's accession to the WTO in 2001 by establishing factories as well as R&D centres (Conlé and Taube, 2010). Yet, subsidiaries of domestic companies also appear to play a major role in the regional development of China's health biotech sector. Almost half of the companies in our sample possess stakes in other (domestic) firms. These subsidiaries have increased the number of firms situated at the same location. Interestingly, about 70 per cent of those firms have subsidiaries that are located in a different city. For academic spin-offs and returnee enterprises, this ratio is even higher.

The acquisition of a minority stake in another health biotech company may possibly be rationalized as a mechanism to support a more intense exchange of knowledge (Pisano, 1989). Yet, only 11 firms have obtained one or more subsidiaries – in science centres or the periphery – by means of acquisition. In contrast, 34 firms have established (or joined in establishing) those subsidiaries themselves. This occurrence is peculiar for several reasons. First of all, whereas MNEs are establishing Chinese subsidiaries in order to tap the domestic market and, maybe, keep informed about local technological developments, domestic enterprises are already in the market. Second, the exploitation of factor conditions may to some extent explain investments between science centres and the periphery. It does not however illuminate the reasons for establishing enterprises in the same type of location. Third, these decisions are all the more surprising as those companies themselves are rather small in terms of labour force and production capacity. So why do firms opt to establish subsidiaries and trigger a high fragmentation of the biopharmaceutical industry (Chen *et al.*, 2011) instead of increasing the production capacity of their existing plants? Why are so many and diverse clusters able to expand by attracting firms and entrepreneurs from outside? In order to get a more complete picture of the firms' localization decisions, we may need to go beyond the available numerical data.

4. Business strategies in China's health biotech sector

We have argued in Section 2 that clusters develop idiosyncratic social dynamics depending on the resident firms and their business strategies. Information on Chinese health biotech firms is still scarce. However, we can rely on two sources to get a better understanding of the sectoral processes. On the one hand, we will base our discussion on five published surveys on China's health biotech sector. These interview surveys provide a comprehensive analysis of a number of selected firms (Table III). The surveys are supplemented by our own interviews with ten firms in Shanghai and Beijing (see the Appendix). Although the surveys address different questions, a review of these surveys reveals that they are remarkably consonant with regard to some aspects that will inform our argument.

First of all, all reports agree that China's health biotech sector overwhelmingly consists of integrated firms with in-house manufacturing facilities. The integrated business model contrasts with the model of the so-called dedicated biotechnology firms (DBFs) encountered in many other countries, particularly the USA. In the USA, only firms such as Genentech or Amgen that participated in the first wave of biotechnology entrepreneurship in the late 1970s to early 1980s managed to become integrated firms (Pisano, 2006). All subsequent industry entrants have remained specialized on a range of activities of the drug discovery and development stages while leaving manufacturing, marketing and distribution to the incumbent pharmaceutical firms. The general explanation for the alliance phenomenon rests on specialized complementary assets and capabilities (Teece, 1986). Whereas the technological discontinuity of the biotechnology revolution eroded the capabilities of the incumbents

Survey	Cases
Sternberg and Müller (2005)	Interviews with 14 returned entrepreneurs in Shanghai. Information of the types of activities performed by their firms and the entrepreneurs' motivations to establish the company in China
Prevezer and Tang (2006)	Information on the sectoral specialization of 131 firms in the Beijing area, 111 in the Shanghai area and 110 in the Shenzhen area. Discussion of characteristics of particular firms based on 20 interviews in Shenzhen and Beijing
Malone *et al.* (2008), Richard *et al.* (2009)	Interviews of 19 Shanghai-based companies. Discussion of the business models of those firms including product markets, access to finance and cost strategy
Frew *et al.* (2008)	Detailed case studies of 22 of China's most innovative biopharmaceutical firms. Information on patenting activity, alliances with domestic and foreign entities, subsidiaries and joint ventures as well as financial background
Chen *et al.* (2011)	Interviews with 72 firms located in the Yangtze River Delta and Beijing including 33 firms founded by returnees and 39 firms with returnees as senior management. Information on their linkages to international knowledge sources

Table III. Previous surveys on China's health biotech sector with regard to R&D, the complementary assets and capabilities with regard to bringing a product through the cost-intensive clinical tests and to the consumer were not affected (Malerba and Orsenigo, 1993; Grabowski and Vernon, 1994).

Chinese biotech firms have faced a different situation. Although a large number of pharmaceutical enterprises were established during the pre-reform period (CPEMA, 2009), these companies were initially mainly manufacturing entities. Due to the strong functional specialization of the Soviet-style economy (Liu and White, 2001), these incumbents also lacked the specialized complementary assets and capabilities in business functions such as R&D and marketing. MNEs, in turn, were generally better positioned. However, several impediments such as trade restrictions and their unfamiliarity with the Chinese market have until recently limited the MNEs' impact on China. In this sectoral environment, integration has proven to be a viable strategy. Yet an integrated business model requires firms to develop assets along the whole value chain. This implies that R&D may not top the priority list for many companies. In fact, the domestic market is dominated by generic biologics (Hu *et al.*, 2006). Malone *et al.* (2008) report that the firms they surveyed were predominately (preparing for) manufacturing biogenerics for the Chinese market. Coinciding with our own observations, they also indicate that the development of sales forces – usually in connection with the opening of sales departments in most provinces – and effective marketing receive most of the enterprise managements' attention.

This does not mean that the firms do not invest in R&D because even the development of biogenerics requires substantial adjustments of process technologies. However, the R&D process differs significantly from those firms that introduce novel products. In China, universities and public research institutes are the primary producer of (patentable) scientific knowledge (Chen *et al.*, 2011). Linkages between academia and industry exist but Chinese firms frequently search throughout the country for a suitable academic institution that can help them to exploit a known (domestic) market opportunity. Academic spin-offs have an advantage, as their entrepreneurs can utilize the technological knowledge gained at their institution, when they migrate into business. Given the focus on biogenerics, geographical proximity does not need to play a significant role. Nonetheless, a rising number of domestic companies are working on new-to-the-world therapies. However, as Frew *et al.* (2008) find, financial mechanisms to support such innovative activities provide a major bottleneck. Venture capital, which is the primary financial vehicle to provide start-ups with sufficient capital, is rather new to China. Moreover, the initial impetus for venture capital provision came from the Chinese Government at national and particularly local levels, while private domestic and foreign firms were only allowed to enter the market since the late 1990s (White *et al.*, 2005). The findings of Richard *et al.* (2009) mirror the important role of local governments in new venture financing. According to their survey of Shanghai companies, new biotech firms are established with funds from founders and their friends and family and/or the local government. Growth financing was almost exclusively provided through retained earnings and government funding schemes. As the available funds are limited in size and distributed across a whole range of firms and projects, they are inadequate to cover the immense costs of new drug development. Frew *et al.* (2008) argue that innovative enterprises therefore try to subsidize their exploratory activities with the manufacturing of generic, diagnostic and other (possibly unrelated) products. Accordingly, the establishment of integrated firms appears not to be merely a viable but also often a necessary option, because it ensures the availability of sufficient funds to maintain a firm's sustainability.

These observations lead us to the main argument of this present paper. On the basis of our own interviews, we suggest a link between the findings of Frew *et al.* (2008) as well as Richard *et al.* (2009) and China's cluster development through the establishment of firm subsidiaries. If local governments are the major suppliers of venture capital, then it may be rational to establish companies in multiple locations in order to collect more funds. Our interviews in Shanghai and Beijing indeed provide some evidence that quite a few localization choices are affected by this consideration. Firms have set up subsidiaries in other cities with a substantial financial support of the local governments. The importance of government finance may also explain to a good degree the localization decision of migrating spin-offs and returnee enterprises. We believe that this is a major difference between China and the USA: while in the USA venture capital is reinforcing the superior dynamics of a particular region (Chen *et al.*, 2009), China's government-dominated and regionally fragmented capital market is preventing the evolution of an elite group of highly concentrated dynamic clusters. Instead, we observe an excessively large number of smaller, less concentrated agglomerations.

5. Conclusions

Studies on China's high-tech agglomerations unanimously complain about a lack of "creative buzz" compared to the vibrant clusters of, e.g. the Bay Area in the USA. In order to approach this problem, a straightforward policy recommendation would be to initiate or strengthen local cluster policies that improve networking and knowledge exchange between resident firms as well as support entrepreneurship through mechanisms such as incubators and the provision of venture capital funds. Several of China's policy programmes, most importantly the Torch Programme, have taken up this advice. However, our analysis indicates that these cluster policies will probably not have the anticipated effect if they are not complemented by significant changes in the overall institutional framework.

The opportunities for specialization and inter-firm collaboration are limited by the dominant business strategies in China's health biotech sector. Our main argument is that these dominant strategies are brought about by the institutional framework, in particular the constitution of the capital market. While, due to the historically grown set-up of the industry, new entrants in recent years have been able to pursue integrated strategies, they also had little other choices. In fact, they had to realize revenues, since China's capital market was and is still not prepared to finance risky pre-revenue ventures. Many (or even most) enterprises, therefore, follow similar strategies that render them direct competitors – "substitutors" rather than "complementors" in the terms of Brandenburger and Nalebuff (1995) – for opportunities to exploit domestic market niches with technologies supplied by universities and public research institutes. According to Hu *et al.* (2006), it is not uncommon for a particular biotech drug to be manufactured by dozens of Chinese firms. Due to this practice, collaboration is restricted to "exploitation alliances" (Rothaermel and Deeds, 2004) between firms and academic institutions, while exploration is not highly valued. The institutional environment gives rise to firms that are more concerned about production capacity and market development than about R&D. Even the finest of China's health biotech firms cannot escape this dominant logic.

The immaturity of venture finance in China constitutes a serious bottleneck for the further development of the health biotech sector. On the surface, this situation supports a claim for local support of venture finance schemes. But this claim is unwarranted as China's localized cluster policies are rather the source than the solution to China's lack of "buzz". By adopting an interregional perspective, we show that the strong involvement of local governments in new venture and growth financing has a significant effect on the anatomy of cluster development in China. Evidently, the source of venture capital plays a decisive role not only in cluster-internal but also in interregional dynamics. In fact, we maintain that these dynamics interact. National capital markets either reinforce or inhibit clustering depending on how much it allows the mobility of financial capital. Local government funds do not travel far. This has an impact on the firms' localization decisions and their business strategies, which, in turn, affects the "culture" inside the clusters. As capital is not coming towards them, China's firms have to travel to where the capital is, i.e. they spawn subsidiaries in order to tap local sources of (venture) capital and in this piecemeal fashion try to secure the financial means necessary for survival and business development, respectively. This situation is most problematic for firms with the potential to create novel products. While the financial support of local governments allows for survival in the Chinese market, it does little to enhance their innovative capacity. Instead, localized capital only allows for the (multiple) establishment of inexpensive production technologies (Jia, 2007), the recruitment of staff in regions with a small science base and reduced opportunities for knowledge exchange.

From a theoretical point of view, we may have thus identified one particular way (among others) in which the national institutional environment affects regional development paths. While local clusters differ, the extent of variation is restricted by the national environment. By comparing Chinese with US clusters, we find an important difference: whereas cluster dynamics in the USA are driven by the local establishment of academic and industrial spin-offs financed by venture capital funds flowing to the successful regions, Chinese clusters grow by attracting direct investments from firms having been established in other regions/countries. Certainly, our argument is based on a limited number of cases. Hence, further studies are required to validate the link between the capital market and local development trajectories in China.

If our view of institutional embeddedness is correct, then the immediate policy implication is that the key to improving cluster dynamics ultimately rests on changes in the national framework conditions, in particular the capital market. Above all, changes would need to be directed towards a reduction in (local) government participation. As long as the mechanism to pool funds, select and finance pre-revenue firms is not altered, the economic organization of the industry will likely reproduce itself. However, despite the current shortcomings, some regions – in particular, Shanghai – appear to gradually distinguish themselves as a consequence of an exogenous shock, the recent influx of R&D centres of large pharmaceutical MNEs. The foreign entrants (and their business models) ameliorate the situation as they provide local firms with new opportunities for collaboration that do not yet exist between domestic firms. To our knowledge, their contribution to the diffusion of technological knowledge is very limited. But as we have argued, local knowledge spillovers above all pertain to subtle changes in perceptions and routines. Some domestic firms have seized the opportunity to specialize on R&D activities predominately financed and guided by MNEs (Sigurdson, 2005). By working with local firms, these MNEs may help to bring about a more collaborative culture and would even more so within an improved institutional framework.

Notes

1. Of course, strategic industrial policy, e.g. the establishment of science parks, is based on the belief of policymakers that the causality between private and public investments works both ways. We return to this issue later.
2. See Cowan *et al.* (2000): "[C]odified knowledge [. . .] [makes reference] to codes, or to standards – whether of notation or of rules, either of which may be promulgated by authority of may acquire 'authority' through frequency of usage and common consent [. . .] Knowledge that is recorded in some codebook serves *inter alia* as a storage depository, as a reference point and possibly as an authority. But information written in a code can only perform those functions when people are able to interpret the code; and, in the case of the latter two functions, to give it more or less mutually consistent interpretations. Successfully reading the code in this last sense may involve prior acquisition of considerable specialized knowledge (quite possibly including knowledge not written down anywhere). As a rule, there is no reason to presuppose that all people in the world possess the knowledge needed to interpret the codes properly. This means that what is codified for one person or group may be tacit for another and an utterly impenetrable mystery for a third."
3. The information on China's science parks is taken from: www.cadz.org.cn (in Chinese) and that on the national biotechnology industrial bases from the website of the Chinese Society of Biotechnology at: www.biotechchina.org (in Chinese) (accessed May 16, 2011).
4. These cities include Beijing, Tianjin, Shenyang, Dalian, Changchun, Harbin, Shanghai, Nanjing, Hangzhou, Hefei, Xiamen, Jinan, Qingdao, Wuhan, Changsha, Guangzhou, Chengdu, Chongqing, Xi'an (+ Yangling) and Lanzhou. See, e.g. www.gov.cn/fwxx/2009gk/content_1314252.htm (in Chinese) (accessed July 28, 2011).
5. Not all of the companies that reside in those parks need to be manufacturing firms. While we recognize that there may be other kinds of firms (e.g. contract research organizations), we nonetheless strictly focus on manufacturing firms in this paper. As other researchers have argued, manufacturing firms constitute the overwhelming majority of China's biopharmaceutical sector. For example, Miller *et al.* (2011) cite a 2003 survey published by the MOST according to which "158 firms, 31 R&D institutions and 22 higher education and subsidiary institutions were active in biotechnology in Shanghai. [. . .] [O]ver three-quarters of all biotechnology firms in Shanghai were in the manufacturing sector."

References

Aoki, M. (2010), *Corporations in Evolving Diversity: Cognition, Governance and Institutions*, Oxford University Press, Oxford.

Audretsch, D.B. and Stephan, P.E. (1996), "Company-scientist locational links: the case of biotechnology", *American Economic Review*, Vol. 86 No. 3, pp. 641-52.

BioPlan (2008), *Directory of Top 60 Biopharmaceutical Manufacturers in China*, BioPlan Associates, Rockville, MD, March.

Boschma, R.A. (2005), "Proximity and innovation: a critical assessment", *Regional Studies*, Vol. 39 No. 1, pp. 61-74.

Brandenburger, A.M. and Nalebuff, B.J. (1995), "The right game: use game theory to shape strategy", *Harvard Business Review*, July/August, pp. 57-71.

Breschi, S. and Lissoni, F. (2001), "Knowledge spillovers and local innovation systems: a critical survey", *Industrial and Corporate Change*, Vol. 10 No. 4, pp. 975-1005.

Breschi, S. and Malerba, F. (2001), "The geography of innovation and economic clustering: some introductory notes", *Industrial and Corporate Change*, Vol. 10 No. 4, pp. 817-33.

Cao, C. (2004), "Zhongguancun and China's high-tech parks in transition: 'growing pains' or 'premature senility'?", *Asian Survey*, Vol. 44 No. 5, pp. 647-68.

Casper, S. (2007), "How do technology clusters emerge and become sustainable? Social network formation and inter-firm mobility within the San Diego biotechnology cluster", *Research Policy*, Vol. 36, pp. 438-55.

Chen, K., Liu, Y. and Chen, Q. (2009), "How much does history matter? An analysis of the geographic distribution of venture capital investment in the U.S. biotechnology industry", *The Industrial Geographer*, Vol. 6 No. 2, pp. 31-55.

Chen, Y., Luo, L. and Zhang, Y. (2011), "Development trajectories in the biotechnology industry: China versus leading countries", *China & World Economy*, Vol. 19 No. 3, pp. 105-23.

Chiaroni, D. and Chiesa, V. (2006), "Forms of creation of industrial clusters in biotechnology", *Technovation*, Vol. 26, pp. 1064-76.

Cohen, W.M. and Levinthal, D.A. (1990), "Absorptive capacity: a new perspective on learning and innovation", *Administrative Science Quarterly*, Vol. 35 No. 1, pp. 128-52.

Conlé, M. and Taube, M. (2010), "Regional specialization in China's biopharmaceutical industry", *Chinese Management Studies*, Vol. 4 No. 4, pp. 339-59.

Cooke, P., Uranga, M.G. and Etxebarria, G. (1997), "Regional innovation systems: institutional and organizational dimensions", *Research Policy*, Vol. 26, pp. 475-91.

Cowan, R., David, P.A. and Foray, D. (2000), "The explicit economics of knowledge codification and tacitness", *Industrial and Corporate Change*, Vol. 9 No. 2, pp. 211-53.

CPEMA (2009), *Zhongguo yiyao chanye fazhan baogao* (*1949-2009*) (*Development Report on China's Pharmaceutical Industry* (*1949-2009*)), Chinese Pharmaceutical Enterprises Management Association, Huaxue gongye chubanshe, Beijing.

Dunning, J.H. (1998), "Location and the multinational enterprise: a neglected factor?", *Journal of International Business Studies*, Vol. 29 No. 1, pp. 45-66.

Eun, J.-H., Lee, K. and Wu, G. (2006), "Explaining the 'university-run enterprises' in China: a theoretical framework for university-industry relationship in developing countries and its application to China", *Research Policy*, Vol. 35, pp. 1329-46.

Feldman, M.P. (1999), "The new economics of innovation, spillovers and agglomeration: a review of empirical studies", *Economics of Innovation and New Technology*, Vol. 8, pp. 5-25.

Feldman, M.P. and Braunerhjelm, P. (2006), "The genesis of industrial clusters", in Braunerhjelm, P. and Feldman, M.P. (Eds), *Cluster Genesis: Technology-Based Industrial Development*, Oxford University Press, Oxford, pp. 1-13.

Feldman, M.P., Francis, J. and Bercovitz, J. (2005), "Creating a cluster while building a firm: entrepreneurs and the formation of industrial clusters", *Regional Studies*, Vol. 39 No. 1, pp. 129-41.

Frew, S.E., Sammut, S.M., Shore, A.F., Ramjist, J.K., Al-Bader, S., Rezaie, R., Daar, A.S. and Singer, P.A. (2008), "Chinese health biotech and the billion-patient market", *Nature Biotechnology*, Vol. 26 No. 1, pp. 37-53.

Gertler, M.S. (2003), "Tacit knowledge and the economic geography of context, or the undefinable tacitness of being (there)", *Journal of Economic Geography*, Vol. 3, pp. 75-99.

Gompers, P. and Lerner, J. (2001), "The venture capital revolution", *Journal of Economic Perspectives*, Vol. 15 No. 2, pp. 145-68.

Grabowski, H. and Vernon, J. (1994), "Innovation and structural change in pharmaceuticals and biotechnology", *Industrial and Corporate Change*, Vol. 3 No. 2, pp. 435-49.

Gu, S.L. (1999), *China's Industrial Technology: Market Reform and Organizational Change*, Routledge, London.

Henderson, J.V. (1986), "Efficiency of resource usage and city size", *Journal of Urban Economics*, Vol. 19, pp. 47-70.

Hu, X., Ma, Q. and Zhang, S. (2006), "Biopharmaceuticals in China", *Biotechnology Journal*, Vol. 1, pp. 1215-24.

Jensen, M.B., Johnson, B., Lorenz, E. and Lundvall, B.A. (2007), "Forms of knowledge and modes of innovation", *Research Policy*, Vol. 36, pp. 680-93.

Jia, H. (2007), "Chinese biotech hamstrung by production issues", *Nature Biotechnology*, Vol. 25 No. 2, pp. 147-8.

Klepper, S. (2001), "Employee startups in high-tech industries", *Industrial and Corporate Change*, Vol. 10 No. 3, pp. 639-74.

Kroll, H., Conlé, M. and Schüller, M. (2010), "China: innovation system and innovation policy", in Frietsch, R. and Schüller, M. (Eds), *Competing for Global Innovation Leadership: Systems and Policies in the USA, EU and Asia*, Fraunhofer, Stuttgart, pp. 241-63.

Krugman, P. (1991), *Geography and Trade*, MIT Press, Cambridge, MA.

Liu, X. and White, S. (2001), "Comparing innovation systems: a framework and application to China's transitional context", *Research Policy*, Vol. 30 No. 7, pp. 1091-114.

Liu, Z.G. (2009), "The emergence of clusters in societal transition: a coevolutionary perspective on the TCM cluster at Tonghua/China", dissertation, University of Frankfurt, Frankfurt/Main.

Malerba, F. and Orsenigo, L. (1993), "Technological regimes and firm behavior", *Industrial and Corporate Change*, Vol. 2 No. 1, pp. 45-71.

Malmberg, A. and Maskell, P. (2006), "Localized learning revisited", *Growth and Change*, Vol. 37 No. 1, pp. 1-18.

Malmberg, A. and Power, D. (2005), "(How) do (firms in) clusters create knowledge?", *Industry and Innovation*, Vol. 12 No. 4, pp. 409-31.

Malone, K., Hales, B., Chan, J., Love, M. and Rayner, J. (2008), "Cloning and industry: strategy typologies of Shanghai biotechnology companies", *Journal of Commercial Biotechnology*, Vol. 14 No. 1, pp. 31-42.

Markusen, A. (1996), "Sticky places in slippery space: a typology of industrial districts", *Economic Geography*, Vol. 72, pp. 293-313.

MIIT (2009), *2008 Zhongguo yiyao tongji nianbao, Zhongyao shengwu zhiyao fence (Annual Statistical Report on Pharmaceuticals in China, Chinese Medicine and Biopharmaceuticals Volume)*, Ministry of Industry and Information Technology.

Miller, C.R., Richard, B. and Arora, S. (2011), "Alternate signs of life: the growth of biotechnology industries in Shanghai and Bangalore", *Technological Forecasting & Social Change*, Vol. 78, pp. 565-74.

Orsenigo, L. (2006), "Clusters and clustering: stylized facts, issues and theories", in Braunerhjelm, P. and Feldman, M.P. (Eds), *Cluster Genesis: Technology-Based Industrial Development*, Oxford University Press, Oxford, pp. 195-218.

Perez, C. and Soete, L. (1988), "Catching up in technology: entry barriers and windows of opportunity", in Dosi, G., Freeman, C., Nelson, R., Silverberg, G. and Soete, L. (Eds), *Technical Change and Economic Theory*, Pinter Publishers, London, pp. 458-79.

Pisano, G.P. (1989), "Using equity participation to support exchange: evidence from the biotechnology industry", *Journal of Law, Economics and Organization*, Vol. 5 No. 1, pp. 109-26.

Pisano, G.P. (2006), *Business: The Promise, the Reality and the Future of Biotech*, Harvard Business School Press, Boston, MA.

Porter, M.E. (1998), "Clusters and the new economics of competition", *Harvard Business Review*, November/December, p. 7790.

Prevezer, M. (2008), "Technology policies in generating biotechnology clusters: a comparison of China and the US", *European Planning Studies*, Vol. 16 No. 3, pp. 359-74.

Prevezer, M. and Tang, H. (2006), "Policy-induced clusters: the genesis of biotechnology clustering on the East Coast of China", in Braunerhjelm, P. and Feldman, M.P. (Eds), *Cluster Genesis: Technology-Based Industrial Development*, Oxford University Press, Oxford, pp. 113-32.

Richard, B., Malone, K., Hales, B.D. and Turkopuls, M.A. (2009), "A world away from venture capital funds: biotechnology and finance in Shanghai", *International Journal of Technoentrepreneurship*, Vol. 2 No. 1, pp. 64-78.

Romanelli, E. and Feldman, M.P. (2006), "Anatomy of cluster development: emergence and convergence in the US human biotherapeutics, 1976-2003", in Braunerhjelm, P. and Feldman, M.P. (Eds), *Cluster Genesis: Technology-Based Industrial Development*, Oxford University Press, Oxford, pp. 87-112.

Rothaermel, F.T. and Deeds, D.L. (2004), "Exploration and exploitation alliances in biotechnology: a system of new product development", *Strategic Management Journal*, Vol. 25, pp. 201-21.

Sigurdson, J. (2005), *Technological Superpower China*, Edward Elgar, Cheltenham.

Sternberg, R. and Müller, C. (2005), "Return migration in regional innovation systems", *Asian Journal of Technology Innovation*, Vol. 13 No. 2, pp. 71-95.

Storper, M. (1992), "The limits to globalization: technology districts and international trade", *Economic Geography*, Vol. 68 No. 1, pp. 60-93.

Stuart, T.E., Ozdemir, S.Z. and Ding, W.W. (2007), "Vertical alliance networks: the case of university-biotechnology-pharmaceutical alliance chains", *Research Policy*, Vol. 36, pp. 477-98.

Su, Y.-S. and Hung, L.-C. (2009), "Spontaneous vs. policy-driven: the origin and evolution of the biotechnology cluster", *Technological Forecasting and Social Change*, Vol. 76 No. 5, pp. 608-19.

Sutherland, D. (2005), "China's science parks: production bases or a tool for institutional reform?", *Asia Pacific Business Review*, Vol. 11 No. 1, pp. 83-104.

Suttmeier, R.P., Cao, C. and Simon, D.F. (2006), "China's innovation challenge and the remaking of the Chinese Academy of Sciences", *Innovations: Technology, Governance, Globalization*, Summer, pp. 78-97.

Teece, D.J. (1986), "Profiting from technological innovation: implications for integration, collaboration, licensing and public policy", *Research Policy*, Vol. 15, pp. 285-305.

Torch and MOST (2010), *China Torch Statistical Yearbook 2008*, Torch High Technology Industry Development Center and Ministry of Science and Technology, China Statistics Press, Beijing.

Walcott, S.M. (2003), *Chinese Science and Technology Industrial Parks*, Ashgate, Aldershot.

Wang, J. and Tong, X. (2005), "Industrial clusters in China: embedded or disembedded?", in Alvstam, C.G. and Schamp, E.W. (Eds), *Linking Industries Across the World: Processes of Global Networking*, Ashgate, Aldershot, pp. 223-42.

White, S., Gao, J. and Zhang, W. (2005), "Financing new ventures in China: system antecedents and institutionalization", *Research Policy*, Vol. 34, pp. 894-913.

Williamson, O.E. (1991), "Comparative economic organization: the analysis of discrete structural alternatives", *Administrative Science Quarterly*, Vol. 36, pp. 269-96.

Wilsdon, J. and Keeley, J. (2007), "(2007)", *China: The Next Science Superpower? The Atlas of Ideas: Mapping the New Geography of Science*, Demos, London, available at: www.demos.co.uk (accessed August 23, 2009).

Zucker, L., Darby, M.R. and Brewer, M.B. (1998), "Intellectual human capital and the birth of the U.S. biotechnology enterprises", *American Economic Review*, Vol. 88, pp. 290-306.

Appendix. Methodology

(1) For our demographic analysis in Section 3 we have studied the web sites and, whenever obtainable, the annual reports of Chinese health biotech companies. According to the *2008 Annual Statistical Report on Pharmaceuticals in China* issued by the Ministry of Industry and Information Technology (MIIT, 2009), there existed 750 enterprises in the biopharmaceutical and biochemical segment of China's pharmaceutical industry. As comprehensive industry directories are unavailable for easy access of information on all these firms, we have restricted our attention on a 10-per cent sample (75 firms). Our selection criterion was importance, or visibility, in terms of manufacturing and new product output. The firms in the sample are focusing on therapeutic drugs, vaccines, diagnostic products and blood products, which, according to Chinese classification, are also included in the biopharmaceutical segment. Since we do not analyse the capabilities of the firms, we have yet not assured ourselves (and we do not claim) that we have really identified the top ten per cent of the market segment. While searching for visible firms, we have relied on three sources of information. First of all, we utilized the list of firms with the largest biopharmaceutical output from the mentioned *Annual Statistical Report on Pharmaceuticals in China*. We also consulted the *Directory of Top 60 Biopharmaceutical Manufacturers in China* compiled by BioPlan (2008). The firms enlisted in these two sources are overlapping to a significant degree. Moreover, the third source employed was written material provided by zone administrations in Shanghai and Beijing, for example, the "Investment Guide for the Biopharmaceutical Industry" of the Beijing Economic-Technological Development Area.

Due to our interest in outstanding firms, we have given priority to the BioPlan list. We did however not blindly rely on the directory but cross-checked the information with the firms' web sites. In this process, we had to exclude some firms that had to stop production for various reasons. As the MIIT list does not only contain biopharmaceutical but also biochemical producers (e.g. genetically modified crops producers), these were also excluded. Finally, we only considered firms with a freely accessible web site. We started at the top of the lists and stopped when we had obtained 75 useful cases. As we were concerned about the linkages between firms, we have explicitly checked the selected firms for parent companies. If such a parent company was identified, then we included the parent company instead of the subsidiary. However, we only considered parent companies that were biopharmaceutical enterprises themselves. Whenever a firm had a parent company that was from the financial sector, an unrelated industry or the traditional pharmaceutical sector, then we neglected the parent company. The same applies to subsidiaries of the firms. We only considered subsidiaries that could be identified as belonging to the health and biotech sector. We excluded those subsidiaries that were mere marketing offices, plasma collection stations (in the case of blood products manufacturers) or were engaged in unrelated sectors.

After having concluded the selection process, we processed all available web site information extracting information about the date of establishment, the origin of the enterprise, the existence of subsidiaries and the locational choices. We employed a simple binary classification scheme to determine whether a firm possessed a certain property or not. The properties we analysed include academic spin-off, industrial spin-off, returnee enterprise, subsidiaries, subsidiaries in other locations, type of cluster, etc. Although this approach does not allow for determining the total number of subsidiaries, we have decided to employ this approach to cope with the fact that some web sites provided only incomplete information.

(2) For our discussion of the demographic analysis in Section 4 we refer to previous interview surveys and own company interviews that we conducted with ten firms in Shanghai and Beijing during February and September 2010 as a part of an exploratory survey. The firms were selected from the same sources named above. Eight of the interviews were unstructured face-to-face interviews that were usually conducted at the firm's headquarters and lasted more than an hour. The interviews were with CEOs, managers from R&D and quality supervision departments, as well as marketing directors. Employing open-ended questions, we asked about the origin of the firm, the development of the business organization, R&D and marketing performance, access to finance and participation in public research projects. In two cases (both in September 2010), the interview questions were administered via the telephone. Both of these interviews were shorter in time and were focused on an understanding of the origin and development of a particular linkage, in the first case the relationship between a firm and a university, in the second case between two firms.

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