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Anatomy of Cluster Development in China: The case of health biotech clusters

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Abstract:

Focussing on China's health biotech clusters the study explores the anatomy of interaction in as well as between various clusters. While the literature has identified the existence of a dense network of durable interactions among firms and between firms and academia at a particular location as one of the most important prerequisites for well-performing clusters, we show that network ties extending beyond regional boundaries are equally valuable for the innovative capacity of China's biotech firms. Analysing the demographic process of cluster emergence we show that there exist different types of biotech clusters in China, which are closely linked and exchange knowledge and technology amongst each other. It appears as if further analysis of these cross-cluster links may provide important insights of how learning and innovation works in China's health biotech industry. Although China's science parks and industrial bases may on an individual basis appear to be badly structured, the organization of China's health biotech industry turns out to be substantially enhanced once these external linkages are taken into consideration.

Keywords:

China, health biotechnology, cluster, entrepreneurship, localization

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Content

1 Introduction

Recent contributions on economic development have identified economic clustering, i.e. the co-localization of related firms and institutions, as a fundamental cause of regional differences in prosperity and welfare (cp. Breschi and Malerba 2001). The general argument, most vividly popularized by Michael Porter (1998), goes that despite removals of trade barriers and major reductions in transportation and communication costs, location has a role to play due to agglomeration economies, which provide a source of competitiveness for individual firms. This idea is part of a general re-evaluation of the proximate environment of a firm for the latter's emergence and viability.[1] While the strategies of a firm or an entrepreneur are certainly relevant, the emphasis is put on firm-external factors for innovation and competitiveness. Empirical studies on successful clusters have shown that research universities, suppliers of venture capital, adequate infrastructure and support services as well as active social networks are key to driving innovation in a particular region. Many of these attributes can in principle be manipulated by economic 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.

China is a case in point. During the past decades, the Chinese government has rendered great efforts to catch up to the leading economies by supporting the creation of internationally competitive enterprises. In particular, technology-intensive industrial sectors are targeted because the utilization of new technologies – such as biotechnology – promise to provide "windows of opportunity" to occupy market niches still void of strong incumbent firms (Perez and Soete 1988). Promotional policies include the initiation of clusters by providing a suitable infrastructure. Under the torch programme (*huoju jihua*), 56 science parks and numerous industrial bases have been established. A growing body of literature has targeted these science parks and industrial bases (many of them located within these parks) as the main object of inquiry. Some authors have acclaimed the parks for their role in regional development (e.g., Sigurdson 2005) but the majority of contributions has criticized China's "park fever" suggesting that most of these parks are unsustainable.[2] Even those parks that are considered to have the potential of becoming vibrant clusters – i.e. Zhongguancun park in Beijing and Zhangjiang park in Shanghai – have been evaluated as lacking the necessary ingredients – most of all, the networks – for the promotion of competitive enterprises (e.g. Cao 2004, Sutherland 2005, Wilsdon and Keeley 2007).[3]

However, both, the pursued policies and the evaluation of China's industrial firm agglomerations, have their limitations. First of all, while Silicon Valley presently provides the general benchmark for policy design and the evaluation of cluster success, it is clear that the model is based on the characteristics of the mature cluster. That is, the features of the Silicon Valley model that have been worked out in the literature were not all present when the cluster emerged (Feldman and Braunerhjelm 2006). This makes it difficult to compare China's still nascent agglomerations with the ideal. Secondly, empirical studies demonstrate that reasonably well-performing clusters can feature quite different structures in the sense of internal and external linkages (e.g. Markusen 1996). It is therefore not quite clear which kind of transactions have to thrive within a cluster and which ones can extend beyond it. This also concerns the question of the boundary of China's "clusters". While most authors appear to accept administrative boundaries, Liefner (2005), for example, demonstrates linkages into the hinterland of Beijing and Shanghai, which would militate in favour of looking at larger regions such as the Yangtze River Delta and the Bohai Rim Region.

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1 Apart from economic geography (e.g., Storper 1992), approaches include Porter's (1990) diamond model in business studies and the systems of innovation approach based on evolutionary economics, both of which originally featured a national focus but have recently been applied to the regional level as well (Porter 1998, Cooke et al. 1997). Network-based approaches in entrepreneurship research (O'Donnell et al. 2001) and economic sociology (cf. Swedberg 2000) share some important similarities albeit without a geographical emphasis.

2 See e.g. Jia et al. (2003) who comments on the "drug valleys" in China and some other emerging economies.

3 Most of the studies are based on a few interviews with enterprise and park managers or on case studies of selected firms. More systematic investigations of linkages in science parks are provided by e.g. Zhou and Tong (2003), Liefner (2005), and Liefner and Hennemann (2008).

In order to get a more thorough picture of networks in China's high-tech industries, it may be worthwhile not to start with networks in the first place, but rather to examine the way regional industrial concentration and dispersion has developed. This is the main purpose of the present contribution. We argue for an entrepreneurial view on clustering that is informed by Feldman's (Feldman 2001, Feldman et al. 2005, Romanelli and Feldman 2006) work on cluster development in the US health biotech industry. Basically, she argues that the features considered above as constitutive for successful clusters lag cluster emergence (Feldman 2001). Instead, she argues, cluster dynamics, at least in the USA, are driven by entrepreneurial activities that shape and draw from their specific environment ultimately leading to the observed structures. Based on this work, we analyse the formation of health biotech clusters in China. As a potential user (and producer) of biotechnological knowledge, the pharmaceutical industry is one of the industries that is specifically targeted by both, the central and local governments. Among the industrial bases pointed out above, there are about 50 national-level pharmaceutical industrial bases and biotechnology industrial bases scattered around the country. Currently, more than 20 of the 31 provinces and province-level cities feature at least one of these bases.

We proceed as follows: In chapter 2, we shortly review the literature on clusters and clustering. On that basis, we outline a model of cluster formation. Subsequently, we discuss the origins (chapter 3) and expansion (chapter 4) of China's health biotech clusters. Here we focus on a few salient features including regional specialization, the contribution of foreign enterprises and returned students as well as some key forms of entrepreneurship. On this foundation we compare the expansion of China's clusters with the processes observed by Romanelli and Feldman (2006) in the USA. As comprehensive firm directories are unfortunately unavailable, we mainly refer to BioPlan's (2008) list of the top 80 protein therapeutic manufacturers (Appendix 1) and, to a more limited extent, the Ministry of Industry and Information Technology's (MIIT 2009) top 200 lists.[4] The data provided is supplemented by a few explorative interviews conducted by the authors in Shanghai and Beijing during February 2010 (Appendix 2). Due to the limitations in data, we restrict our discussion to a number of representative clusters: Beijing, Shanghai, Shenzhen (Guangdong province), Taizhou (Jiangsu province), and Tonghua (Jilin province). Conclusions are drawn in chapter 5.

2 Theoretical Foundations of Cluster Formation

2.1 What Constitutes a Cluster?

According to Porter's popular definition, "[c]lusters are geographic concentrations of interconnected companies and institutions in a particular field" (Porter 1998). One part of this definition includes the organizations the cluster is composed of, that is a) economic organizations, e.g. suppliers of intermediate products, of financial capital, of services, and rival firms, b) academia, i.e. universities and public research institutes, and c) organizations comprising the (local) state, e.g. government, administrative agencies and business associations.[5] The other part concerns the interrelations between these organizations (i.e. their external organization).

Leaving aside these linkages for the moment, co-location of enterprises of a given industry may be associated with economies of agglomeration in the sense of increasing the opportunity sets for the suppliers and potential users of specialized inputs.[6] Arguably, the most important type is labour market externalities. 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

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4 We prefer BioPlan's list because the ranking is based on factors that consider innovation in a broader sense: the number of biological products currently on the market and products in the pipeline. In contrast, the lists of the MIIT merely focus on differences in size, output, and profits.

5 Porter himself does not explicitly consider state entities. These are, in turn, more strongly emphasized in systems of innovation approaches (cf. Cooke et al. 1997). The listed types of organizations are also highlighted in the "triple helix" of university-industry-government relations (cf. Leydesdorff 2000).

6 Alfred Marshall has identified three types of agglomeration externalities: a pooled skilled labour market, a market large enough to enable specialization of intermediate products, and technological knowledge spillovers (cf. Krugman 1991).

not yet managed to attain 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. In other words, clustering is driven by a shared belief among (ignorant) agents that the opportunities (the likelihood of "meeting") at a given location are larger than those in other locations.

This coordination game rests on the fact that suppliers of financial capital have to localize their investments so that, after its establishment, a given firm is restricted in its mobility. These ex post barriers to exit renders co-location of investments a dominant choice. Suppliers of human capital are more mobile but they also have to bear the costs of relocating to another place once enterprise failure, firm layoffs or changing career objectives renders the search for a new employment necessary. While information and communication technologies may reduce the initial search costs and therefore may increase labour mobility, the future relocation costs militate against that. As the firms expand in number and/or size, the beliefs get reinforced thereby attracting further suppliers of labour and financial capital to the cluster. This logic also applies to entrepreneurs and venture capitalists if the latter's monitoring of investee firms requires them to reside in geographical proximity (Gompers and Lerner 2001).

Besides labour 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.[7] To put it succinctly, the likelihood of meeting an industry-friendly government rises with the number of resident firms.

The pooling of inputs at one particular location generally improves the environment for all resident firms, which potentially raises their competitiveness. However, (patient) capital and (skilled) labour are not the only relevant factors for competitiveness and innovation of individual firms. Innovation requires learning, and one of the externalities ascribed to geographical proximity consists in regionally bounded knowledge spillovers. Alfred Marshall considered knowledge to be "in the air" in innovative clusters (cf. Krugman 1991). Scholars of knowledge diffusion, in turn, have focused on the networks through which knowledge flows. The geographical aspect has been identified in the "tacitness" of specific kinds of knowledge, which is supposed to render necessary the geographical proximity of transmitter and receiver. However, this idea has been refuted (e.g. Breschi and Lissoni 2001), since tacitness does not so much refer to the transmission procedure (codified and commonly accessible vs. inexpressible and merely personally transmittable knowledge) as to the problems of interpreting the "messages" exchanged.[8] Tacit knowledge is hence closely associated with the concept of "absorptive capacity" coined by Cohen and Levinthal (1990), who argue that the exploitation of new knowledge requires prior related knowledge. That is, information may in general be available to everyone but only the members of the "epistemic community" have the ability (i.e. the knowledge) to make use of it. Therefore, it is not geographical but rather cognitive proximity that appears to be relevant for knowledge diffusion (cp. Boschma 2005).

7 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.

8 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."

A related argument is based on the observation that knowledge is generated through user-producer interaction (Lundvall 1985). This concerns the cooperation among enterprises along the value chain and between academia and enterprises. A by now large literature ascertains that inter-organizational networks are vital as they facilitate knowledge exchange and learning. In contrast, ephemeral transactions governed by markets are said to be not conducive to the same learning intensity, while the firm ("hierarchy") may not be flexible enough to try new ways of doing things (Boschma 2005). Networks are therefore seen as an intermediary mode of governance between markets and hierarchies, which is particularly amenable to interactive learning and innovation. Since successful clusters like Silicon Valley and the "Third Italy" distinguish themselves through the existence of dense intra-regional networks, clusters have come to be associated with networks by several authors. For example, Porter (1998) argues that "[c]lusters represent a kind of new spatial organizational form in between arm's length markets on the one hand and hierarchies, or vertical integration, on the other." But the conflation of clusters with networks is misleading because networks are not defined in geographical terms. As a mode of governance, network organization requires repeated interaction but not co-location. In fact, several authors have pointed out that cluster-external linkages are important for a firm's competitiveness (Orsenigo 2006). Hence, it is organizational rather than geographical proximity that appears to be important for knowledge generation through feedback. Clustering of organizations is only instrumental insofar as it increases the likelihood of meeting potential transaction partners. Yet, co-location neither forces firms to interact nor does it determine a particular mode of governance.

These arguments imply by no means that inter-organizational linkages are unimportant for a firm's competitiveness. Instead, the main thrust is that these linkages are not necessarily locally bounded and that therefore diverse structures may exist at various locations thought to feature industrial clusters (e.g. Markusen 1996). Often, network structures are influenced by the wider institutional environment (e.g. institutions at the national level) or by sectoral singularities (cf. Malerba and Orsenigo 1997). More generally, networking can be considered to be one of the key enterprise strategies. That is, firms emerge within given networks but their viability hinges on their capacity to expand and reconfigure these (cp. O'Donnell et al. 2001), likely reaching beyond regions. In order to account for cluster dynamics, we thus consider it to be more appropriate to focus on the embryonic (i.e. initial, firm-centric) networks instead of mature region-level networks in some ideal clusters such as Silicon Valley. As a consequence, we do not define clusters via network density and intra-cluster collaboration like e.g. Porter (1998) or Cooke (2001) but rather use the concepts agglomeration and cluster interchangeably. The emphasized embryonic networks refer to the general ability of a firm to secure those basic inputs required to start operation. As has been argued above, the suppliers of these inputs – skilled labour and, to a certain degree, venture capital – co-locate due to a shared belief that a given locality provides exceptional opportunities. While the production and reproduction of these beliefs are the driving force in clustering, the types of firms coming into existence at a particular place determine the emergent network structure.

2.2 An Entrepreneurial Model of Clustering

The main idea outlined above is broadly consistent with the model of cluster formation developed by Maryann P. Feldman and her collaborators (in particular, Feldman 2001, Feldman et al. 2005, Romanelli and Feldman 2006). The model is based on the observation that entrepreneurship is the key ingredient for cluster formation. Building on their previous work, cluster formation is viewed as a quantitative expansion of firms of a given industrial sector at a particular location. We define entrepreneurship broadly as any kind of establishment of a firm. This definition includes various types of firm foundations such as start-ups, spin-offs but also enterprise subsidiaries and re-establishments of firms at a new location. We do not consider psychological attitudes towards entrepreneurship but assume that individual dispositions are evenly distributed across space.[9] Given that there are no psychological limitations on entrepreneurship, the capacity to produce a marketable good first and foremost hinges on the availability of the

9 For a justification of this working hypothesis see Orsenigo (2006).

specialized inputs required for innovation.[10] Combining these inputs rests on prior relationships that have to exist in at least an embryonic form. We treat these networks implicitly by focusing on the above-mentioned types of firms established. Larger networks, in turn, result from the relationships these firms enter into once they are established. Due to our research focus, we particularly emphasize the following cases: a) second-order entrepreneurship, i.e. the initiation of a firm by staff of a previously established firm (as supplier of capital and/or knowledge[11]), b) serial entrepreneurship, i.e. the initiation of several firms involving the same organization or individual entrepreneur (as supplier of capital and/or knowledge), and c) enterprise acquisitions (as suppliers of capital). As has been stressed above, the firm's external linkages do not necessarily have to be local in nature.

The local availability of suppliers of skilled labour and (venture) capital are partly given as initial endowments. However, in order for clusters to expand, inputs have to increase accordingly. Government policy can make a contribution to this increase but due to the general mobility of suppliers, it cannot determine it. For example, public universities can be newly erected or pushed to provide special education targeted at the needs of an industrial sector. Nevertheless, assuming university graduates are free to locate wherever they think fit, a locality may end up with a "brain drain". Hence, it is the capacity of a locality to retain and attract these suppliers which determines the abundance of input factors. As we have argued in the previous section, the beliefs of the suppliers are key to the localization decision in what may be viewed as a coordination game. A simple feedback mechanism may be introduced due to which the success of existing enterprises – determined by the (relative) quality of a firm's organization, i.e. the internal organization of a firm and its external linkages – influence the beliefs of the suppliers with regard to their opportunities. That is, previous successful entrepreneurship at a given location attracts suppliers, which provides the foundation for subsequent entrepreneurship. In this sense, success breeds success.

Cluster formation can arguably be rationalized along the lines of the model of Feldman et al. (2005) as a process structured in three phases. At the beginning, the concomitance of several exogenous events opens opportunities for entrepreneurship. Given the initial endowments of a location, new firms come into existence. If these firms are able to grow into viable enterprises, the next phase sets in. As a stylized process, the second phase may be described as follows: "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" (Feldman et al. 2005). Expressed in the language introduced above, initial entrepreneurship influences the beliefs (and therefore the localization decision) of suppliers of human and financial capital, the expansion in turn draws the attention of local policymakers who provide additional investments into infrastructure etc. Under ideal circumstances, all of these activities constantly reproduce the beliefs on which the expansion rests. It is these beliefs that mark the third stage and may be viewed as the "culture" of a particular cluster.

If clustering is primarily stated in terms of entrepreneurship, then the type of firms populating a cluster is an important variable that offers insights about differences in dynamics among various clusters. As Romanelli and Feldman (2006) show with regard to health biotech clusters in the USA, particular regions develop in idiosyncratic ways through the establishment of particular firms. We can distinguish between a) start-ups or spin-offs from a university or public research institute, b) start-ups or spin-offs from existing enterprises, c) subsidiaries of enterprises from other locations and/or industrial sectors, and d) re-locations of existing firms in a given industrial sector. Arguably, these firms display different forms of organization, i.e. internal and external linkages. The distribution of firms in a cluster is closely

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10 In this contribution, we use a broad definition of innovation that also encompasses subjective novelty. While objective novelty is new to the world, subjective novelty concerns novelty that is new to an actor (individual or organization) given his current stock of knowledge (cf. Witt 2009). Considering China's health biotech sector, the domestic market is dominated by biogenerics (Hu et al. 2006). Due to our broad definition that focuses on learning, we also treat these products as innovation.

11 We use knowledge in order to indicate that the input may include disembodied (e.g., technology) and embodied knowledge (skilled labour).

associated with local cultural "beliefs", because different types of firms are salient to different suppliers of input. For example, it can be hypothesized that a cluster with a strong presence of domestic and foreign enterprise subsidiaries will attract a different set of skilled workers than a cluster with many start-up firms. The former cluster will probably be not very attractive for venture capital firms. Moreover, subsidiaries will likely have the strongest interaction with their parent companies, wherever they are located. This implies that local cultures have a historic flavour as the local expansion of firms tends to be based on present suppliers observing previous suppliers.

In summary, the general reasoning behind the model is that cluster genesis may be analysed by tracing the type of firms, which are co-locating at a given location. Entrepreneurship is viewed in a broad way encompassing all firm entries of an industrial sector. Larger regional networks emerge in this model mainly from second-order and serial entrepreneurship, while the location of the derived firm is determined by the beliefs of the suppliers of inputs. Hence, new firms may be located at the same site implying cluster expansion, or at a different site which also leads to an expansion, but of a different cluster. Cross-regional entrepreneurship induces cross-regional linkages. In the following chapter, an exploratory investigation of a number of Chinese clusters will be undertaken.

3 Cluster Genesis in China's Health Biotech Sector

China's economic performance over the past three decades rests less on the growth of firms, which have been set up under the planning system of the period before the 1980s, but rather on a rapid entry of new firms, most of which have never been included in the plan. As has been already discussed at length elsewhere (cf. Naughton 2007), the reforms, which were initiated in the late 1970s, have brought along these manifold opportunities for entrepreneurship. The changes in the political domain are the most obvious exogenous shock to China's economy. Incentives for entrepreneurship were high, because the shortage economy of the pre-reform period implied that demand for industrial goods was still largely untapped. In turn, wages in the existing firms and organizations were artificially depressed, and this was most strongly felt by scientific staff and technicians, since the egalitarian wage structure provided for low returns to human capital (Yueh 2004). Moreover, the "iron rice bowl", the life-long employment guarantee, effectively began to erode in the mid-1980s when temporary labour contracts were introduced for recent graduates (Meng 2000). All of this rendered self-employment or employment in the "non-state" sector increasingly attractive. And as long as political uncertainty with regard to private entrepreneurship prevailed throughout the 1980s and early 1990s, cooperation between firms and local state organizations helped to overcome entry barriers for new firms.

In fact, local governments have been eager to foster economic growth in their jurisdictions in order to secure fiscal income.[12] Gradually, entrepreneurship in high-tech industries[13] became a focus of government support. Following initial attempts by entrepreneurial scientists in the early 1980s, the central government acknowledged these initiatives and launched the torch programme (*huoju jihua*) to provide a suitable environment for these "new technology enterprises" (cf. Gu 1999). One of the primary objectives of the programme is to support the commercialization of new technologies. In the pharmaceutical industry, the biopharmaceutical and biochemical segment therefore draws significant attention. Government support mainly occurs through science parks (*gaoxin jishu chanye kaifaqu*) and industrial bases (*tese chanye jidi*) as the most salient feature of the torch programme. Although the programme is initiated by the central government, it is local governments that sponsor those parks and assume the main responsibility for their operation.

12 The main thrust of the tax reform of the early 1980s was to overcome the earlier system of "unified income and expenditure" (*tongshou tongzhi*). Instead, local governments were supposed to "eat in separate kitchens" (*fenzao chifan*), i.e. to assume the responsibility for their revenue and expenditure. The tax system has been identified as one of the main reasons for local governments' staunch support of industrial growth.

13 The Chinese classification follows that of the OECD. Industries considered to be high-tech include pharmaceuticals, aircraft and spacecraft, electronic and communication equipment, computers and office equipment, and medical equipments and meters.

Hence, there are two basic forces that account for China's geography of innovation. On the one hand, the reforms provided ample opportunities for entrepreneurship by individuals dissatisfied with their situation in the state organizations prevailing at that time. While the exogenous shock of the reforms worked evenly on the whole country, access to inputs rendered some locations a more likely candidate for clustering than others. On the other hand, local governments have been proactively involved in the development of clusters. That is, instead of reacting to endogenous local developments (as assumed in the model outlined above), they have taken supportive measures at a very early time of the life cycle of a given industrial cluster. This interference appears to separate the Chinese approach from its US counterpart (cp. Romanelli and Feldman 2006). However, as will be discussed in more detail, the relative impact and combination of these forces has varied among locations. Accordingly, some clusters developed more endogenously, whereas others are rather the product of policy design. While the distinction between endogenous and policy-induced clusters may be one of degree,[14] it is arguably helpful to distinguish between those clusters that are based on comparative advantages with regard to input factors, and those that are not. These differences are most pronounced at the origin; while later in the life cycle the institutional environment at the locations tend to converge.

As the pharmaceutical industry is knowledge-intensive, endogenous cluster formation is often based on a strong academic foundation at the locality. That is, renowned research universities and public research institutes with a record in the scientific field provide the skills needed to develop marketable products. In China, a few municipalities feature such research institutions, but the two cities with the densest net are Beijing and Shanghai. Unsurprisingly, it was Beijing where China's high-tech entrepreneurship has its roots.[15] The early enterprises were usually academic spin-offs.

Two spin-off varieties should be kept apart: One variety involves investments of the parent academic institution. That is, the enterprises are only "quasi-spin-offs" since they remain attached through their ownership arrangement. This kind of entrepreneurship was the unintended outcome of a policy approach of forging science-industry linkages. In 1985, the Central Committee of the Communist Party issued the "Decision on the Reform of the S&T Management System", which called for a reduction of budget appropriations for public research institutions. The institutions were supposed to make up for the budget cuts by offering their services to industrial enterprises. For several reasons – including weak intellectual property rights and weak absorptive capacity of state-owned enterprises – the research institutions opted for supporting academic spin-offs instead (Eun et al. 2006). As investments, spin-offs are supposed to provide a source of income for the parent unit. The Chinese Academy of Sciences (CAS) has been quite prolific in this regard: The then-leadership of the Academy encouraged research staff to establish enterprises under the concept of "one Academy, two systems" (i.e. research and business) (Suttmeier et al. 2006). The most prominent of the academy's spin-offs is arguably *Lianxiang* (internationally known as Lenovo), but there are equivalents in the pharmaceutical sector. For example, BioSino (*Zhongsheng Beikong*) was established in 1988 as a spin-off of the CAS Institute of Biophysics in Beijing.[16] The second variety is constituted by spin-offs with academic staff venturing into business rather autonomously.[17] One of these spin-offs is Shanghai Fudan-Zhangjiang Bio-Pharmaceutical founded by six teachers from Fudan University, a university with a proven record in the field located in Shanghai. Although the university has a stake in the company, merely limited ties exist between company and university. In fact, the 5 % share the university holds is a kind of compensation for the university's name rights (authors' interview).

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14 In their overview of the biotech clusters of Beijing, Shanghai, and Shenzhen, Prevezer and Tang (2006) therefore treat all of these clusters as "policy-induced".

15 For an informative account of Beijing's early high-tech entrepreneurship see Zhou (2008).

16 The Institute of Biophysics has established six enterprises altogether, four of which failed (authors' interview). The second enterprise, Beijing Baiao Pharmaceuticals, is part of the BioSino Group. Another example of a CAS spin-off is Di'ao Group established also in 1988 by the Chengdu Institute of Biology of CAS (cf. Yu 2007). Other major public research institutions have also been involved in such spin-off activities. For example, Beijing Four Rings Biopharmaceutical used to be affiliated with the renowned Academy of Military Medical Sciences.

17 Entrepreneurs listed in BioPlan's top 80 featuring such a background include the leaders of 3S Bio (Shenhou Institute of Military Medicine), Anhui Anke Biotechnology (Anhui Institute of Biology), and Beijing SL Pharmaceutical (Chinese Academy of Military Medical Sciences). Note the importance of the military sector in the development of China's pharmaceutical industry.

The academic spin-offs described above are one of the major constituting parts of the clusters in Beijing and Shanghai, but also in other cities with important research establishments, e.g. Hangzhou (Zhejiang province) and Chengdu (Sichuan province). However, Beijing is unique with regard to a different type of entrepreneurship, which rests on its comparative advantage from being the country's capital. Beijing is the primary location of the country's administration, which has provided opportunities for entrepreneurship. For example, the two founders of Beijing Kinghawk Pharmaceutical have worked at precursor institutions of the State Food and Drug Administration (SFDA). During their work at these institutions, they received valuable information about HIV products and about domestic market demand, which led them to establish their own company (authors' interview). The president of Biotech Pharmaceutical, a joint venture with the Cuban Centre for Molecular Immunology, is a former staff of the Ministry of Science and Technology (MOST). It was him who headed an official delegation to Cuba in 1994 (authors' interview).

Besides these types of entrepreneurship, there is another kind of endogenous development. As Feldman et al. (2005) have argued, the early firms in the US biotech clusters were usually not involved in very research-intensive activities. Instead, innovation is the outcome of longer processes of learning. Theoretically then, increasing returns to learning may help firms to enter into more technology-intensive sectors. The pharmaceutical cluster in Tonghua (Jilin province) is one example for endogenous clustering in the face of low entry barriers and huge market opportunities. Tonghua is situated at the foot of the Changbai Mountains, which host a wealth of flora that can be used in traditional Chinese medicines. Until 1980, eight factories had been established to exploit these natural resources. On their foundation, new enterprises emerged once the reforms provided a more amenable environment for entrepreneurship.[18] The number of enterprises rose rapidly during the reform period, when many entrepreneurs followed the example set by the early firms (Liu 2009). In 2007, 84 tenants were residing in the two torch programme pharmaceutical bases established in Tonghua (Torch 2008). A few of these enterprises have become quite large and have managed to produce more sophisticated biopharmaceutical drugs. Among them, Tonghua Dongbao Pharmaceutical has brought to market a recombinant human insulin product, Gansulin (BioPlan 2008).

However, many Chinese clusters have not shown this kind of dynamics. Instead, their initial development hinges on industrial policies pursued by local governments. Shenzhen (Guangdong province) provides an outstanding illustration. In 1979, Shenzhen was designated a "special economic zone" created for the purpose of experimenting with institutional reform (Ge 1999). Due to the superior regulatory environment, it attracted a large number of export-oriented foreign-invested enterprises. Moreover, domestic enterprises also moved into the city to profit from (more) secure property rights, preferential taxes, easier access to foreign suppliers of capital and less complicated regulatory procedures. Although the city, which used to be a village only three decades ago, did not have any academic institutions, the first (however not nationally sanctioned) science park was established here in 1985 sponsored by the municipal government and the Chinese Academy of Sciences (Gu 1999). In the case of the (bio-)pharmaceutical industry, domestic movements to Shenzhen are even more important than the investments of foreign actors. In fact, Shenzhen is home to China's first modern health biotech company, Shenzhen Kexing Biotech, which was established in 1989. The company was set up jointly by the Chinese Academy of Preventive Medicine (CAPM) in Beijing, the Shanghai Institute of Biological Products, the Changchun Institute of Biological Products,[19] and the Bio-Engineering Center of the State Science and Technology Commission (SSTC, now Ministry of Science and Technology, MOST).

18 Many companies were based on out-contracting of the former state-owned factories to individual entrepreneurs. For example, Li Yikui, Tonghua Dongbao's entrepreneur, was a technician at the Tonghua Baishan General Pharmaceutical Plant before he contracted out the Baishan No. 5 Pharmaceutical Factory (Liu 2009).

19 At that time, both institutes were subordinate to the Ministry of Health. In 1989, the China National Biological Product Corporation (CNBPC) was established, which included these two and four other institutes of biological products. The corporation was restructured in 2003 and renamed into China National Biotec Group (CNBG). But this change was only ephemeral as CNBG was merged in late 2009 with the China National Pharmaceutical Group (Sinopharm).

Shenzhen Kexing shows that spin-offs are not necessarily located at the place of the academic institutions. The company was set up to commercialize a recombinant alpha interferon against hepatitis B and C developed at the CAPM. To our knowledge, there are not yet any thorough investigations about the determinants of spin-off localization in China. Yet, it appears that the early spin-off activities are a type of governance mode devised to enable technology transfer. That is, instead of choosing conventional contractual technology transfer arrangements with a given firm via a technology licensing office of the academic institution, the project is incorporated into a new firm with investors and academia acquiring a stake. Hence, the academic spin-offs set up at other locations differ from those, which have been outlined above with a view on clustering in Beijing and Shanghai, in an important way: External investors participate in the project from the very beginning.[20] Often, these firms appear to be located at the place the investor has selected.

While Shenzhen had an artificial comparative advantage for quite some time due to its ability to take reforms "one step ahead" (Vogel 1989), other localities have also attempted to create a conducive environment for the development of high-tech industries.[21] The establishment of science parks provided an avenue for extending preferential treatment to firms willing to reside at the location. Provinces like Jiangsu and Shandong have been particularly aggressive in this regard. Jiangsu province used to be associated with the South Jiangsu (*Sunan*) model of development, which featured the establishment of collectively owned rural enterprises. However, this approach gradually gave way to the Kunshan model, coined after the strategy pursued by the government of Kunshan, a county-level city under Suzhou municipality (South Jiangsu). Kunshan thrived on attracting foreign and domestic investment (cf. Wei 2002). As Suzhou is directly neighbouring Shanghai, it poses an attractive alternative to locating in the more expensive metropolis. Consequently, some of Suzhou's counties have managed to lure some pharmaceutical enterprises into their parks. The strategy has been imitated by governments farther away. Often, these localities focus on a few selected industries with some of the localities basing their choice upon a number of already existing enterprises. An example is Taizhou in Middle Jiangsu (*Suzhong*), which claims to be "China's medical city". The city has a history of pharmaceutical industry development that dates back to the pre-reform period. In particular, Yangtze River Pharmaceutical, a company established in 1971, has contributed to bringing Taizhou on the map. Firms like these are utilized by local governments as "anchor" firms around which the parks are developed.

4 Sketches of China's Health Biotech Cluster Development

In chapter 2, it was proposed to view cluster development as a quantitative expansion of firms of a given industry at a given location. Given some initial impetus, the second stage of cluster development rests on suppliers of skilled labour and capital continuing to "invest" their inputs at a certain place or moving to a different location. As the location decision concerns a choice between locations, the analysis hence just naturally has to go beyond looking at one of the potential sites. Unfortunately, information on Chinese biotech firms is scarce and we cannot refer to such comprehensive firm directories, as they exist for the US biopharmaceutical industry.[22] For the time being, we can therefore just report some preliminary observations.

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20 According to Walcott (2003), Shenzhen Kexing used to be a joint venture with an investor from Singapore. The partnership was dissolved when disputes arose over marketing strategy. SinoBioway Group (*Beida Weiming*), one of the three big groups established by Peking University, has acquired the company together with Sinogen, a company controlled by US-based venture capitalist H&Q Asia Pacific (BioPlan 2008).

21 When the pharmaceutical industry took root in these localities, local governments worked on the improvement of the environment. Although Shenzhen did not originally feature a strong academic base, the city has attempted to make up for this deficit by establishing the "Shenzhen Virtual University Park" (cf. Walcott 2003). Furthermore, a university town was set up within the science parks, where leading universities such as Tsinghua and Peking University opened branch campuses (Chen and Kenney 2007). This approach was also adopted at other places without strong research institutions: For example, Taizhou features a branch campus of Nanjing University of Science & Technology, a medical college was established in Tonghua by Jilin University. Altogether, the quality of the general infrastructure in those clusters converged, although the major research sites maintained or even improved their status.

22 Empirical studies of the US biopharmaceutical industry often employ information from BioScan, a comprehensive industry directory.

4.1 Regional Specialization

Particularly since the late 1990s, Jiangsu province, and even more so, Shandong province have rapidly expanded the size of the pharmaceutical sector. In fact, Shandong, Jilin, and Jiangsu head the list of China's provinces with the largest share in biopharmaceutical output (MIIT 2009). Often, this expansion rests on some cities with a longer industrial history. In cities like Taizhou in Jiangsu province or Jinan in Shandong province, the pharmaceutical and biotech industries have a higher significance and have received a strong attention by the local government. This contrasts, for example, with places such as Shenzhen whose growth of the early reform years was substantially in industries like electronic and communication equipment.[23] While proactive industrial policies are pursued by most local governments with financial clout, the relative importance of the industry in a locality's industrial mix affects the way how industrial sectors are showered with government money.

And many localities have been ready to spend quite some money for industrial location. As a particular feature of China's nascent venture capital industry, local governments are one of the most important suppliers of early-stage finance (cf. White et al. 2005). As the pharmaceutical industry is rather capital-intensive, domestic firms are starved for capital. Hence, they appreciate the funds set aside by the local governments. As several of our interviewees indicated, the governments are very accommodating in their proactive search for new park residents. Take again the example of Shanghai Fudan-Zhangjiang. The company has set up a manufacturing base in Taizhou, whose government has acquired a 49 % stake in Taizhou Fudan-Zhangjiang. Far from being a singular case,[24] the strategy to establish manufacturing enterprises in locations other than the home base appears to be common. Often (but by no means always), companies are established in provinces neighbouring their home provinces. Hence, despite fierce competition between local governments for growth opportunities and a seeming reluctance by them to cooperate, the investment strategies of companies have led to stronger economic connections within larger regions such as the Yangtze River Delta and the Bohai Rim.

Movements of firms have also gone the other way. Many firms, which are home to places other than the cities with strong research institutions, have set up subsidiaries in these very cities. For example, Zhejiang Apeloa Bio-pharmaceutical Co., a member of the Hengdian Group, has founded Shanghai Apeloa Pharmaceutical Research Institute. Large firms in Tonghua have also established a presence in cities. Tonghua Xiuzheng Pharmaceutical – Tonghua's largest company, which has been designated a "national innovative enterprise" by the Chinese government – has set up its R&D facility in Changchun, Jilin province's capital (company's website). The same applies for Tonghua Dongbao Pharmaceutical, which likewise has also invested in Changchun (BioPlan 2008). As it appears, a division of labour is emerging between the locations. While some locations are rather attracting manufacturing activities, others – most importantly, Beijing and Shanghai, but also other cities like Hangzhou or Chengdu – are attractive with regard to more research-intensive activities. As a consequence, Shanghai's Zhangjiang park reports that the majority of resident biotech organizations are concentrating on R&D activities of some sort (Zhangjiang Hi-Tech Park 2009). This division of labour is reinforced by the strategies of those cities. Based on the initial spin-off activities from universities (and public research institutes), university parks were set up to provide such fledgling firms with a range of services. Furthermore, potential entrepreneurs are lured into the city to start innovative projects. One example is Shanghai GENON Bio-engineering. The company's chairman, Cheng Guoxiang, was the youngest professor of Yangzhou University (Jiangsu province), before he was invited by the Shanghai government to set up a company. Again, the local government has invested some funds to get the company off the ground (authors' interview).

23 Shenzhen's initial focus on electronics may account for its relative strength in medical treatment equipments. In this segment, it only trails Jiangsu province (NBS et al. 2009). Companies like Mindray Medical International (*Shenzhen Mairui Shengwu Yiliao Dianzi Gufen Youxian Gongsi*) are among the most prolific firms with regard to patenting in Shenzhen (cf. Shenzhen Intellectual Property Office, http://www.szipo.gov.cn).

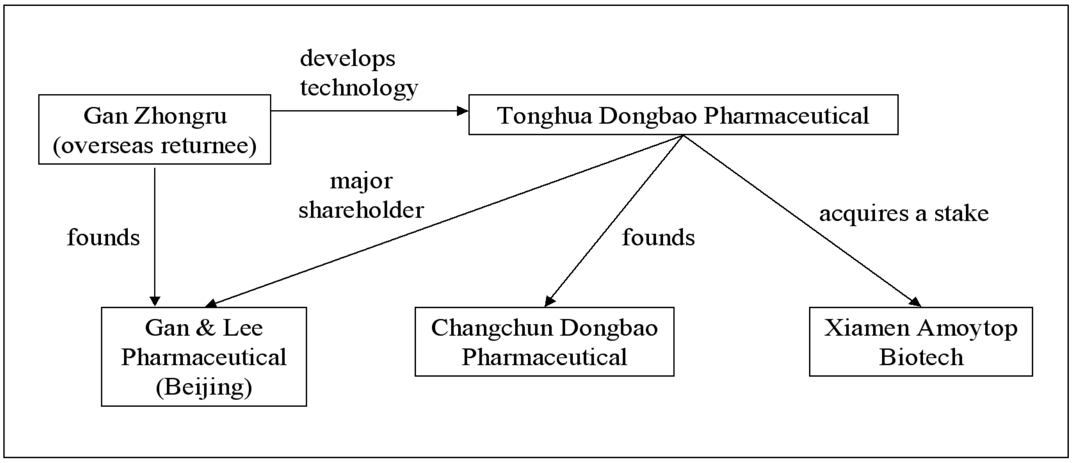
24 For example, Huzhou HealthDigit (Jiangsu province) has been identified in MIIT (2009) as one of the outstanding firms in the biopharmaceutical segment. However, this firm is the manufacturing base of Shanghai HealthDigit. Since all firms are treated as legally independent entities, these connections are often difficult to pin down.

4.2 The Contribution of Foreign Enterprises and Returned Entrepreneurs

Foreign multinationals have participated actively in the regional distribution of economic activities in China. In recent years, many multinationals have established a presence in China. As these companies have arrived rather lately, they are however not as dominant as in other industries. In comparison to an average penetration of about 70 % for all high-tech industries, the 37 % output share of foreign-invested enterprises in gross biopharmaceutical output is rather modest (MIIT 2009). Moreover, the main thrust of their activities is not on exports, as almost 85 % of their sales in the biopharmaceutical segment is realized on the Chinese market (MIIT 2009). This indicates that foreign investment is mainly of the market-seeking type.[25] Due to their focus on the domestic market, foreign firms have yet also gradually engaged in more strategic asset-seeking activities in order to learn more about the technological capacity of domestic organizations and to get better acquainted with the preferences of domestic consumers (and regulators). Hence, firms like Roche or GlaxoSmithKline have increasingly opted to set up R&D institutes alongside their manufacturing activities. For example, Eli Lilly, a US pharmaceutical enterprise, has established a manufacturing base in Suzhou (Jiangsu province), but it has also opened its main R&D centre in neighbouring Shanghai. As a matter of fact, the majority of autonomous pharmaceutical R&D institutes that have been established in recent years are apparently located in Shanghai.

Foreign multinationals appear to mainly collaborate with domestic academia and contracted research organizations (CROs). For example, while the Shanghai Institutes of Biological Sciences (SIBS) of CAS have some technology licensing agreements with domestic companies – usually larger companies from outside Shanghai (e.g. Jiangsu and Zhejiang province), their transfer office preferably license out technology to multinationals. About half of the licensing and sponsored research activities concern multinational companies (authors' interview). Besides, multinationals such as Eli Lilly entertain collaborations with several CROs in Shanghai.[26] Collaboration is pronounced in R&D, while it is rare in manufacturing due to the problematic enforcement of IPR (Jia 2009). Nonetheless, a few production-oriented joint ventures exist, the most outstanding of which are the already mentioned Sino-Cuban JV Biotech Pharma[27] and Tianjin Hualida Biotechnology, a joint venture originally established with Fermentas Institute (Lithuania) and Vniigenetika Institute (Russia) (BioPlan 2008).[28]

Figure 1: Tonghua Dongbao Group



Own illustration

25 Dunning (1998) has proposed a taxonomy of variables influencing the location decision of multinational enterprises. According to this taxonomy, the type of investment is ressource seeking, market seeking, efficiency seeking, or strategic asset seeking. Some of the R&D activities of multinationals in China may be considered to be strategic asset seeking in the sense that these investments are made to investigate consumer demands and the nature of the Chinese competitors as well as to tap knowledge sources.

26 See Jia (2009). Sigurdson (2005) takes Shanghai ChemExplorer as an example of a domestic CRO that cooperates closely with Eli Lilly.

27 Another Sino-Cuban JV, Changchun Heber Biological Technology, was established together with the Changchun Institute of Biological Products (BioPlan 2008).

28 Meanwhile, ownership has changed and Hualida has turned into a Sino-Israeli JV.

Yet, the most important transfer of knowledge from advanced economies into China derives from return migration. In China's health biotech sector, professionals with extended periods of working and research experience abroad – in particular the United States – play a significant role. Courted by the Chinese government, the so-called "sea turtles" have returned to take leading positions in several research institutions and businesses. Several domestic companies, e.g. CapitalBio (Beijing), have staffed the R&D departments of their companies with such returned students. Other forms of technology transfer have also evolved. Take again Tonghua Dongbao Pharmaceutical (Figure 1). The company started with simple products made from the abundant natural resources of the Changbai mountains. In order to further develop, there had to be some infusion of knowledge. Gansulin, the recombinant human insulin product named above, was actually developed by an overseas returnee who later moved on to establish his own company, Gan & Lee Pharmaceutical, in Beijing.[29] The major shareholder of the latter company is Tonghua Dongbao (WiCON 2009).

Several returnees have launched their own enterprises.[30] Another example, Peng Zhaohui, the entrepreneur that established Shenzhen SiBiono GeneTech, was trained in gene therapy techniques in Japan and the US before he returned to China (Krimsky 2005). SiBiono became internationally known as the first company worldwide that brought to market a gene therapy product, Gendicine. Other such enterprises include Wuxi AppTech (formerly Wuxi PharmaTech) located in Jiangsu province, which is an outsourcing firm mostly to multinational companies such as Merck (Capie 2006). As Wuxi AppTech already suggest, these kinds of enterprises are well-placed to connect between the Chinese and US industry, which also shows in the setting up of subsidiaries or parent firms in the USA. In recent years, some studies have targeted returned students, but they have usually focused on particular cities rather than industries (e.g., Müller and Sternberg 2008). Hence, the localization decision of these entrepreneurs still seems under-researched. A look at the most visible "sea turtle" firms in China's health biotech sector suggests that they are not clustered at a particular location. However, their localization decision is also not random. Most returnees seem to settle in China's top ten regions with regard to health biotech development. These regions embrace both, manufacturing bases and sites with a strong research foundation. As may be hypothesized from our previous theoretical considerations, their location decision may hinge on their particular strategies requiring different kinds of inputs available at various clusters. For example, Wuxi AppTech's strategy is based on China's labour cost advantages. In this regard, it makes sense to locate outside the major research centres, where input costs are lower.

4.3 Serial Entrepreneurship

Since the health biotech sector is science-based, academia has come to be intimately involved in this industry (cp. Pisano 2006). As we have described above, although China's domestic firms are scattered around the country, the overwhelming majority of firms have developed ties to research institutions, some of them expanding over long geographical distances. While some of these ties are based on technology transfer and sponsored research,[31] a significant amount of enterprises display capital relationships with academic institutions. As we have already mentioned above, there are two kinds of academic spin-offs: in one type of spin-off, the sponsoring academic institution participates in the development of the firm, in the other it merely supports autonomous entrepreneurial activities of its staff or students. The former type is interesting insofar as a few key individuals have become intimately involved with the sponsored firms. These outstanding individuals help in the expansion of the industrial sector by acting as serial entrepreneurs. For example, Yunde Hou, the director of the Institute of Virology at the Chinese Academy of Preventive Medicine (CAPM) who is dubbed China's "father of interferon", is such a personality (Figure 2). He had contributed strongly to the development of the recombinant alpha interferon that was eventually commercialized by setting up Shenzhen Kexing Biotech in the 1980s. Later, he went

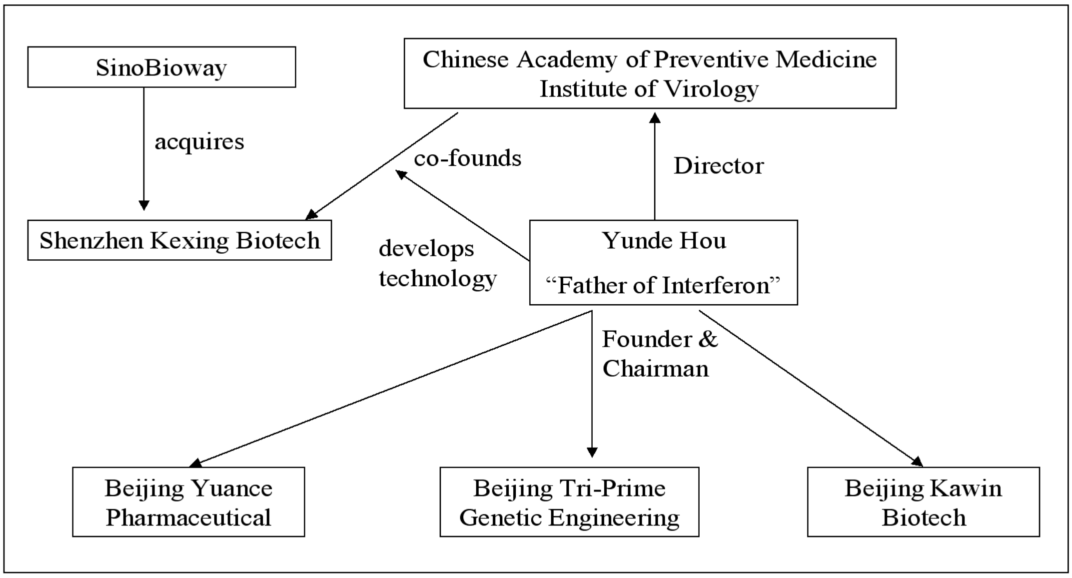
29 As is well-established in the literature on China, personal networks play an important role. This also applies in this case. Li Yikui, the founder of Tonghua Dongbao, and Gan Zhongru, the developer of Gansulin, were university classmates (Liu 2009).

30 Other companies listed in the BioPlan top 80 include e. g., Changchun GeneScience Pharmaceuticals and Shandong Simcere Medgenn Bio-pharmaceutical.

31 For example, firms like Hisun Pharmaceutical (*Zhejiang Haizheng*) have grown due to technologies bought from research institutions in Shanghai (CPEMA 2009).

on to establish his own firms including Beijing Yuance and Beijing Tri-Prime, both of which are key players in China's health biotech sector and the latter of which was designated to be the anchor firm for Beijing's Daxing Bio-medicine Park.[32] By doing so, he contributed greatly to the sector's development in Beijing.

Figure 2: Yunde Hou



Own illustration

Besides such academic spin-offs, other actors can also be engaged in the setting up of multiple firms thereby furthering endogenous development in a region. Owen-Smith and Powell (2006) show in their comparative analysis of two US regions, that while the Boston region was based on the above-mentioned kind of start-ups with academic involvement, companies in the Bay Area (around San Francisco) were predominately linked to venture capitalists. In China, the venture capital industry is still young and immature. However, a few incidences can be found. In a similar manner that can be observed in the USA, some pharma firms have themselves invested in promising start-ups. For example, Shenzhen Xinpeng Biotech has co-founded (at least) three other enterprises, which have improved Shenzhen's status in China's health biotech sector (Figure 3). As most of Shenzhen's growth is based on the relocation of entrepreneurs and the commercialization of technologies developed elsewhere, these endogenous start-ups appear to distinguish the municipality from regions with a similar dependency on inflows of capital and knowledge.

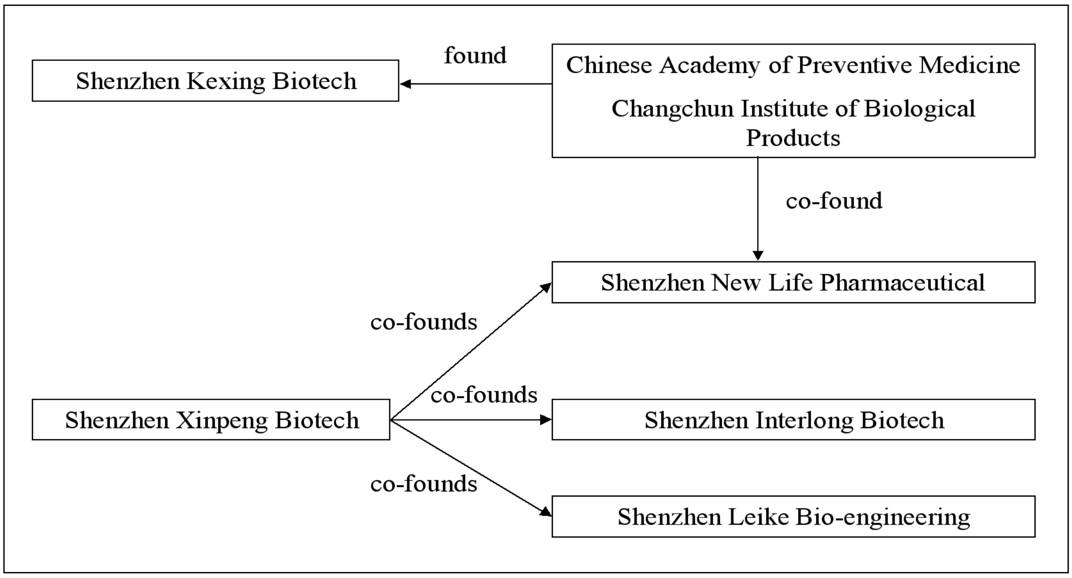
Yet, despite these incidences, a more highly visible number of enterprise creations are transcending regional boundaries. The same applies even more so for enterprise acquisitions. Another prominent figure, Pan Aihua, the founder of SinoBioway (*Beida Weiming*), one of Peking University's three large business groups,[33] has apparently chosen to establish firms at different locations in China. Enterprises belonging to the SinoBioway Group include inter alia firms in Xiamen, Chengdu, and Guangzhou. Furthermore, SinoBioway has also acted as investor. When Shenzhen Kexing got into a predicament, because the commercialization of its product was more difficult than envisioned, SinoBioway teamed up with a US venture capital firm, H&Q Asia Pacific, and injected new capital into the firm (BioPlan 2008). Both of

32 Altogether, Beijing's science park, Zhongguancun, actually features ten parks, which are spilled over the whole city. Regarding Beijing's health biotech sector, the most important of these are Haidian Park – the original Zhongguancun – and Yizhuang, which is also known as the Beijing Development Area (BDA), since it was initially established as an Economic and Technological Development Zone (ETDZ). Similar to developments in other parts of the country, Beijing has merged the ETDZ into its high-tech park (cp. Li et al. 2004). Another important health biotech base in Beijing is Changping Park to the north of Haidian, where Bio-Sino acts as "anchor" firm.

33 The other two business groups are Peking University Founder (*Beida Fangzheng*), an IT hardware firm, and Peking University Jade Bird (*Beida Qingniao*), a software firm.

these investors were also in charge, when Shenzhen Kexing established its subsidiary, Shandong Kexing Bioproducts. Sinovac Biotech is however located in Beijing.[34]

Figure 3: Shenzhen Xinpeng Biotech



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4.4 Second-order Entrepreneurship

The foregoing discussion concerned the establishment of firms through hierarchical mechanisms, i.e. the establishment of firm subsidiaries or the initiation of new enterprises by the management of an existing organization, be it an academic institution (or its business group) or an enterprise. As it appears, these mechanisms constitute one of the major approaches to enterprise formation in China's health biotech sector. In the preceding chapter on cluster genesis, we have also pointed at the importance of autonomous academic start-ups. Particularly those locations with comparatively strong research institutions in this sector – and therefore a large pool of skilled workers and potential entrepreneurs – feature that kind of enterprises.

There is however another possibility for the initiation of autonomous start-ups. Besides those by academic staff and students, enterprises may also be launched by staff from established firms. In their study on cluster formation in the US health biotech sector, Romanelli and Feldman (2006) dub this phenomenon "second-order" entrepreneurship. They argue that it is exactly this kind of entrepreneurship, which distinguishes dynamic clusters from those that perform rather poorly. Accordingly, clusters like that in the New York region are predominately attractive as a site for enterprise subsidiaries, most importantly those of foreign multinationals. While in the beginning, New York displayed strong activity with regard to academic start-ups, this activity receded in the beginning of the 1990s, although the establishment of subsidiaries continued. On the other hand, clusters like that in the Bay Area, the Boston and San Diego regions have thrived on enterprises established by academic staff and students as well as by enterprise staff. For example, in San Diego merely six firms had been set up until the mid-1980s. The following expansion has rested mainly on enterprises having been established with both, entrepreneurial and firm origins in these original firms. In turn, the endogenous cluster dynamics has lured entrepreneurs and firms from other regions to move into these clusters.

While we have to admit that our information is too limited to draw substantiated conclusions, it is yet hard to find evidence of second-order entrepreneurship in China's clusters. A possible exception is

34 Sinovac was formally established by Shenzhen Kexing and Tangshan Yian Biological Engineering (Hebei province). The latter firm's general manager, Weidong Yin, was responsible for the development of a hepatitis vaccine that eventually was commercialized by establishing Sinovac. Later, Sinovac acquired Tangshan Yian.

Tonghua where entrepreneurial activities were originally based on spin-offs from those enterprises that had been established during the pre-reform period. Second-generation growth, however, appears to be more seldom in later stages of Tonghua's cluster development.[35] In a sense, the firms founded by returnees with working experience abroad may be interpreted as such kind of entrepreneurship. Yet, these activities are obviously not locally bounded, and the network structure emanating from it is transcending national boundaries. Returnee enterprises may be more strongly connected to the health biotech clusters in the USA than to the firms in their direct geographic proximity. In fact, Frew et al. (2008) report that many returnees mainly deal with foreign organizations inside and outside of China.

5 Conclusion

Clustering of economically relevant activities is viewed as an important ingredient of industrial development. Hence, policymakers and innovation researchers alike have tried to identify and establish the prerequisites for well-performing clusters. One of the most important features identified is the existence of a dense network of durable interactions among firms and between firms and academia at a particular location. Follow-up studies have however insisted that network ties extending beyond regional boundaries are equally valuable for the innovative capacity of firms. These findings have effectuated analyses on different network configurations.

Informed by these previous analyses, we have set out to examine the geography of China's health biotech industry. We have mainly concentrated our analysis on the examination of firms included in BioPlan's top 80 list of protein therapeutic product manufacturers (BioPlan 2008). Although these firms constitute only a minority of the whole sector, these firms are supposedly the strongest in terms of innovative capacity, and their linkages arguably provide a clue on the structure of this particular industry. Industrial bases focusing on pharmaceuticals and biotech as pillar industries are numerous, and we were curious about the type of firms that were established at a particular locality. On the surface, the bases can be roughly divided according to the relative distribution of firm types. In some of the bases – those that feature a rather well-developed academic infrastructure – academic spin-offs and start-ups constitute the backbone of the base. This applies most pronouncedly for Beijing and Shanghai. But there are a number of secondary cities such as Hangzhou and Chengdu – but also Xiamen, Changchun or Shenyang – that also feature research institutions with spin-off activities.

By contrast, several clusters seem to predominately owe their expansion to the establishment of subsidiaries. Although data is scarce so that a meaningful comparison is yet impossible at this stage of our research, it looks as though relocations of enterprises and individual entrepreneurs comprise a larger share than it applies for clusters in the USA.[36] In fact, a number of clusters have none or a very little number of backbone firms – consisting of those firms established during the pre-reform period – while cluster expansion is almost exclusively driven by the establishment of subsidiaries. The nature of China's capital markets, which are heavily penetrated by local governments, provides one explanation for this phenomenon. In a sense, these differences suggest that just a limited number of health biotech clusters are worth investigating. Hence, the usual approach is to focus on the most obviously important clusters in Beijing and Shanghai, and (following emerged beliefs) add Shenzhen (e.g., Prevezer and Tang 2006). However, a more thorough analysis of networks reveals that this view may be premature. First of all, the division of labour between R&D and production is not as clear-cut as it appears. Shanghai Fudan-Zhangjiang, the company used as an example, has built a production line in both cities, Taizhou but also in Shanghai. Furthermore, subsidiaries and similar types of enterprises established in the periphery appear to have substantial autonomy. They may trigger some endogenous cluster development themselves, as we have evidenced in the case of Shenzhen's cluster expansion.

35 Apparently, Tonghua Tianma is an example for second-order entrepreneurship as the enterprise was established by a former vice general manager of Tonghua Dongbao (Liu 2009).

36 Romanelli and Feldman (2006) have shown for the USA that about 70 % of firms are founded by individual entrepreneurs or organizations from the home region, while 30 % are the outcome of relocations. About 60 firms have actually relocated wholesale to a new region. This type of relocation appears to be uncommon for China, although we learned about one case, Shanghai Tauto Biotech, that indeed moved wholesale from Shenzhen to Shanghai.

The main objective of this contribution is to show that there are several types of linkages spanning local clusters. Manufacturing bases are only one kind of linkages. Indeed, firms that are located in places other than the major research sites have established R&D facilities to connect to China's centres of knowledge. While places like Beijing and Shanghai may indeed be viewed as the major loci of invention, they are not necessarily where innovation takes place. Technology transfer between regions appears to be significant. Some enterprises that exist in the periphery have come into existence as a mechanism of technology transfer: firms like Tonghua Yujin Pharmaceutical in China's northeast that commercializes a research output of CAS's Shanghai Institute of Plant Physiology.[37] Obviously, manifold linkages exist between enterprises and academic institutions that are not locally bounded. Even more importantly, returned students contribute heavily to the development of China's health biotech sector. These entrepreneurs help to provide a connection between China and advanced countries, in particular the United States. Apparently, these returned entrepreneurs have not shown a particular preference for the major research sites such as Beijing or Shanghai.

The presented evidence does not militate against a consideration of cluster-internal connections. Relationships between academia and local enterprises exist just naturally due to the science-intensity of this industrial sector. In particular, the labour market has a very local flavour, as resident firms attract students from academic institutions via such means as doctoral and post-doc work stations. Likewise, networks consisting of foreign enterprises and domestic CROs appear to be rather local. As students of China's clusters (in particular, Liefner and Hennemann 2008) have already shown, it is these two kinds of networks that may be discovered when analyzing the clusters in Beijing and Shanghai. On the other hand, linkages between domestic enterprises are said to be sparse. By analyzing cluster formation, we have sought to show that connections between academia and enterprises as well as among enterprises can be more appropriately captured by looking beyond individual clusters. In fact, there exist numerous links between the most outstanding of China's domestic health biotech enterprises. Hence, it is these external linkages that require further analysis as they provide a richer picture of how learning and innovation works in China's health biotech industry.[38] The present contribution merely constitutes an initial step in this endeavour.

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37 When the Shanghai Institutes of Biological Sciences (SIBS) of CAS were established, the institute was restructured and put under the roof of the SIBS. It is now the Institute of Plant Physiology and Ecology.

38 The structures outlined above may be industry-specific and may not apply to other industries. Nonetheless, even in other high-tech industries, the study of inter-regional networks appears to be worthwhile. Compare, for example, Zhou (2008) who points to the connections between ICT firms in Beijing and the firms in the Yangtze and Pearl River Deltas. The phenomenon of delocalization and the emergence of multiregional enterprises have been also observed in China's low-tech clusters, most notably Wenzhou (Wei et al. 2007). In fact, the cluster in Tonghua, which we have analyzed above, shares a lot of similarities with these low-tech clusters.

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Appendix 1: BioPlan's List of Top 80 Protein Therapeutic Manufacturers

Companies mentioned in the text include (ranking in brackets):

3S Bio (1)
Changchun GeneScience Pharmaceutical (2)
Shenzhen Kexing Biotech (3)
Tonghua Dongbao Pharmaceutical (4)
Anhui Anke Biotechnology (5)
Tianjin Hualida Biotechnology (8)
Beijing SL Pharmaceutical (9)
Beijing Tri-Prime Genetic Engineering (11)
Xiamen Amoytop Biotech (12)
Beijing Four Rings Biopharmaceutical (13)
Beijing Baiao Pharmaceutical (16)
Shandong Simcere Medgenn Bio-pharmaceutical (18)
Shandong Kexing Bioproducts (22)
Shenzhen Neptunus Interlong Bio-Technique (23)
Shenzhen Xinpeng Biotechnology (25)
Beijing Yuance Pharmaceutical (26)
Shenzhen SiBiono GeneTech (27)
Biotech Pharmaceutical (28)
Changchun Heber Biotech (33)
Gan & Lee Pharmaceutical (42)
Institutes of Biological Products of China National Biotec Group (49–52)
Chengdu Di'ao, Jiuhong Pharmaceutical Factory (57)
Tonghua Yujin Pharmaceutical (58)
Shanghai Roche Pharmaceutical (80)

Appendix 2: List of Organizations Visited by the Authors in February 2010

Technology Transfer Office of the Shanghai Institutes of Biological Sciences
Investment Promotion Office of Zhangjiang Science Park
Shanghai Fudan-Zhangjiang Bio-Pharmaceutical
Shanghai CP Guojian Pharmaceutical
Shanghai GENON Bio-engineering
Beijing SL Pharmaceutical
Investment Promotion Office of Beijing Yizhuang Park (BDA)
Beijing Kinghawk Pharmaceutical
Biotech Pharmaceutical
BioSino Group

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