CHINA'S PHARMACEUTICAL INDUSTRY: CLUSTER TYPOLOGIES AND CHARACTERISTICS

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This paper uses aggregate and firm level data to emphasize the characteristics of the Chinese pharmaceutical industry in general and its geographical agglomeration in particular. The major research questions are 1) Are there geographical agglomerations in China's pharmaceutical industry? 2) What are the specific features of these industrial clusters[1] and can they be classified in a typology? and 3) What is the role of FDI in the cluster formation, development and upgrading of Chinese pharmaceutical industry?

The paper consists of four major sections. The first section provides an overview of China's pharmaceutical industry and a brief discussion of the characteristics and its changing patterns. The second part looks into the literature about the typologies and 'life cycle' of industrial clusters on the one hand and the role of FDI in the cluster development on the other hand. The third part presents the ownership structure of China's pharmaceutical industry and its location patterns. The relative importance and specific characteristics of foreign invested enterprises (FIEs) are compared to domestic firms. The fourth section analyses the geographical agglomeration of the industry and its evolution. Different types of Chinese pharmaceutical clusters are identified and their specific characteristics are analysed on the basis of the literature review presented in the section two. The factors that shaped the characteristics of Chinese pharmaceutical clusters are referred to, but could not be submitted to a thorough examination due to the lack of relevant data.

A. Overview of China's pharmaceutical Industry

The pharmaceutical industry has been one the fastest growing sectors of the Chinese economy since 1978, when China initiated its 'opening door' policy. The output of pharmaceuticals increased with 16.1% annually between 1978 and 2005 and registered an exceptional annual growth rate of 22% during the period 1990–1995. Recent data show that the total production of the Chinese pharmaceutical industry reached RMB451 billion in 2005 as compared to RMB187 billion in 2000, which accounts to an annual growth of 19.2% during 2000-2005. The total sales and added value of the pharmaceutical industry respectively amounted to RMB427 billion and RMB161 billion in the same year. It was estimated that China accounted for about 10% of world pharmaceutical output in 2005 (National Development and Reform Commission, 2006).

China's exports of pharmaceutical products reached US$13.8 billion in 2005, while its imports amounted to US$11.84 billion. The annual growth rate of Chinese exports and imports of pharmaceuticals (including medical equipment) amounted respectively to 28.1% and 18.5% between 2004 and 2005. The exports of the Chinese pharmaceutical industry consisted mainly of chemical raw materials, accounting for 57.3% of the sector, followed by medical equipment (26.7%) and traditional Chinese medicine (TCM) (6.7%). About half of the chemical materials (i.e. pharmaceutical raw materials and intermediates) produced by Chinese companies were exported. These exports represented about one quarter of world trade in pharmaceutical products. Although the Western pharmaceuticals only took up a small part in China's export of pharmaceutical industry, their relative importance rapidly increased: the export volume of bio-drugs doubled between 2004 and 2005 to reach US$480 million, while for other Western medicines, the sales abroad went up by 22.3% to US$380 (MOFCOM, 2006).

The aggregate data that are used for the comparison of China's pharmaceutical industry with other Chinese manufacturing sectors come from the annual survey of large state owned enterprises (SOEs)[2] and private and foreign manufacturing companies[3] (Industry Economic Statistical Yearbook, 2002-2004). In 2003 the output value of 4,000 SOEs and large private and foreign pharmaceutical companies included in the survey reached RMB345 billion, and recorded an annual growth rate of 21% during 2001-2003 (Table 1). These enterprises generated US$12.35 billion in added value, and created 1.15 million jobs in 2003, which accounted respectively for 2.44% and 2.01% of the total Chinese manufacturing sector. The total sales value of these enterprises reached RMB272 billion in 2003, which represented 1.95% of China's industrial sector and 6.6% of the total pharmaceutical sales (IMS Health, 2005)[4].

Among various sub-sectors of China's pharmaceutical industry, chemical drugs, e.g. raw materials, intermediates and drugs, accounted for 64.7% of the total output of the sector in 2003, followed by traditional Chinese medicine (TCM) (20.2%), medical equipment (5.6%) and bio-medicines (5.4%). Other products, such as medical machinery, packaging for pharmaceutical products, TCM extracts, etc., represented 4.1%. In recent years, the Chinese government has provided research platform and tools to develop next generation TCM products and biotech-derived drugs, and attempted to capitalise on these products as a new source of pharmaceuticals. Bio-medicine and sliced medical herbs (i.e. natural drugs) grew faster than the average of the industry (Chinese Medical Statistical Yearbook, 2004).

Compared to other Chinese manufacturing sectors, China's pharmaceutical industry has a number of specific characteristics. First, the pharmaceutical industry is less export oriented and is less open to foreign direct investment. Exports accounted for 11% of the sales of the pharmaceutical industry in 2003, while the average exports to sales ratio for the manufacturing sector as a whole was 19%. With regard to FDI, foreign capital accounted for 19% of total capital in China's pharmaceutical industry in 2003, while the relative ratio was 23% for the total manufacturing sector, 73% for electronics and 43% for transport equipment. Also, capital provided by the state is much lower in China's pharmaceutical industry (19%), as compared to the average of the manufacturing sector (31%). Conversely, this indicates that non state owned domestic firms, e.g. private and joint stock or liability limited companies, play a significant role in China's pharmaceutical industry. Secondly, the pharmaceutical industry is much more innovative as compared to the average of China's manufacturing sector. New products represented 14% of the output value of the industry in 2003, while the ratio for the whole manufacturing sector was less than 10%[5]. Thirdly, the productivity of the pharmaceutical industry, measured by the added value per employee, was higher than the average of the manufacturing sector, i.e. RMB88 thousand as compared to RMB73 thousand, while its return on asset ratio was also above the average level, indicating a higher efficiency by the pharmaceutical industry in the use of its business assets. Yet, the plant size of the pharmaceutical industry, measured by sales value per company, was smaller than the average of the manufacturing sector. Its capital intensity, i.e. fixed capital per employee, was also lower. Since 2004, the profit-earning power of pharmaceutical industries decreased significantly, due to factors such as the decrease in price for medical products, the limited sales of antibiotics, the increasing manufacturing costs of raw materials, the cost of energy, and packaging materials, as well as environmental protection, (APBN, 2006).

Table 1. Main characteristics of China' pharmaceutical industries, 2003

Indicators	Pharmaceuticals	In % of total manufacturing
Number of companies	4,063	2.07
Number of employees (in thousand)	1,154	2.01
Industrial output (billion RMB, constant price of 1990)	389.56	3.03
Added value (billion RMB)	102.47	2.44
Sales (billion RMB)	271.81	1.95
Export value (billion RMB)	30.03	1.11
Assets (billion RMB)	431.65	2.56
Ratios		
New products in output (%)	14.13	9.89
Exports in sales (%)	11.05	19.32
% of foreign owned capital	19.28	23.15
% of state owned capital	19.27	31.19
Added value per employee (thousand RMB)	88.8	73.04
Size of plant (sales in million RMB)	66.9	71.07
Fixed assets per employee (thousand RMB)	145.21	183.62
Return on assets (%)	11.44	10.50
CAGR (2001-2003)		
Industrial output (%) (constant prices of 1990)	21.34	21.79
Employment (%)	5.85	2.78
Exports (%)	28.04	28.78

Note: Data collected for annual survey of about 4,000 SOEs and large private and foreign manufacturing companies.

Source: China Industry Economy Statistical Yearbook (2004) and Chinese Medical Statistical Yearbook, 2004

During 1995-2005, China's pharmaceutical industry has undergone a substantial restructuring process, especially with regard to the ownership patterns, geographical agglomeration and industry structure.

The ownership structure of the industry has become enormously diversified since the second part of the 1990s as a result of the carrying out of a set of new reform measures for SOEs - e.g. privatisation and introduction of Western corporate governance - on the one hand and the increase of merger and acquisitions (M&As) launched by non-state owned companies on the other hand. Also, about 120 companies have been listed to the stock exchanges of Shanghai, Shenzhen and even abroad and constituted the most dynamic group of Chinese pharmaceutical manufacturers. Foreign invested enterprises (FIEs) also started to play a substantial role in the industry since the second part of the 1990s. FIEs were responsible for 15% of the employment of China's pharmaceutical industry in 2003, and accounted for 19% of industrial output, 24% of added value, 22% of sales, and 26% of exports (Table 2).

Table 2. Foreign invested enterprises in China's pharmaceutical manufacturing industry, 2003

	FIEs	SOEs	Collective firms
% of the total industry			
Number of companies	17.25	24.64	6.65
Number of employees	14.66	41.66	5.29
Industrial output (constant price of 1990)	18.82	46.47	4.71
Added value	23.88	36.8	6.08
Sales	21.63	37.32	6.44
Export value	25.91	39.83	3.89
Assets	17.90	46.78	3.92
Ratios (2003)			
New products in output (%)	16.22	14.52	10.5
Exports in sales (%)	13.23	11.79	6.67
Added value per employee (thousand RMB)	144.61	78.43	102.15
Size of plant (sales in million RMB)	83.89	101.34	64.83
Fixed assets per employee (thousand RMB)	208.28	159.37	135.58
Return on assets (%)	15.86	9.98	13.77
CAGR (2001-2003)			
Industrial output (%) (constant price of 1990)	22.79	14.91	0.13
Employment (%)	16.74	-7.23	-12.64
Export (%)	42.64	19.97	-11.23

Note: Data collected for annual survey of about 4,000 SOEs and large private and foreign manufacturing companies.

Source: China Industry Economy Statistical Yearbook (2004)

As compared to other domestic firms in the pharmaceutical industry, FIEs registered an outstanding performance. Measured by the proportion of new products in total output, FIEs have to some extent a higher innovation capability: 16.2% of the output of FIEs in 2003 consisted of new products, while the relative ratio was only 14.5% for SOEs and 10.5% for collective enterprises. FIEs are also more export oriented as compared to other firms. The export to sales ratio for FIEs was 13.2% in 2003, as compared to 11.8% for SOEs and 6.7% for collective enterprises. FIEs also showed a higher productivity. Measured by added value per employee (i.e. RMB144 thousand as compared to the industrial average of RMB89 thousand), which could be partly related to the higher capital intensity and larger production scale of FIEs. The growth of foreign invested pharmaceutical enterprises between 2001-2003 was comparable to the average of the industry in terms of output, but its CAGR for employment and exports were much higher.

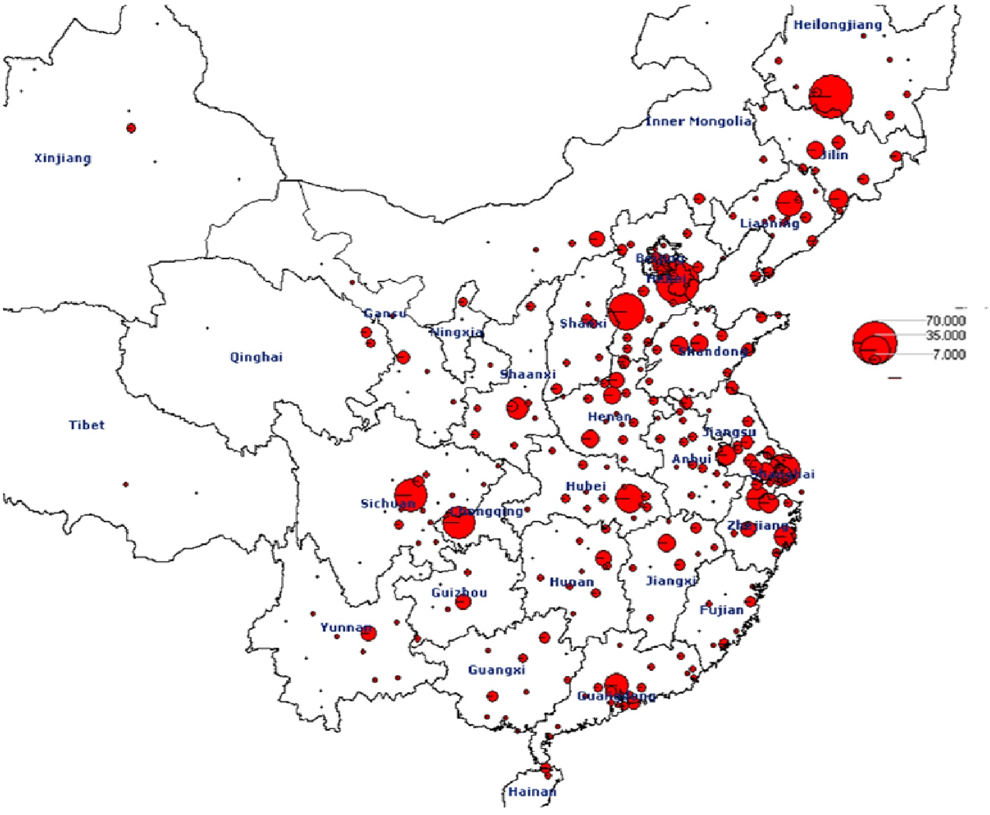
For a long time, China's pharmaceutical industry was characterised by a highly fragmented and dispersed geographical lay-out. This largely resulted from the 'self-sufficient" policy followed by the Chinese government before the economic reforms. The government considered the pharmaceutical industry as a part of public healthcare, which needed a vast and nationwide coverage. After the de centralization of the economic decisions from the Central government in the mid 1980s, local governments tried to protect their local industry and market. Consequently, many county-level governments established new pharmaceutical companies in their regions because of the high profitability that was expected for pharmaceuticals. These dispersed and replicated investment projects often resulted in the over-capacity of production, and was responsible for the numerous idle production lines in the mid-1990s. Within such a fragmented industrial structure, pharmaceutical firms were often small sized and specialized in the production of off-patent products with low technology intensity, such as antibiotics or copied drugs, traditional medicines, pharmaceuticals for animals, etc.

In the mid 1990s, the Chinese government started to restructure the pharmaceutical industry and encouraged M&As among companies as a strategic choice to consolidate the dispersed and small sized companies. As a result, some regions have succeeded in enhancing their locational advantages and gradually built up agglomerations or clusters (Yin and Salmon, 2003), while others had to reduce or withdraw from the sector. This development path of industrial clusters might be one of the main reasons to explain the decline of some regions/cities (see further).

The Eastern regions, including 3 of 4 municipalities directly under the Central government (i.e. Beijing, Tianjin and Shanghai) and 8 coastal provinces, accounted for 65.8% of the total production of the industry in 2005, and were successful in developing specialized industrial clusters, especially in the provinces of Zhejiang (raw materials and intermediate products)[6], Jiangsu (chemical drugs with strong participation of FIES) and Shanghai and its surrounding area in Zhangjiang (bio-medicine) (Figure 1). In the Peal River delta in Guangdong province, private and other non state owned companies are relatively more active, taking a leading position in the production of TCM, bio-drugs and medical equipment, especially in Shenzhen. The Bohai Bay Basin (including Beijing, Tianjin, Hebei, Shandong and

Liaoning Provinces) has a long tradition for pharmaceutical production with a quite diversified and complementary value added chain. The administrative regions of Beijing and Tianjin are more competitive in high-tech bio-pharmaceuticals, while the Shandong and Liaoning provinces are specialised in mass production of chemical raw materials and genetic drugs. In Central and Western China, the pharmaceutical industry is based more on natural resources and is more oriented towards TCM manufacturing. In order to promote industrial clusters in the pharmaceutical industry, China's Central government as well as many local authorities have created about 64 biopharmaceutical parks in different Chinese regions until 2004[7]. In 2005, MOFCOM selected 15 Chinese county cities as national export bases for pharmaceuticals.

Figure 1. Geographical agglomeration of the Chinese pharmaceutical industry (Number of employees), 2006



Note: Own map based on the location and employment data from the Directory of Chinese Manufacturing Enterprises (2006)

The Chinese pharmaceutical industry was made up of a large number (i.e. about 5,000 firms) of small- and medium sized companies with a very scattered geographical layout. The industry structure was very fragmented as compared e.g. to the American pharmaceutical sector. However, recent data showed that the concentration ratio (CR4) in the sub-sector of chemical medicines slightly increased from 13% to 15% between 1997 and 2003, while the concentration ratio for TCM went up from 20% to 21% during the same period. The implementation of Good Manufacturing Practice (GMP) certification in China since the 1990s[8], has to some extent limited the low-level repeated construction and production and raised the standard of the pharmaceutical industry, thus accelerated the upgrading of the industry and improved its overall production level. Small and medium sized domestic companies with limited financial and technological resources were forced to consolidate and become more cost-effective in the post GMP period.

In the following parts, the geographical agglomeration and ownership structure of China's pharmaceutical industry are discussed on the basis of company level data after a literature review about the typology and life cycle of industrial clusters, and the impact of foreign direct investment on the development of clusters.

The data used in the analysis of the ownership structure and industrial clusters of the Chinese pharmaceutical industry are collected and compiled from the 'Directory of Chinese Manufacturing Enterprises' for the years 1999 and 2006. This database includes almost all pharmaceutical companies operating in China and provides information of individual firms about their location, number of employees, business activities, ownership, size category (measured by sales), etc. Yet, the reliability of the database is a concern for using this type of company level data. The 1999 dataset includes 47,567 manufacturing, wholesale and retail companies operating in the Chinese pharmaceutical industry, of which 9,781 are pharmaceutical manufacturing companies, while the database in 2006 has 84,952 manufacturing and sales companies, of which 10,803 are manufacturing companies for pharmaceuticals and 4,234 for medical equipment. As this study focuses on pharmaceutical manufacturing firms, the service and sales companies as well as medical equipment manufacturers are not included.

B. Literature review

Literature studies about the tendency of industries to agglomerate in particular geographical locations often go back to the nineteenth century, especially to the pioneering works of Marshall (1891), in which the phenomenon of the concentration of production in space, and its persistence over time, are regarded as source or/and consequence of three fundamental factors (or externalities): 1) A pooled market for skilled workers with industry-specific competencies, which, from the viewpoint of firms, prevents labour shortages; 2) The availability of non-tradable and intermediate inputs, provided by local suppliers and 3) The easy transmission of new ideas (knowledge and informational spillovers), which allow for a better production function through technical, organisational and production improvements.

Besides the basic conceptual approaches for understanding *how* and *why* enterprises cluster in geographic space (Bergman and Feser, 1999, Freeman, 1982, Nelson and Winter 1982, Aydalot, 1986, Becattini, 1987, Saxenian, 1994, Howells, 1998, Florida, 1995 and 1998, Enright, 1996, DeBresson, 1996), scholars have also attempted to classify industrial clusters into different categories on the basis of their scope, density, pattern of activities, growth potential, innovation capability, governance structure and foreign participation (Dunning, 2000). For instance, Pavitt (1984) distinguished between: 1) science-based; 2) scale-intensive; 3) supplier-dominated; and 4) specialised supplying clusters. Each type of these clusters has its own characteristics with regard to the predominant form of knowledge flows. For the *science-based clusters* (*e.g.* pharmaceuticals, aerospace), direct access to basic research and to public research institutes and universities are essential as a complement to their own research activities. These sectors are highly R&D- and patent-intensive and tend to engage in close collaboration with the public research sector. *Scale-intensive clusters* (*e.g.* food-processing, vehicles) tend to establish links with technical institutes and universities without performing much research of their own. Consequently their innovative performance depends on their ability to import and build upon science developed elsewhere, particularly with regard to process improvements. *Supplier-dominated clusters* (*e.g.* forestry, services) tend to import technology mainly in the form of capital goods and intermediary products; their innovative performance is largely determined by their ability to interact with their suppliers. *Specialised supplier clusters* (*e.g.* computer hardware and software) are R&D intensive and emphasize product innovations, generally working closely with each other, as well as with customers and users.

On the basis of the size of clustered firms, their links and their local embeddedness, Markusen identified three additional types of industrial districts to Marshallian or

Italian industrial clusters. These are the so-called hub-spoke district, satellite platform district and state-anchored district (Markusen, 1996). Hub-and-spoke districts are characterised by a dominance of one or several large and vertically integrated firms, which are surrounded by smaller and less powerful suppliers (e.g. Boeing in Seattle, Toyota City). Core firms act as anchors or hubs to the regional economy, with suppliers and related activities spread out around them like spokes of a wheel. This type of clusters presents substantial cooperation and linkages between key players and suppliers in the district and high degrees of inter-firm cooperation with external competitors. As compared to hub-and-spoke districts, satellite industrial platforms are dominated by large and externally owned and headquartered firms. These clustered firms have a high degree of cooperation and linkages with external firms, especially the parent company which makes the key investment decisions. Since platforms generally host heterogeneous firms in terms of product if not industry and are remotely controlled, they do not operate as cooperative ventures among resident plants to share risk, stabilise the market, or engage in innovative partnerships. State-anchored districts are dominated by the presence of government sponsored institutions and enterprises, such as military bases, defence plants, universities, administrative complexes, etc. The agglomeration of such activities is determined by political decisions, rather than by private initiatives. On the basis of Markusen's classification, Dunning (2000) divided industrial clusters into six types, i.e. 'hub-and-spoke' clusters, traditional clusters of SMEs (i.e. Marshallian and Italian cluster), clusters of knowledge based organisations (university and labs), industrial clusters of government sponsored institutions, export processing zones and science and technology parks. Many other studies have also developed typologies of industrial clusters in order to differentiate various concepts.

Traditional vs. emerging industrial cluster: The distinction between traditional and emerging industrial clusters relies on the sectoral specification. Traditional clusters can be perfectly illustrated by the Italian industrial districts or the so-called 'Third Italy'. The concept of the 'Third Italy' started to be used in the late 1970s. The most common sectors represented in these industrial districts are textiles, shoes, furniture, tiles and mechanical engineering. Overall, these regions are specialised mainly in traditional industries that are characterised by the following: 1) the business structure is dominated by small, locally owned firms with limited size; 2).

The operations in traditional sectors consist of substantial intradistrict trade among buyers and suppliers; 3) the low degree of cooperation or linkages with firms external to the district and 4) the successful competition in international export markets (Schmitz and Musyck, 1993, Markusen, 1996). These clustered companies are highly geographically concentrated and 'either work directly or indirectly for the same end market, share values and knowledge so important that they define a cultural environment, and are specifically linked to one another in a complex mix of competition and cooperation' (Rosenfeld, 1995). Key source of competitiveness of these clusters are elements of trust, solidarity, and cooperation between firms, a result of a close intertwining of economic, social, and community relations (Harrison, 1992).

As compared to traditional industrial clusters, emerging industrial clusters may be less 'visible', but have the potential to become more economically significant in the future. This type of cluster may fit to some extent into the third category of Dunning's cluster classification, i.e. a cluster of knowledge-based institutions with strong interaction with local universities and laboratories. Firms are at their early stages of development and are operating in 'younger' sector, such as e.g. the environmental industry. Emerging clusters may also be branches from older, more established industries that have chosen to pursue a new direction. These clusters may be more sensitive to market conditions and policy decisions due to their smaller size and lack of entrenchment in the regional economy.

Natural resource bonded vs. knowledge based clusters: This classification is based on factor endowment of industrial clusters. Over time, the main source of wealth has switched from natural assets, through tangible created assets to intangible created assets (Dunning, 2000). As compared to natural resource bonded clusters (e.g. mining and metal industrial clusters in the 19 century), knowledge and information, rather than the natural resource endowment and unskilled labour, have become more and more important in creating agglomerations of economic activities. Although knowledge, as embodied in human beings (as '*human capital*') and in technology, has always been Central to economic development, only during the last few years is its relative importance increasingly recognised.

SMEs cluster vs. large or/and transnational corporations cluster: Altenburg and Meyer-Stamer's definition of clustering (1999) is based on the size of firms that are clustered, i.e. 1) Survival clusters of micro and small-scale enterprises; 2) Clusters made up of more advanced and differentiated mass producers and 3) Clusters of transnational corporations.

Life cycle of clusters: Clusters are considered by many scholars as a dynamic phenomenon, as they often develop along a life-cycle model (Swann, 1998, Enright, 2001). Porter (1998) has started that as a cluster begins to form, a self-reinforcing cycle promotes growth, especially when local institutions are supportive and local competition is vigorous. Enright (2001) suggested a progressive typology of clusters, including 1) working, or 'overachieving', clusters that are self-aware and able to realize their full potential and produce more than the sum of their parts; 2) latent, or 'underachieving', clusters where opportunities exist but are not exploited and synergies are not yet realized; and 3) 'potential, or wannabe', clusters where some of the requirements are in place but critical mass and/or key conditions or inputs are missing. This classification is different from the above mentioned 'traditional and emerging clusters', as the later ones are identified according to their sectoral specification, rather than their life-cycle stage.

Although different clusters have varying trajectories, their life-cycle owes to new developments in technology. When a new technology or innovation process occurs, new or embryonic clusters emerge (Brown, 2000). Therefore, a dynamic cluster is constantly innovating, changing shape and altering its internal dynamics (Baptista, 1998). By contrast, clusters which remain quite stable and do not transform themselves may end up stagnating, especially if they do not upgrade and keep abreast of new technology.

Birkinshaw (2000) compared industrial clusters at different stage of development and assumed that high-growth industries often constitute emerging clusters, which are mostly less well-established, while the mature industries are frequently located in a small number of well established clusters. As a result of differences in the nature of clusters, the opportunities for foreign direct investment and its impact on clusters are different.

On the basis of above discussed theoretical analysis, the following parts will investigate different types of clusters in China's pharmaceutical industry, especially with regard to their industrial structure, ownership and changes over time. The importance of foreign direct investment and its interactions with different types of clusters will be also discussed.

Dunning suggests that foreign MNEs play a major role in the formation, structure and development of industrial clusters, especially for knowledge-based clusters, exports processing zones and technological parks (Dunning 2000). Zander and Solvell (2000) proposed that MNEs can be considered as boundary-spanning vehicles, furthering the integration of regions through international trade, foreign direct investment and international knowledge exchange. Cantwell and Iammarino (2000) examined the concentration of technological activity by foreign affiliates and found that it is correlated to the concentration of the same activity carried out by local firms.

Empirical studies showed that a number of clusters have resulted from the agglomeration of the facilities of foreign subsidiaries, especially in the case of 'satellite platform clusters', while other have identified the substantial influence of multinationals on individual clusters located both in industrial and developing countries. The dominant role of foreign MNEs in cluster formation and development can be illustrated by the cases of German and Swiss firms in the New York-New Jersey-Pennsylvania pharmaceutical cluster (Enright 1991) and foreign MNEs in the development of Venezuela's oil and petrochemical cluster (Enright, Frances et al. 1996).

The impact of MNEs on industrial clusters depends on the nature and form of assets of the investing company, the location-bound resources and capabilities of the host clusters and the organisational mechanisms through which they interact (Enright 2000). Young, Hood and Peters (Young, Hood et al. 1994) found that MNEs with wide product franchise, an export orientation, highly skilled production process and personnel, incorporated substantial local content and own research capabilities ranked are most likely to contribute positively to the regional development as 'developmental MNEs'.

Birkinshaw (Birkinshaw 2000) studied the specific link between the process of upgrading in industrial clusters and their level of foreign ownership. This study attempted to emphasize the impact of FDI on industrial cluster at different levels of cluster maturity (or life-cycle) and cluster dynamism.

Enright (Enright 2000) developed an interdependent model (as compared to independent and dependent approaches) to analyse the inter-actions between MNEs and industrial clusters. The empirical survey showed that the benefits that foreign service MNEs have brought to the Hong Kong financial service cluster went well beyond the direct benefits of employment, output, skill transfer, as well as the indirect benefits of spillovers into other industries identified with the presence of foreign MNEs. The impact of foreign MNEs is related to the market creating, cluster creating, infrastructure creating, linkage creating and information creating. The role played by MNEs in Hong Kong's financial service clusters resemble Birkinshaw and Hood's (Birkinshaw and Hood 1998) 'contributing subsidiaries' in that they do in an important way contribute in terms of strategy setting and developing and deploying substantial skills and capabilities. On the basis of the assumption that regional agglomerations of knowledge and capabilities attract FDI in R&D to a different extent and with a different sectoral spread -depending upon the position of the region in a locational hierarchy - which can be established both within and cross national boundaries.

C. Ownership structure of China's pharmaceutical industry

During the last decade, China's pharmaceutical industry experienced substantial changes as a result of the reform of Chinese SOEs and the expansion of foreign companies in the industry, especially with regard to the ownership structure, industrial restructuring, and location patterns. In 1999 there were 9,781 manufacturing enterprises in the China's pharmaceutical industry, while this number increased to 10,800 in 2006[9], recording a growth of 10% during this 6 year period. The number of employees, however, decreased by 4%, which resulted in, or as consequence of, a decrease of the average number of employees per company, i.e. from 167 to 145 persons (Table 3).

The Chinese pharmaceutical industry consists of several sub-sectors, i.e. chemical raw materials, chemical drugs, TCM and bio-drugs. The companies which produce chemical raw materials accounted for 19% of the pharmaceutical industry in terms of number of companies and 36% in terms of employment in 1999. By contrast, the share of bio-pharmaceutical companies went up from 10% to 14% during the same period, while the share of this sub-sector in the total employment of the industry increased from 5% to 7%. The chemical drug companies, also recorded an expansion, especially in terms of employment, i.e. from 468 to 512 thousand between 1999 and 2006, which accounted respectively for 29% to 33% of the total employment of the industry.

Between 1999 and 2006 the ownership structure of China's pharmaceutical industry changed significantly, as the proportion of State Owned Enterprises was practically halved, i.e. from 32% to 17% in terms of number of companies and declined by more than half for employment (from 58% to 25%). Joint stock and liability limited companies, which 'emerged' rather quickly in China as a result of the privatization of small and medium SOEs and the corporatization of large SOEs during the second half of the 1990s, became an important form of corporate governance of Chinese enterprises. Between 1999 and 2006 the share of joint stock and liability limited companies in China's pharmaceutical industry more than tripled from 8% to 28% in terms of number of companies, while in terms of employment the expansion was even stronger, namely from 11% to 45%. Yet, the restructuring of SOEs into new corporate forms also resulted in the laying off of employees, and was the major reason for the decline of employment in China's pharmaceutical industry during the period 1999-2006.

Table 3. Profile of Chinese pharmaceutical manufacturing companies, 1999 and 2006

	1999	2006	Changes (%)
Number of companies	9,781	10,803	10.45
Number of employees	1,635,773	1,566,650	-4.23
Number of employees per company	167	145	-13.17
Sub-sectors (%)			
Chemical raw materials	18.76	15.71	-16.27
Chemical drugs	23.29	24.40	4.77
Traditional Chinese medicines	36.37	33.19	-8.72
Animal Drugs	11.89	12.81	7.74
Bio-drugs	9.69	13.89	43.26
Ownership structure (%)			
SOEs	31.79	16.76	-47.26
Private and collective enterprises	46.90	42.30	-9.80
Joint stock and limited liability companies	7.79	27.29	250.28
FIEs	13.53	13.64	0.87
Location (%)			
Eastern region	51.80	54.00	4.24
Central region	28.50	25.02	-12.22
Western region	19.69	20.98	6.52

Source: Directory of Chinese Companies (1999 and 2006)

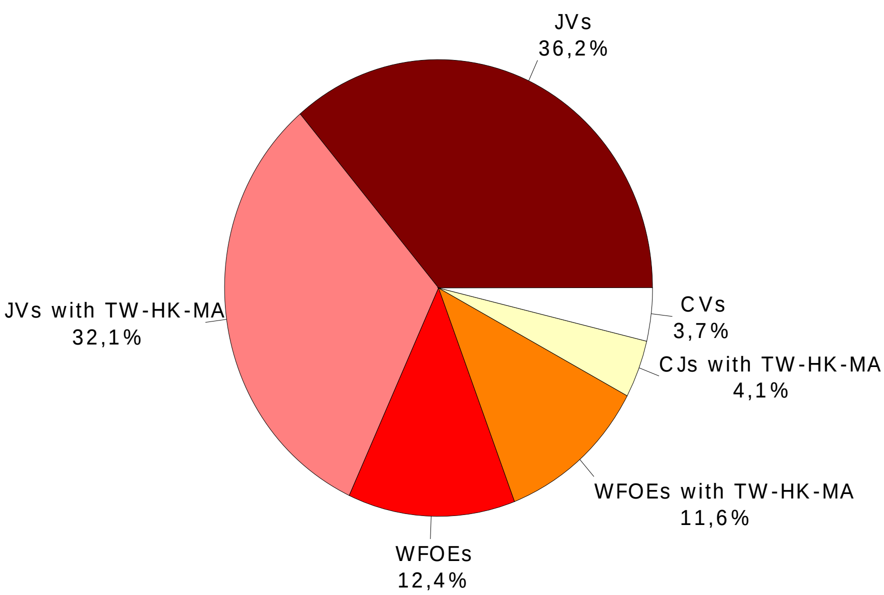
As briefly mentioned in the first part, China's pharmaceutical industry is highly concentrated in Eastern China, i.e. the coastal area, as more than half of Chinese pharmaceutical companies in number as well as in employment were located in this part of the country. The employment share of the Eastern region in China's pharmaceutical sector remained unchanged between 1999 and 2006, even though the number of companies registered a small increase (i.e. from 51% to 54%) as a result of the dismissal of employees of SOEs in the restructuring process was compensated by the jobs in newly established small private companies, especially in Zhejiang province.

The Central region hosted about one quarter of the Chinese pharmaceutical companies, of which the employment accounted for more than one third of the industry, indicating that pharmaceutical companies located in Central China are on average larger than in the other regions. By contrast, the pharmaceutical companies located in inland China, i.e. the Western region, are quite often smaller (see further).

Since the establishment of the first pharmaceutical joint venture (JV) in China by the Japanese multinational Otsuka[10], the number of foreign invested enterprises in China's pharmaceutical industry increased rapidly, i.e. from less than 100 firms at the end of the 1990s to 566 in 2002 and 1,790 in 2005. Two thirds of 106 large and medium-sized SOEs have established JVs with foreign companies, while almost all global leading pharmaceutical multinationals have set up joint ventures or wholly owned facilities in China (Mao, 2005). In the 1990s, international pharmaceutical companies have mainly invested in China for the reasons of market expansion (Van Den Bulcke, Zhang and Li, 1999). After China's entry into WTO, many leading pharmaceutical companies are transferring their research and development centres to China. For instance, Roche of Switzerland opened its R&D centre in Shanghai; while GSK has established its OTC research and development centre in Tianjin. Pfizer, Glaxo Smith Kline, Johnson & Johnson, Eli Lilly, Novo Nordisk, Servier, AstraZeneca, Bayer, Eli Lili, and Hoffman-La Roche have also set up R&D in China for research on traditional chemical drugs, Chinese herbs, nonprescription drugs, and experimental modelling design and clinical evaluation of some therapeutic drugs, etc. (APBN, 2006). The establishment of R&D centres by global multinationals in China was considered as a way to create a win-win situation. On the one hand, China would have access to the latest international pharmaceutical R&D technologies, innovations, and ideas, thus enhancing the ability of the domestic industry to produce therapeutical drugs targeted at Chinese patients. On the other hand, multinational companies would be able to lower their costs and gather large sample quantities from patients, thus speeding up the progress of clinical research for new pharmaceutical. Stimulated by government spending, leading multinational pharmaceutical companies are already playing a key role by outsourcing chemistry-based R&D to China (BCG, 2005).

The Directory of Chinese Manufacturing Enterprises in 2006 includes 1,474 foreign invested pharmaceutical enterprises (FIEs) operating in the Chinese market, of which nearly half (47.8%) were established by companies from Taiwan, Hong Kong and Singapore, and are mostly owned by overseas Chinese. Joint ventures (JVs) accounted for 68% of all FIEs, while wholly foreign owned enterprises (WFOEs) take up 24%. The remaining 7.8% of FIEs were established as cooperative ventures (CVs) (Figure 3).

Figure 2. Forms of Foreign invested enterprises in the Chinese Pharmaceutical Industry, 2006



Source: Directory of Chinese Companies (2006)

Although the comparative analysis could not identify significant differences between Western and Overseas Chinese owned firms (OCOFs) with regard to the investment form, their sectoral orientation and regional distribution are quite different. OCOFs are clearly more concentrated in the sub-sector of chemical raw materials and TCM, while Western MNEs are highly concentrated in the bio-pharmaceuticals and chemical drugs and drugs for animals. On the other hand, the former group of enterprises tends to locate in the inland provinces of China, especially in the centrally located ones, such as Guangxi, Hubei, Guizhoiu, Jiangxi, Hunan, etc. These specific location patterns of OCOFs might be explained by their higher presence in TCM products, which are more located in the inland regions because of the proximity to raw materials. Yet, OCOFs are also highly present in Guandong and Fujiang provinces, which are the home regions of most of overseas Chinese entrepreneurs. Western MNEs are, by contrast, highly concentrated in the Eastern region, especially in Tianjin, Beijing, Shanghai, Zhejiang and Jiangsu which are specialized in biopharmaceuticals.

The comparison between enterprises with different ownership modes indicated that WFOEs are smaller as compared to JVs or CV, as the average employment of the former group is about 75 persons, while that for the latter category is above 150 employees. WFOEs established by Western multinationals are more concentrated in the research-intensive bio-pharmaceuticals, while the Western JVs are relatively more present in manufacturing of chemical drugs, for which large-scale of production is more typical. With regard to OCOEs, they prefer WFOEs rather than JVs in TCM manufacturing, while in the chemical sub-sector, i.e. ingredients and drugs, JVs are more frequently used.

Foreign invested pharmaceutical companies created 195 thousand jobs in China, accounting for 12% of the total employment in China's pharmaceutical manufacturing sector (Table 4). These enterprises are highly concentrated in the manufacture of chemical drugs and bio-drugs, which account for 31% and 19% of FIEs in the industry, while the relative proportion is 28% and 10% for SOEs, 24% and 13% for private companies and 18% and 15% for joint stock and liability limited firms (Table 4). Compared to FIEs, SOEs are strongly active in the manufacturing of traditional Chinese medicines, while private companies had a higher degree of specialisation in veterinary pharmaceuticals.

More than two thirds (69%) of FIEs are located in the Eastern region, mostly in Shanghai, Guangdong, Jiangsu and Shandong provinces, which host more than one third of FIEs in China's pharmaceutical industry (i.e. 37%). SOEs are highly present in Central and Western China. This results from the dominance of SOEs in the traditional industrial bases of China's pharmaceutical industry, which are more frequently located in the inland region. The geographical distribution of private and joint stock and liability limited companies is regionally more balanced.

Table 4. Profile of Chinese pharmaceutical manufacturing companies by ownership, 2006

	FIEs	SOEs	Private and collective enterprises	Joint stock and limited companies	Total
Number of companies	1,474	1,811	4,57	2,948	10,803
Number of employees	194,851	390,254	279,941	701,604	1,566,650
% of total employment	12.44	24.91	17.87	44.78	100.00
Number of employees per company	132,19	215,49	61,26	237,99	145.02
Age (years)	11.23	23.55	11.64	13.68	14.18
Sub-sectors (%)					
Chemical raw materials	15.81	13.58	16.26	16.11	15.71
Chemical drugs	31.28	28.33	18.91	27.07	24.40
Traditional Chinese medicines	29.38	36.61	32.71	33.75	33.19
Animal Drugs	4.68	11.93	17.72	9.80	12.81
Bio-drugs	18.86	9.55	14.40	13.26	13.89
Location (%)					
Eastern region	68.93	44.89	54.42	51.49	54.00
Central region	18.59	32.74	23.63	25.64	25.02
Western region	12.48	22.36	21.95	22.86	20.98
Year of establishment (%)					
Before 1980	1.19	34.11	5.62	12.44	11.74
1980-1989	5.20	20.82	11.55	6.84	10.99
1990-1999	77.23	40.53	56.99	54.96	56.35
2000-2001	16.37	4.54	25.84	25.77	20.92
Sales volume category (%)					
<1 million RMB	13.50	38.54	62.06	28.66	42.38
1-4.9 million RMB	33.31	30.20	24.38	26.15	27.06
5-9 million RMB	16.69	11.49	6.43	13.13	10.51
10-50 million RMB	25.51	15.02	6.08	22.22	14.63
>50 million RMB	10.99	4.75	1.05	9.84	5.42

Source: Directory of Chinese Companies (2006)

The comparison of the sales volume between companies with different types of ownership indicated that except for FIEs the other types of firms have the higher presence are more present in the categories of companies, of which the sales amounted to less than RMB1 million. The foreign owned subsidiaries are proportionally more concentrated in the highest sales categories, for instance, 11% of FIEs generated a sales volume of more than RMB50 million, while the share for all pharmaceutical companies is only 5%. By contrast, the sales volume of private companies was on average very small, as more than three fifths of these companies are in the category of companies with sales volumes lower than RMB1 million. SOEs and joint stock companies are highly concentrated in the middle sized categories.

D. Typology of industrial clusters and characteristics

The geographical agglomeration of China's pharmaceutical industry was measured by using the location data of individual firms included in the Directory of China's manufacturing companies. The location of these enterprises was divided into 366 sub-regions/cities at county level according to China's administrative divisions[11]. The traditional method of 'Location Quotient' (LQ) is used to identify the existence of industrial agglomeration or clusters in a given region:

$$LQi = (ei/e)/(Ei/E)$$

where ei is area employment in the industry i, e is the total employment in the area, Ei is the total employment of the country in the industry i, and E is total employment in the country. Given the fact that the data about total employment at the sub-regional level is not available, the total population of these sub-regions is used as a proxy indicator. If LQ of an industry is greater than 1.0 in a region, it can be assumed that some portion of its production is exported out of the region and there is an agglomeration trend for this industry in the region. For instance, a LQ of 3.0 would mean that employment in this particular industry is three times more concentrated in the region than for the nation as a whole.

The location data in the two directories (1999 and 2006) are compiled and classified on the basis of the analytical framework presented in Figure 3 in order to not only identify the current industrial clusters in the Chinese pharmaceutical industry, but also to emphasize their 'dynamics' in the development process, i.e. emergence, sustainable development and decline.

The upper left quadrant (Quadrant A) represents the regions which were identified as industrial clusters in 1999 but no longer have agglomeration of the pharmaceutical industry in 2006, i.e. the LQ value was higher than 1 in 1999, but less than 1 in 2006. These regions can be regarded as '**disappearing clusters**'.

The upper right quadrant (Quadrant B) includes the regions, of which the LQ value in both 1999 and 2006 data is higher than one, indicating they maintained their cluster position in China's pharmaceutical industry between 1999 and 2006. These regions can be considered as '**sustainable clusters**' given the fact that their clusters persisted over time and continued to perform better than other regions.

The regions, which did not host 'industrial clusters' either in 1999 or in 2006 as the LQ value in both years was lower than 1, are included in the lower left quadrant (Quadrant C). Given the fact that the pharmaceutical industry in these regions was underdeveloped as compared to other economic activities, there was '**no cluster formation'** in these regions.

Figure 3. Analytical framework of industrial clusters of Chinese pharmaceutical industry

Agglomeration in 1999	Agglomeration in 2006: No	Agglomeration in 2006: Yes
Yes	**A. Disappearing clusters** (23 regions, e.g. Yichun, Weinan, Zhangjiakou)	**B. Sustainable clusters** (63 regions, e.g.Harbin, Shenzhen, Tianjin, Chengdu)
No	**C. No cluster formation** (208 regions)	**D. Emerging clusters** (18 regions, e.g. Lhasa, Changsha, Tianmen, Xianyang)

The lower right quadrant (Quadrant D) presents the regions, of which the LQ value is lower than 1 in 1999, but higher in 2006, indicating that new clusters have '**emerged**' during the period 1999-2006.

In addition to the comparative analysis between each of the four above discussed regions, the comparison between quadrants A and C on the one hand and quadrants B and D on the other hand can be used to identify differences between regions with and without industrial clusters and to exam the effects of geographical agglomerations on China's pharmaceutical industry.

China's pharmaceutical manufacturing enterprises are present in almost all regions/cities in China, i.e. in 312 of 366 (85%) administrative regions and cities at county level. The analysis of the 2006 location data show that the LQ value is higher than 1 in 82 cities and regions (Quadrants B and C), indicating the existence of agglomeration or cluster phenomena in these areas. Although these regions/cities accounted only for 31% of the total Chinese population in 2002, they host more than 6,500 manufacturing companies in 2006, i.e. 62% of all China-based pharmaceutical firms, and occupy 72% of the total employment of the industry (Table 5). Yet, almost all industrial clusters can be considered as 'sustainably developed clusters' (Quadrant B) as the cluster phenomenon persisted during the period 1999-2006. These clusters accounted for 54% of the total number of Chinese manufacturing pharmaceutical companies and 63% of the employment in the industry.

FIEs have a slightly higher presence in the 'sustainably developed clusters' as compared to their share in the sector as a whole. They accounted for 16% of all enterprises located in such clusters, while their share in the whole industry was less than 14%. Joint stock and liability limited companies are also somewhat more concentrated in this type of regions, but less so than FIEs. By contrast, SOEs and private companies all underrepresented in these locations.

With regard to the sector distribution, bio-medicine companies are proportionally more active in the sustainable clusters. Although they accounted for only 13% of Chinese pharmaceutical companies, their share in the Quadrant B regions/cities reached 17%. Yet, while companies for chemical products, i.e. raw materials and Western drugs, also reach a higher share in these regions/cities as compared to the industry as a whole. TCM companies clearly are much less represented.

Large enterprises as measured by the number of employees and sales are proportionally more concentrated in the clusters of Quadrant B. Almost a quarter (23%) of these enterprises have a sales volume above RMB10 million as compared to 20% for the whole industry, while the average number of employees reached 170 persons per company as compared to 146 for the total sample. To conclude, it can be started that the ‘sustainably developed clusters’ are mainly characterized by the presence of large pharmaceutical companies, which are specialized in manufacturing bio-pharmaceuticals and chemical raw materials and drugs. A high proportion of these companies are foreign invested enterprises.

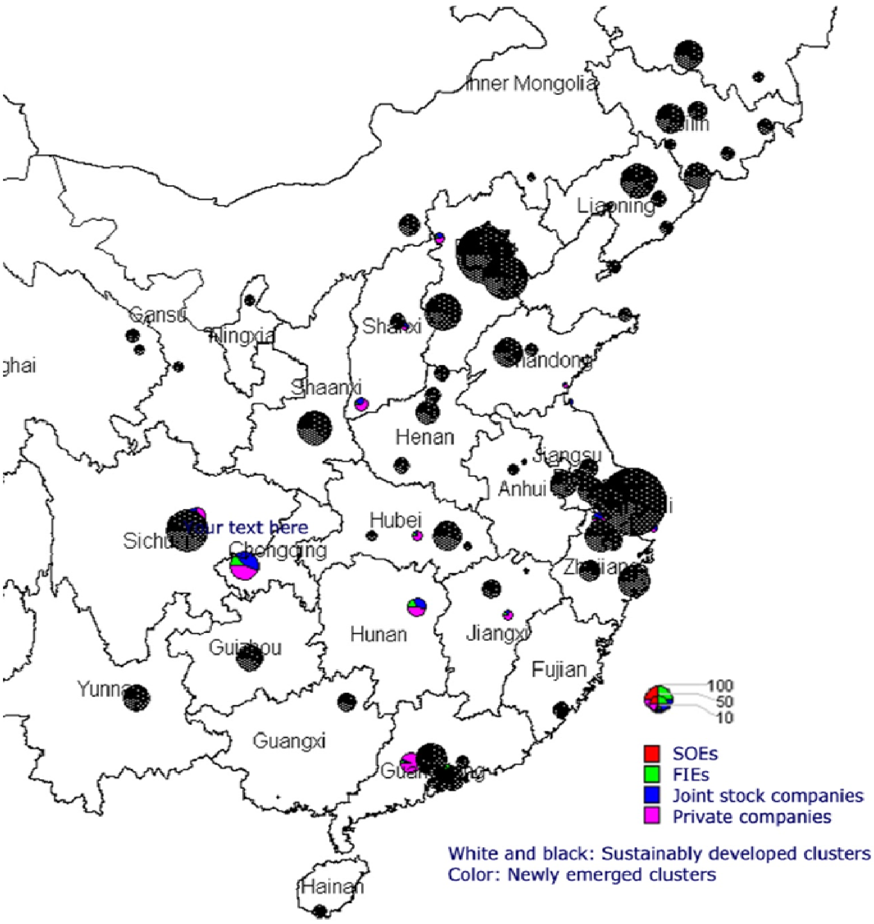
Table 5. Characteristics of Chinese manufacturing pharmaceutical agglomerations and their characteristics,2006

	A	B	C	D	Total
Number of regions/cities	23	63	208	18	312
Number of companies	643	5,768	3,432	749	10,592
% in number of companies	6.07	54.46	32.40	7.07	100.00
Number of employees	76,892	978,327	362,335	131,205	1,548,759
% in number of employees	4.96	63.17	23.40	8.47	100.00
Number of employees per company	119.58	169.61	105.58	175.17	146.22
Age (year)	15.12	13.94	14.52	14.44	14.24
Ownership structure (%)					
SOEs	19.91	14.84	20.02	15.22	16.85
Private and collective enterprises	39.50	40.19	44.84	48.87	42.27
Joint stock and limited liability companies	26.59	28.71	24.91	26.97	27.23
FIEs	14.00	16.26	10.23	8.95	13.65
Sub-sectors (%)					
Chemical raw materials	14.62	16.54	15.18	15.49	15.91
Chemical drugs	27.68	25.55	22.32	22.16	24.40
Traditional Chinese medicines	33.13	29.87	37.21	38.85	33.08
Animal Drugs	11.66	11.46	15.38	12.28	12.80
Bio-drugs	12.91	16.57	9.91	11.21	13.81
Location (%)					
Eastern region	49.14	64.63	42.37	30.84	54.09
Central region	31.42	20.56	32.02	24.97	25.25
Western region	19.44	14.81	25.61	44.19	20.67
Year of establishment (%)					
Before 1980	15.66	9.92	14.08	13.72	11.89
1980-1989	11.08	11.00	11.45	9.65	11.06
1990-1999	52.85	58.46	52.91	57.20	56.22
2000 -	20.41	20.62	21.56	19.43	20.83
Sales (%)					
<1 million RMB	42.15	40.50	45.34	44.86	42.48
1-4.9 million RMB	30.79	25.19	29.72	25.10	26.99
5-9 million RMB	9.49	10.58	10.40	10.28	10.43
10-50 million RMB	14.46	16.14	12.33	13.89	14.64
>50 million RMB	3.11	7.59	2.21	5.87	5.46

Source: Directory of Chinese Companies (1999 and 2006)

As shown in Figure 4, the industrial clusters with sustainable development are mostly located in the Eastern region, while the newly emerging clusters (Quadrant D) are concentrated in inland China. These industrial clusters in the Western part of China are still relatively small as compared to the Eastern region. The companies located in the Western region accounted for only 7% of the total companies and 8% in the total employment. These 'newly emerged or emerging clusters' were characterised by the following specific characteristics. First, private companies are more strongly presented in these areas, as they made up almost half (49%) of the clustered enterprises in the regions, while their share in the total sample was only 43%. Secondly, these clusters are more oriented towards TCM products, as 39% of the companies located in these regions are carrying out TCM production, as compared to 33% for the whole industry. Most of the companies located in these clusters are small sized firms in terms of sales, but account a relatively large number of employees, reflecting their lower technology intensity and higher labour input as compared to pharmaceutical firms in other regions.

Figure 4. Mapping of Chinese pharmaceutical clusters (number of companies), 2006



The counties where the agglomeration effect in the pharmaceutical industry disappeared during 1999-2006 (Quadrant A) are mostly situated in the Central provinces of China, where many of them specialized in chemical drugs. Companies located in these cities accounted for 6% of China's pharmaceutical enterprises and 5% of the employment. The average size of companies located in these counties is smaller than in the other regions both in terms of number of employees and sales volume, while a higher proportion of these enterprises are still state owned.

Most of the Chinese counties in the Central and Western provinces of China have not succeeded to develop pharmaceutical clusters (Quadrant C), although they have to some extent established manufacturing capability, especially for TCM and drugs for animals. These latter cities/regions host 32% of all Chinese pharmaceutical companies and occupy 23% of its total employment. Most pharmaceutical companies in these regions are small-sized both in terms of sales value and number of employees.

The 81 regions/cities which were identified as industrial clusters in the Quadrants B and C in the analytical framework presented in Figure 3 are further classified into subgroups by using the segmentation or taxonomy analysis. The purpose of this additional analysis is to identify similarities and differences between Chinese regions/cities according to their ownership structure and specific business segments in order to better understand the impact of the ownership and location patterns on the industry structure. The statistical method which helped to carry out the classification is called *k-means clustering* (SPSS, 2002). Three sets of variables, i.e. 9 in total, about the ownership structure, industrial specification and size of the companies are used to calculate the cluster centre of these subgroups and the distance between them (see appendix 1 for the methodology and result). This exercise allowed to classify 57 of 81 cities or regions into 4 distinguished subgroups, while the remaining 24 regions were excluded due to the invalidity of the data (Table 6).

Clusters of bio-pharmaceuticals: The bio-pharmaceutical clusters are characterised by the strong presence of large MNEs, which accounted for 44% of the total employment of the clusters and 29% of the clustered enterprises. Yet, small-sized private enterprises are also agglomerated in these areas, i.e. 24% in the total employment and 43% in terms of number of firms. These clusters have specialised in Western drugs and bio-medicines with strong support from the government with regard to IP rights. The size of these clusters, i.e. the total number of clustered enterprises, is quite small, as there are less than 60 enterprises on average per cluster. Referring to the literature review, this type of clusters can be considered as knowledge intensive and emerging clusters. Two types of cluster linkages can be distinguished. On the one hand, there are subsidiaries of large MNEs, which are frequently operated as satellite platforms to manufacture patent products from their parent companies or to some extent participate in the R&D cycle of the groups. Intra-firm and vertical linkages are of course more pronounced in this type of companies. On the other hand, small domestic 'starters' are co-located in hi-tech zones, often in the so-called 'incubators', to benefit from incentives and infrastructure provided by the government and to share entrepreneurial 'spirit' between them. Inter-firm linkages and networked entrepreneurial relationships are quite important as key agglomeration factors, as illustrated by IT clusters in the Silicon Valley. Yet, because of the weak legal environment for IP protection, the intra-firm linkages between MNEs and local firms are likely to be limited. From the point of view of the host country, this is a major constraint for spill-over effects of MNEs in the Chinese pharmaceutical clusters.

Domestic clusters of traditional Chinese medicines: Although the size of these clusters is quite large as compared to the the-biopharmaceutical one, i.e. 120 firms per cluster, only a few large domestic groups, often listed on the stock exchange, dominate the clusters with high concentration ratio, e.g. Zhongxin Pharmaceuticals and Tasly Group in Tianjin (34% and 30% of the total sales of TCM enterprises in Tianjin), Tongrentang in Beijing and Huiren Group in Nanchang with respectively 66% and 51% in their area. Most of these clusters are located in Central and Western China, and are strongly based on natural resource. From the perspective of the cluster structure and governance, TCM clusters can be considered as 'hub-and-spoke' clusters, which are characterised by the dominance of one or several large and vertically integrated firms, surrounded by smaller and less powerful suppliers. These leading companies have rather strong brand names as well as very established distribution network as their key assets and are often very important in the local economy. Yet, the promotion of substantial cooperation and linkages between the key players and suppliers are crucial for the sustainable development of this type of clusters.

Table 6. Typology of the Chinese pharmaceutical industry, 2006

Type of clusters	Characteristics (on average)
A. MNEs cluster of biopharmaceuticals (9 clusters)	• High presence of MNEs (44% in employment, 29% in number of companies) • Small cluster (56 firms) • Small sized companies (mean=115 person; median=28 persons) • Co-location with small private firms (24% in employment and 43% in number) • Specialised in Western drugs (24%) and bio-drugs (26%) • Concentration in Eastern region (100% in the Eastern region) • Heterogeneous structure of clustered enterprises, i.e. small private firms vs. large MNEs
B. Domestic cluster of TCM (13 clusters)	• Large listed companies as key players (55% in employment and 30% in number) • Big cluster (120 firms) • Relatively large companies (mean=154 persons; median=34 persons) • Specialised in TCM (42% in number and 57% in employment) • High presence in the Central and Western regions (40% in number) • Heterogeneous structure of clustered enterprises, i.e. small private firms vs. very large listed firms
C. Domestic cluster of bio-pharmaceuticals (18 clusters)	• Large listed companies as key players (61% in employment and 35% in number) • Large sized companies (mean=179 person; median=41 persons) • Co-location of small and medium-sized private firms (16% in employment and 39% in number) with SOEs (14% in employment and 12% in number) • Strongly concentrated in the Eastern and Central regions (14 out of 18) • Heterogeneous structure of clustered enterprises, i.e. small private firms vs. very large listed firms
D. Domestic cluster of pharmaceuticals and chemical raw materials (17 clusters)	• Large SOEs as key players (41% in employment and 18% in number) • Large size of clusters (122 firms per cluster) • Co-location with small-sized private firms (16% in employment and 42% in number) • High concentration ratio • Concentration in the Eastern and Central regions • Differences between clusters of SOEs in traditional industry bases and entrepreneurial clusters in Zhejiang and Jiangsu

Domestic clusters of bio-pharmaceuticals: The Chinese pharmaceutical clusters for drug preparation and bio-medicines are mostly concentrated in the Eastern and Central regions (14 out of 18) and dominated by large listed companies and non-state owned enterprises, such as joint stock and liabilities limited firms, collective or private firms, which have often high concentration ratio with large employment share in the region. For instance, the top five leading pharmaceutical companies in

Wuhan, account for about half of the total employment of the sector in the city, while the concentration ratio of the 4 largest companies (CR4) is 28% as compared to 17% at the national level. In Chengdu's pharmaceutical cluster, only one of the 10 top companies is state owned, the remaining 9 are joint stock companies (6), collective companies (2) and foreign joint venture. Yet, collective and private firms in drug preparation and bio-medicines are smaller as compared to listed companies, and they are often specialised in a few number of drugs with large market share is the product segment.

Domestic clusters of chemical drugs and raw materials: These 17 clusters in manufacturing of chemical raw materials and Western drugs are mostly located in the Central and Eastern regions, i.e. 8 in Jiangsu and Zhejiang and surrounding provinces and 8 in Northeast China. SOEs play a dominant role in the clusters located in the Northeast China, especially in Shijiazhuang and Ha'erbin. Two large SOEs in Hebei province, i.e. Huabei Pharmaceuticals and Sjijiazhuang Pharmaceuticals Group, accounted for 71% of the total sales of chemical raw materials and pharmaceuticals in Hebei, while the largest company in Heilongjiang province, i.e. Ha'erbin Pharmaceuticals Group, generated more than 88% of the total sales of sector in that region. These companies even succeed in establishing a competitive position in the global market for a number of products, while their clusters have become to some extent the world manufacturing bases for chemical raw materials and intermediates. The clusters of chemical raw materials in Zhejiang and Jiangsu provinces are concentrated in two small areas, i.e. Taizhou and its neighbouring counties in Zhejiang and Changzhou area in Jiangsu. Contrary to the industrial clusters in Northeast China, these clusters are dominated by private enterprises. As a result of a strong entrepreneurial culture of the regions, these clusters were built up on the initiatives and capability of local private enterprises, driven by high profitability of the sector. The competitiveness of the clustered enterprises is mainly related to their flexibility in manufacturing with low-technology. Yet, at the later stage, the support provided by the government in reinforcing agglomeration effect was also of key importance. For instance, Taizhou was selected by MOFCOM in 2005 as one of the 15 export bases of pharmaceuticals in China.

E. Conclusion

The study has identified clustering trends in the Chinese pharmaceutical industry and indicated some changes over time. It also analysed different types of clusters, and identified different attributes of those clusters with regard to ownership patterns, corporate governance, industrial cluster structure, specialisation and linkages within and among firms. Although the study also tried to examine the development path or the life cycle of the cluster, the lack of systematic data at this stage did not allow to sufficiently explore the determining factors of the cluster formation and development. The main finding of the study can be summarised in the following points.

First, as a result of the reform of SOEs, combined with the introduction of Western corporate governance, the increase of M&As and the implementation of the GMP certificate system, the Chinese pharmaceutical industry has undergone a substantial industrial and corporate restructuring process during the last decades. This process has positively affected the agglomeration of the sector, especially in the sub-sector of TCM and chemical raw materials, which traditionally had a dispersed and fragmented geographical lay-out. The agglomeration in these two sub-sectors has enhanced the industry structure and global competitiveness of the Chinese pharmaceutical industry and resulted in the increase of the concentration ratio of the industry on the one hand and its export performance on the other hand. Consequently, China has emerged as a world manufacturing base for bulk and intermediate pharmaceutical products. Besides a number of large SOEs and listed companies, which established and reinforced their dominant position in a number of sub-regions, and a large number of surrounding SMEs are actively looking to create strong linkages with the key players in a 'hub-and-spoke' structure. Since the clusters in these sub-sectors are natural resource bound, they tend to locate in inland China, especially the TCM clusters, which are sometimes located in very remote areas in order to be close to the necessary raw materials. The cooperation and linkages between key players and suppliers are quite substantial in this type of clusters.

Secondly, in addition to the traditional clusters with a dominance of SOEs and listed firms, new agglomerations in the sub-sector of chemical raw materials emerged in Zhejiang and Jiangsu provinces. These clusters are often smaller than the previous ones, and consist of private SMEs, of which the competitive advantages are mainly based on their flexibility in production and new product development. This type of entrepreneurial clusters is quite different from the traditional clusters in inland China, and heavily relies on the initiatives and capabilities of private entrepreneurs. Intensive networked social relationships and the strong entrepreneurship qualifications are essential elements in the formation and development of these entrepreneurial clusters. Yet, the support from local governments is also important, especially when there is a need to reinforce the agglomeration in the region.

Thirdly, as compared to the entrepreneurial clusters in the production of chemical raw materials, the emerging knowledge intensive clusters in Chinese bio-medicines, especially 'hi-tech starters', are built up in the hi-tech industrial zones or 'enterprise incubators' which receive strong support of both the local and central government. The favourable industry policy as well as tax incentives and subsidies are pre-conditions for the formation of this type of research based clusters, while the linkages between knowledge institutions and enterprises are also of key importance. These type of clusters can be considered as 'State-anchored districts' which are often determined by political decisions, rather than by private initiatives.

Fourthly, large bio-pharmaceutical MNEs have become 'key players' in several Chinese regions, although the participation of FDI in China's pharmaceutical industry is not as important as in some other sectors, such as the automobile industry, electronics, telecommunication equipment, etc. The bio-pharmaceutical clusters with a strong dominance of MNEs are mostly located in the coastal cities, more particularly in the Special Economic Zones, which were opened to FDI at the very beginning of the 1980s. These clusters can be considered as 'satellite platforms' for foreign subsidiaries to produce, on a large scale, patented products and over-the-counter (OTC) products for the Chinese market. The intra-firm linkages between the parent company and its subsidiaries are important in transferring manufacturing technology and marketing knowledge, but cooperation in R&D activities is rather limited. Also because of the weak legal environment and implementation of the IP protection in China, the inter-firm cooperation of MNEs with other clustered Chinese domestic companies has been limited. As a result, the spill-over effects of MNEs in the cluster are smaller and have worked more as a 'demonstrator' effect of e.g. GMP, rather than 'boundary-spanning vehicles' for knowledge transfer. Yet, the newest development indicates that a number of MNEs have started to locate parts of their research activities in China because of low pre-clinical and clinic research costs on the one hand and the large pool of talented human resources with technology/manufacturing knowledge and skills on the other hand. Also the strong supports of the central and local government with favorable tax policies and grants provide new opportunities for MNEs to optimize their research activities from a new perspective.

The growing agglomeration trends in China's pharmaceutical industry is an interesting case for understanding the cluster formation and development in the process of industrial restructuring, which has been 'orchestrated' by the government. In order to carry out some useful implications for both the government and the business sector, the next stages of the research should be oriented towards two directions. On the one hand, more socio-economic data at county level should be collected and used to identify the determining factors of cluster formation and development. On the other hand, firm level data are needed to mapping the corporate structure and linkages between clustered firms and its supporting institutions. The findings in the first direction should provide the government with useful information for policy implementation and create better location advantages for building up regional competitiveness. Additional research in the second direction might be helpful for companies as it could allow them to carry out a cluster strategy to upgrade their competitive resources.

Appendix 1. K-means clustering analysis of the industrial clusters of China's pharmaceutical industry, 2006

On the basis of the literature about the cluster typology and knowledge about the location and sectoral patterns of China's pharmaceutical industry, 3 sets of 9 variables are selected to carry out the taxonomy analysis by using k-means clustering method in SPSS. The first set of 4 variables deals with the ownership/corporate governance of clustered enterprises. The percentage of 4 types of enterprises, i.e. SOEs, FIEs, private enterprises and joint stock and liability limited firms, in the total employment of a given region/city is used to look at the importance of different enterprises in the county cluster. The second set of variables represents 4 major sub-sectors of China's pharmaceutical industry, i.e. chemical raw materials, Western drugs, TCM and bio-drugs, of which the proportion in the employment is used to determine the industrial specialisation of a given cluster. An additional variable, i.e. the median value of the number of employees, is used to emphasize the size of clustered enterprises.

After a large amount of trials, the 81 regions/cities with pharmaceutical industry clusters were classified into four sub-groups. Table A1 shows the 'final cluster centres', indicating the mean abundance of each species in each of the clusters. This provides information about the key characteristics of each cluster based on their dominant species. Table A2 presents the results of the ANOVA test to show the degree of difference between clusters with regard to the variables used in the classification. Table A3 provides descriptive information about the 57 Chinese pharmaceutical clusters which are divided into four distinguished groups.

Table A1. Final Cluster Centres

	Cluster			
Variables	1	2	3	4
% of FIEs in the total employment (FIEPCT)	46.34	9.33	8.20	11.21
% of SOEs in the total employment (SOEPCT)	10.19	21.16	13.62	41.44
% of Private enterprises in the total employment (PRIVPCT)	25.19	20.99	16.46	18.22
% of joint stock and liability limited firms in the total employment (SHARPCT)	18.28	48.52	61.72	29.12
% of raw material producers in the total employment (RAWPCT)	13.12	10.78	25.46	27.92
% of drug manufacturers in the total employment (DRUGPCT)	42.17	21.20	32.86	47.44
% of TCM manufacturers in the total employment (TCMPCT)	32.40	60.82	25.18	13.56
% of bio-drug manufacturers in the total employment (PIOPCT)	8.65	4.47	10.67	6.71
Median of the number of employees (MEDIAN)	31.11	41.00	43.15	55.63

Table A2. ANOVA test

	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
FIEPCT	3464.070	3	103.099	53	33.599	.000
SOEPCT	2779.327	3	258.794	53	10.740	.000
PRIVPCT	176.072	3	145.888	53	1.207	.316
SHARPCT	5261.186	3	231.660	53	22.711	.000
RAWPCT	1010.090	3	257.519	53	3.922	.013
DRUGPCT	1779.428	3	211.262	53	8.423	.000
TCMPCT	5602.865	3	172.736	53	32.436	.000
BIOPCT	110.823	3	98.584	53	1.124	.348
MEDIAN	1218.823	3	249.343	53	4.888	.004

The F tests should be used only for descriptive purposes because the clusters have been chosen to maximize the differences among cases in different clusters. The observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal.

Table A3. Descriptive information about Chinese pharmaceutical clusters

City/region	LQ	N. of firms	N. of jobs	Size	% of FIE (employment)	% of FIEs (number)
MNEs Clusters of biopharmaceuticals						
Dongguan	1.21	21	2,375	113.10	46.23	47.62
Foshan	1.42	52	6,051	116.37	57.35	23.08
Sanya	4.98	33	3,075	93.18	45.43	36.36
Shenzhen	6.31	101	10,146	100.46	57.44	38.61
Taizhou	1.57	65	10,142	156.03	20.04	10.77
Wuxi	1.87	87	10,391	119.44	42.37	19.54
Xiamen	3.68	51	6,197	121.51	22.99	35.29
Zhenjiang	1.40	45	4,826	107.24	42.33	11.11
Zhuhai	3.51	50	4,697	93.94	82.86	50.00
TCM clusters						
Beijing	2.96	447	52,712	117.92	12.45	17.00
Deyang	1.36	67	6,622	98.84	0.44	2.99
Guilin	1.19	60	7,387	123.12	7.19	10.00
Guiyang	3.18	120	13,580	113.17	12.67	9.17
Hangzhou	3.11	158	24,881	157.47	34.79	22.15
Nanchang	2.63	68	14,605	214.78	9.26	14.71
Tianjin	6.26	297	80,679	271.65	12.46	24.92
Tonghua	5.91	122	17,121	140.34	10.08	8.20
Weihai	1.04	37	3,298	89.14	7.52	18.92
Wulumuqi	1.82	35	3,771	107.74	3.87	11.43
Xianyang	1.15	80	7,210	90.13	2.98	2.50
Yanji	2.21	54	6,188	114.59	3.67	20.37
Yuci	1.02	25	3,944	157.76	3.90	4.00
Domestic Clusters of bio-pharmaceuticals						
Anyang	1.20	43	7,987	185.74	9.55	9.30
Changsha	1.58	62	11,798	190.29	6.63	14.52
Chengdu	3.72	264	48,474	183.61	13.71	14.39
Chongqing	1.10	160	43,668	272.93	2.72	10.63
Guangzhou	3.10	159	28,001	176.11	12.89	22.01
Huzhou	2.34	60	7,698	128.30	2.57	5.00
Jilin	1.75	61	9,708	159.15	5.46	9.84
Jinan	2.02	144	14,654	101.76	11.89	15.28

Jinhua	1.99	79	11,395	144.24	0.45	2.53
Jining	1.29	77	11,335	147.21	11.37	9.09
Kunming	1.99	109	12,315	112.98	15.11	18.35
Lanzhou	2.36	29	8,788	303.03	0.81	6.90
Nanjing	2.67	121	18,690	154.46	14.28	23.97
Shaoxing	3.35	68	18,593	273.43	2.97	11.76
Wuhan	3.53	135	34,064	252.33	3.58	8.89
Yinchuan	2.27	24	3,704	154.33	0.76	8.33
Zhengzhou	2.11	93	17,031	183.13	12.16	11.83
Zibo	3.08	41	16,173	394.46	13.83	17.07
Domestic Clusters of chemical pharmaceuticals and raw materials						
Changchun	1.82	126	16,348	129.75	9.39	14.29
Changzhou	2.39	122	10,475	85.86	17.83	14.75
Ha`erbin	6.40	128	76,935	601.05	1.46	7.81
Huai`an	1.04	34	6,809	200.26	11.12	11.76
Jinzhou Qu	1.79	30	7,053	235.10	3.67	6.67
Linchuan	1.34	34	6,221	182.97	15.13	5.88
Nanyang	1.13	48	15,099	314.56	0.82	6.25
Shanghai	3.41	578	73,546	127.24	20.67	18.86
Shenyang	3.50	188	30,814	163.90	7.80	19.15
Shijiazhuang	4.86	207	54,913	265.28	21.44	15.94
Suzhou	1.91	137	14,149	103.28	20.38	20.44
Taiyuan	1.67	44	6,428	146.09	28.81	20.45
Taizhou	3.02	161	21,184	131.58	5.47	6.21
Xi`an	2.38	171	21,045	123.07	17.00	8.19
Xinxiang	1.82	48	12,615	262.81	7.45	10.42
Yichang	1.05	27	5,390	199.63	0.06	3.70
Yuncheng	1.21	41	7,505	183.05	2.98	4.88

Reference

Altenburg, T. and J. Meyer-Stamer (1999). "How to Promote Clusters: Policy Experiences from Latin America." World Development 27(9): 1693-1714.

APBN (2006) Review of China's Biopharmaceautical Industries in Recent Years, Asia Pacific Biotech News, Vol 10, No 16, 30 August.

Aydalot, P. (1986). Milieux Innovaterus en Europe. Paris, Gremi.

Bergman, E. M. and E. J. Feser (1999). Industrial and Regional Clusters: Concepts and Comparative Applications, Regional Research Institute, WVU. (Web Book).

Brown, R. (2000) Cluster Dynamics in Theory and Practice with Application to Scotland, Regional and Industrial Policy Research Paper, Number 38, European Policies Research Centre, University of Strathclyde.

Chen J, Yang X. (1997), Analysis on the construction of corporate groups in our pharmaceutical industry. J Pharma Economy. 5:5-6.

Chen Z. (2005) Research on the Planning an Establishment of National Biopharmaceutical Park (in Chinese).

DeBresson, C. (1996). Why Innovative Activities Cluster. Economic interdependence and innovative activity: An input output analysis. C. DeBresson and et al. Cheltenham, U.K., Elgar; distributed by Ashgate: 1996, pages 149-64.

Dunning, J. H. (2000). Regions, Globalisation, and the Knowledge Economy: The Issues Stated. Regions, Globalisation, and the Knowledge Economy. J. H. Dunning. Oxford. Oxford University Press: 7-41.

Enright, M. J. (1996). Regional clusters and economic development: A research agenda. Business Networks: Prospects for Regional Development. U. H. Staeber, N. V. Schaefer and B. Sharma. Berlin, Walter de Gruyter.

Florida, R. (1995). " Towards the learning region." Futures 27(5): 527-536.

Florida, R. (1998). Calibrating the learing region. Local and Regional Systems of Innovation. J. D. L. Mothe and G. Paquet, Kluwer Academic Publishers. 19-28.

Freeman, C. (1982). The Economics of Industrial Innovation. Cambridge, MIT Press.

Guo F. (1998), Lessons from the mergers and acquisitions in the global pharmaceutical industry. China Pharm J. 75:4.

Harrison, B. (1992). "Industrial districts: Old wine in new bottles?" Regional Studies 26(5): 469-483.

Larry Davidson, L. and G. Greblov (2005), The Pharmaceutical industry in the Global Economy, Research report, Indiana University Kelley School of Business.

Mao, Y (2005) The Investment Strategy of Multinationals in China, China Financial and Economic Publishing House, Beijing (in Chinese).

Markusen, A. (1996). "Stocky Places in slippery space: A typology of industrial districts." Economic Geopraphy(72): 293-313.

Marshall, A. (1891). Principles of Economics. London. London and New York, Macmillan.

Nelson, R. R. and S. G. Winter (1982). An Evolutionary Theory of Economic Change. Cambridge, Mass. and London, Belknap Press.

Pavitt, K. (1984). "Sectoral Patterns of Technical Change: Toward a Taxonomy and Theory." Research Policy 13.

Rosenfeld, S. A. (1995). Overachievers: Business Clusters that Work. Chapel Hill, NC, Regional Technology Strategies, Inc.

Saxenian, A. (1994). Regional Advantage: Culture and Competition in Silicon Valley and Route 128. Cambridge, Harvard University Press.

Schmitz, H. and B. Musyck (1993). "Industrial Districts in Europe: Policy Lessons for Developing Countries?" IDS Discussion Paper(324).

SMEI (2006). Online database of Chinese pharmaceutical companies. http://www.smei.net.cn.

Van Den Bulcke, D., H. Zhang and X. Li (1999) Interaction between the Business Environment and the Corporate Strategic Positioning of Firms in eh Pharmaceutical Industry: A Study of the Entry and Expansion Path of MNEs into China, Management Internatioanl Review, Vol. 39, 4:353-377.

Yin, Hongjun Yin and J. Warren Salmon (2003), Strategic Restructuring of China's Pharmaceutical Industry: Mergers and Acquisitions, Journal of Pharmaceutical Marketing & Management, Vol. 15(4): 69-84.

Notes

[1] The industrial cluster is used to definite the geographic and sectoral agglomeration of enterprises. Bothe terms, i.e. cluster and agglomeration, will be used interchangeably in this study.

[2] According to the classification of China's Bureau of Statistics, the SOEs include not only wholly state owned enterprises, but also Sino-foreign joint ventures, of which the Chinese government has a majority share in equity capital or has management control by agreement.

[3] This includes all state owned enterprise enterprises and large collectively owned, private and foreign enterprises, of which the sales amount to RMB5 million (National Bureau of Statistics of China, 2005). China's pharmaceutical industry consists of 10,344 registered companies, of which 1,916 state owned enterprises (SOEs), 1,500 foreign invested enterprises (FIEs), 1,283 collective enterprises, 3,788 share holding companies and 1,801 with other ownership structures (SMEI, 2006). Yet, most of these companies are small sized (82%) and have only limited production capabilities.

[4] Although China has the largest pharmaceutical industry among developing countries, its size is still very small as compared to industrial countries, e.g. the sales of Pfizer amounted to US$44.74 billion in 2003 and US$51.3 billion in 2005, which are higher than the total output value of China's pharmaceutical industry.

[5] Although China's pharmaceutical industry experienced rapid growth, many Chinese pharmaceutical companies produce similar lines of products and compete in the low-end market. The product pipelines of Chinese companies contain only about 4,500 dosage forms, while there are more than 150,000 in the U.S. and 44,000 in Japan (Yin and Salmon, 2003). Most domestic companies lack the capital and technology necessary for advanced R&D. The expenditure of R&D to sales ratio in China's pharmaceutical industry was only 2.5% in 2001, while the relative ratio is much higher for global leading companies, e.g. it was 13.9% for GlaxoSmithKline, 17.7% for AstraZeneca and 14.9% for Novartis in 2004 (Davidson and Greblov, 2005).

[6] In 2005, MOFCOM selected 15 Chinese cities as export bases for the pharmaceutical industry, i.e. Tonghua, Chengdu, Guangzhou and Tianjin for TCM; Zibo, Shenzhen and Shanghai for medical equipment and other pharmaceutical products; Hangzhou, Shijiazhuang and Taizhou for chemical drugs; Xian, Guilin and Changsha for TCM extracts and Changchun and Beijing for bio drugs. These cities accounted for more than 50% of the total industrial output of the Chinese pharmaceutical industry in 2004 and 40% of Chinese exports of pharmaceutical products.

[7] Incomplete data showed that China has established 64 biopharmaceutical industry parks till 2004, of which 23 are located in the hi-tech zones, and 41 are in independent parks. 18 of these parks were initiated or approved by the central government, while 26 by provincial governments and the rest by the administration at the county level (Chen, 2005).

[8] From July 1st, 2004, onwards, China's State Food and Drug Administration required all pharmaceutical preparation and bulk drug manufacturing enterprises without GMP certificates to stop production. From December 31st, 2004, onwards, all pharmaceutical management enterprises must accord with pharmaceutical product quality management orders and obtain the good storage practice (GSP) certificate. At the same time, the national food and pharmaceutical product control and management department issued GMP authentication regulations for manufacturing enterprises concerning the promotion of traditional Chinese medicine decoction, pharmaceutical gases, and external biological diagnosis preparations. As of the first season of 2005, 3959 out of 5071 national pharmaceutical manufacturing enterprises passed the GMP authentication, while one fifth of the remaining enterprises stopped their production. By the end of 2004, GSP authentication was obtained by 7,445 out of the 8,108 national pharmaceutical product wholesale enterprises, 1,410 out of the 1,624 pharmaceutical retail chain-like enterprises, and 58,065 out of the 76,295 pharmaceutical retail enterprises; at the same time, 1,400 pharmaceutical product wholesale enterprises and 11,600 pharmaceutical product retail enterprises were eliminated from the industry (APBN, 2006).

[9] The companies which produce medical equipment and machinery, packaging materials, etc, are not included in this study.

[10] FDI in the Chinese pharmaceutical industry started more than a century ago, when Bayer entered the Chinese market in 1882 and Hest, known as Aventis today, sold its products through more than 120 distribution agents across China in 1887. Of course, these companies had to reenter China at later stage as FDI was banned from 1949 to 1979.

[11] China's administrative units are currently based on a three-level system dividing the nation into provinces, counties, and townships. There are in total 34 provinces, including 5 autonomous regions, 4 municipalities directly under the Central Government, and 2 special administrative regions. These provinces and regions consist of 400 counties.