# Institutions, Entrepreneurship and Transition:

# The Pharmaceutical Technology System in Shanghai

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## Abstract

The purpose of this paper is to examine the role of institutions in explaining the entrepreneurship and transitional path of the pharmaceutical clusters in Shanghai. Four types of institutional factors are examined: the comparative competence of the various pharmaceutical firms; the science base and mechanisms of technology transfer; the connectivity of networks and intermediary institutions; and public policy as well as other government infrastructure.

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## INTRODUCTION

What are the linkages between institutions and entrepreneurship in a transitional economy?

Shanghai was the home of the Chinese pharmaceutical industry before the 1980s. It had leading research institutions and universities, the most advanced hospital system, the largest regional pharmaceutical market, and a local government well known for its pioneering role in formulating government policies in the whole nation. However, the Shanghai pharmaceutical system lost its leadership in the country when the system was transiting from the centrally planned system to the market economy system. By the early 1990s, the value added of the pharmaceutical industry in Jiangsu Province and Guangdong Province exceeded that in Shanghai. In 1995, the value added of the pharmaceutical industry in Jiangsu Province and Guangdong Province were about 847 million dollars and 780 million dollars, respectively, while that in Shanghai was around 722 million dollars. At the same time, Shanghai pharmaceutical firms have been continuously losing market share to their domestic competitors. In 1995, the largest Shanghai pharmaceutical firm, Sanwei, ranked only the 27$^{th}$ among the 132 largest Chinese pharmaceutical firms (Luo, 1998).

What prevented the Shanghai pharmacy and biotechnology system from staying ahead of those in other Chinese provinces? The purpose of this paper is to examine the role of institutions in cultivating entrepreneurship and industrial dynamics in Shanghai with a technological system perspective (Carlsson, 1995, 1997, 2000).

The paper is organized as follows. It starts with a discussion of the rationale for looking at clusters and why certain economic activities tend to cluster, and the technological system

perspective is adopted as the theoretical framework in this paper. This is followed by an overview of the comparative receiver competence, e.g. manufacturing, marketing and R&D strength, of various pharmaceutical firms in Shanghai. Next, it explores the science base and technology transfer mechanisms. Fourth, the connectivity of the Shanghai pharmaceutical system in terms of networks and intermediary institutions is carefully examined. Fifth, it examines public policy and other government infrastructures in the system to discuss the roles of government in influencing the system effectiveness in absorbing knowledge spillovers. The concluding section formulates the policy issues to which the analysis gives rise.

## DYNAMIC CLUSTERING OF ECONOMIC ACTIVITY

In recent years, there have been numerous studies of clustering of economic activity or innovation systems, particularly in 'high technology' sectors such as biotechnology and electronics (Porter 1990, 1998; Freeman 1988,1995; Lundvall 1988, 1992; Nelson 1993; Saxenian 1994; Malerba & Orsenigo 1990, 1993, 1995 etc.). While these frameworks increase our understanding of clustering of economic activity, there are several inherent problems with these frameworks. First, the definitions of clusters or innovation system often lack rigor. The concepts of national innovation system (e.g., Freeman 1988, 1995; Lundvall 1985), regional innovation clusters or local industry systems (Porter 1990, 1998; Saxenian 1994) are primarily geographical. This system definition overlooks the fact that the geographical boundaries are becoming more and more porous for the flow of knowledge and competence, which are increasingly important for a nation or a region to achieve sustainable development. Clusters of economic activities or innovation systems often differ greatly in characteristics across industries and sectors.

Second, these frameworks are largely static. The literature on innovation systems focuses attention on the major institutional determinants of innovative activities while this line of research assumes that the system is always ready to turn these innovations into unusual economic performance. Unfortunately, new technologies, especially those major ("architectural") innovations, often require combination with new economic competence to realize their potential value (e.g., Henderson & Clark 1990).

The concept of sectoral systems of innovation defines system on the base of the idea that different sectors or industries operate under different technological regimes (e.g., Malerba & Orsenigo 1990, 1993). This approach provides a more finely grained delineation of the innovation processes and their institutional and organizational determinants than do national innovation systems and takes into account the differences in the industrial structure and dynamics of different branches. However, since it usually analyzes well-defined industries, the technological regimes of these industries are treated as given. In other words, the concept of technological regimes is largely a black box in the approach. Therefore, much of the sectoral systems of innovation perspective entails *ex post* rationalization for clustering of economic activities and is less powerful when used to analyze emerging systems of innovation or radical transformation of existing ones.

The perspective adopted in this paper is that of technological systems developed by Carlsson and his colleagues (1995, 1997, 2000). This approach argues that a technological system is defined jointly by the technological and economic dimensions while the system can be separated into three independent dimensions: technological, institutional or organizational, and economic. The development of a technological system is based on the continuous positive feedback between the technological dimension and the economic dimension through the

intermediary institutions. The institutions work as bridges and/or filters between technological innovations and economic competence. In the technological perspective, the evolution of an economic system is based on two seemingly contradictory processes: the creation of variety in technology and economic competence and synchronizing of these two dimensions through bridging and filtering processes by institutions. The flow of knowledge and competence in a technological system is often bi-directional through the actor network.

To exploit the universal technological opportunities and change an actor network into a development bloc, certain actors have to be included and connected with each other to form coherent channels for knowledge and competence flows. These critical actors for a sustainable system include competent and active customers, innovators who integrate technologies, entrepreneurs who identify profitable innovations, competent venture capitalists who recognize and finance the entrepreneurs, exit markets that facilitate ownership change, and industrialists who take successful innovations to industrial scale production (Carlsson 1995; Eliasson 2000). These actors together help the system to form a certain 'functional pattern' (Johnson & Jacobsson 2000). The more diverse, competent and connected these actors are, the more viable a technological system will be.

## FIRM COMPETENCE

Shanghai is regarded as the cradle of the Chinese pharmaceutical industry. The development of its pharmaceutical industry can be separated into several stages: before and right after the so-called liberation in 1949, under the centrally planned system between the 1950s and the early 1980s, before and after the declaration of Pudong area as Special Zone in 1992.

### The origin of the system and its development under the centrally planned system

The earliest pharmaceutical factories in Shanghai were founded by medicine retailers who owned some medicine shops on the major streets of Shanghai and were familiar with consumer demands (Liu, 1998). In the late 1940s, right before the so-called liberation, there were about 130 pharmaceutical factories, most of which were privately owned and had less than 10 employees. These companies altogether had 297 major manufacturing establishments and they imported their crude drugs from abroad since they could not find local suppliers (Zheng, 1998).

In the early 1950s, some state-owned brand-new pharmaceutical companies were established and some privately owned companies were merged with state-owned companies. In January 1956, all the private companies of the pharmaceutical industry in Shanghai were required to become either state-private joint ventures or be sold to the state. The number of pharmaceutical firms was increased to 810 (Zheng, 1998). From time to time, new state-owned pharmaceutical firms were set up, and new investments in machinery and equipment were made by the state. However, because the whole country was largely separated from the western countries and was not able to import the needed chemicals for manufacturing preparations, the Chinese pharmaceutical industry had to concentrate on the upstream of the industry. Therefore, the whole Chinese pharmaceutical industry has traditionally been dominated by manufacturing firms, and the Shanghai pharmaceutical manufacturers happened to be the most efficient. In the centrally planned economy, the Shanghai pharmaceutical firms were known for their manufacturing capability and high product quality. Thus before the 1980s, the Shanghai pharmaceutical industry, took a leading place all over China because of its strong industrial base and high-quality work force.

In the centrally planned economy system, every unit of the whole system was required to specialize in some field to help improve the production efficiency. The system was formed

according to the traditional linear model of innovation from basic research to applied research, sample development and production. The manufacturing function was regarded as the central process of the whole centrally planned system to meet the demands of a shortage economy. All raw and processed materials and final products were distributed according to government plan by the commercial sector, instead of directly through the market. Since the governmental distribution system was responsible for distributing their products around the country, their marketing capability was very limited. And like their competitors in other parts of China, most Shanghai pharmaceutical companies did not have an R&D department until the mid-1990s. The level of R&D investment has been very low in the Chinese pharmaceutical companies. In the early 1990s, the largest Chinese pharmaceutical firms spent still only about 0.7% of their revenues on R&D, while this rate was around 10-25% in most multinational companies (Tang, 2000). Since China adopted a self-reliance strategy since the 1950s to deal with the blockade by the western countries and, similarly, with an emphasis on the domestic market the Shanghai pharmaceutical firms did not care seriously about intellectual property rights either. It was not until China started to apply for entry into the former GATT and now WTO and the importance of intellectual property rights was acknowledged by Chinese governments and firms. The specialization of organizations to efficiently produce the needed products led to a systemic separation of core capabilities, overemphasis on manufacturing activity and small overall size of organizations inside a centrally planned system[2]. The revenue of the Huabei Pharmaceutical Company, the largest pharmaceutical company in China, was around 373 million dollars in 1998 while that of Glaxo-Wellcome in 1999 was 32.7 billion dollars (Tang, 2000).

The Culture Revolution between 1966 and 1976 destroyed the pharmaceutical industry and most factories were partially closed. During the Culture Revolution, a lot of managers and

technologists of the state-owned companies were exiled to the countryside and had no chance to get access to any information about the world pharmaceutical industry. When these managers and technologists regained their position in the industry after the Culture Revolution, they started their work on the base of their already outdated knowledge achieved before the Culture Revolution. What these elite members of the Chinese pharmaceutical industry tried hard to do was to resume the manufacturing capacity of the industry that was broken down by the Culture Revolution, rather than to reposition their firms according to the world pharmaceutical development trends.

However, before these manufacturing factories were renovated, the country started to open its door to the external world. Unfortunately, the Chinese leaders at that time hesitated to open Shanghai, the most important industrial base of China, to the western world (Deng, 1994). Shanghai was not open until 1992, in which year the plan to open and develop the Pudong district of Shanghai was disclosed. Between the early 1980s and early 1990s, the Shanghai pharmaceutical industry was largely operating in the old centrally planned system, while firms from the southern provinces started to distribute the imported products all over the country through both official distribution channels and firm sales networks. Shenzhen and several other southern coastal cities became the distribution centers of imported medicines because of the much lower import taxation enjoyed by these 'Special-Zone-Cities'. Since most of these imported medicines could not be produced by the domestic firms, these southern firms swiftly seized a large share of the Chinese pharmaceutical market. The most important effect of imported products on domestic competition in the pharmaceutical industry in 1980s was that during the process the southern firms were able to set up their sales networks and form their marketing capabilities with which till now most Shanghai companies have found it difficult to

catch up. Having acquired large market shares and accumulated capital, the southern firms were more flexible in importing the advanced manufacturing equipment and attracting experienced managers and technicians from other parts of the country.

The Shanghai pharmaceutical firms responded to the emerging southern competitors by updating their manufacturing facilities, rather than by cultivating marketing or R&D capabilities, to defend their market positions. Under the centrally planned economy system, profits of the firms were controlled by the central government and therefore the Shanghai pharmaceutical companies could not achieve capital accumulation. To update their manufacturing facilities, these Shanghai firms had to go through the time-consuming procedures to get approval from various government agencies. The amount of each investment project appropriated by the central government was determined according to the regulations of the centrally planned system. Unfortunately, there was no provision for investment in sales network in these regulations. Therefore, even though the executives of the Shanghai pharmaceutical firms knew the importance of sales networks and marketing capability, it was practically impossible to fund these capabilities under the centrally planned system.

**Regional Market Segmentation**

In 1992, the declaration of the Pudong district as a Special Zone was a turning point for the whole country in terms of its Opening Policy. The policy gap between Shanghai and other coastal cities disappeared. The centrally planned system was also largely rejected and most former official distribution channels were replaced by firm sales networks. Local governments were urged to become economy-oriented and the rate of gross regional product growth was regarded as the most important measure of performance of local government officers. Therefore, local government officers together with local firms started to import equipment and to actively

recruit foreign firms. At the same time, the local governments systematically drove the products of other provinces out of their markets and gave the local markets to the local firms[3]. This localization strategy worked effectively for most local governments to increase local gross regional product when the whole nation was experiencing high gross regional product growth rates. It was this local market protection policy that further decreased the market share of most Shanghai pharmaceutical companies. During the process, most Shanghai pharmaceutical firms declined from national firms to local ones. However, the southern companies, who based their strategy on marketing and selling pharmaceutical products rather than manufacturing, can often prosper in spite of this local market protection policy.

Although the Shanghai pharmaceutical firms could take advantage of the local Shanghai pharmaceutical market and those of adjacent Zhejiang and Jiangsu provinces, which together constituted the biggest pharmaceutical markets of China, the overall competitive advantage of the Shanghai pharmaceutical firms over their domestic competitors was further seriously weakened. Since each local provincial government of China was importing manufacturing equipment, often the Shanghai pharmaceutical firms were importing the same equipment and producing the same products as their domestic competitors did. Thus, they lost their comparative advantage in manufacturing as well.

Because of the small scale of the local market, most domestic companies can not achieve economies of scale in manufacturing to fully exploit their manufacturing capacity. Since 1992 the manufacturing overcapacity in the pharmaceutical industry has become a national problem. For example, in 1998, the capacity utilization rate for crude drugs was 58.8%. Those for tablet drugs and for capsule drugs were 44.7% and 42.3%, respectively (Zheng, 1998). The Shanghai pharmaceutical industry was one of the most serious examples of manufacturing overcapacity

among the Chinese provinces. In the early 1990s Shanghai firms invested about 2 to 3 billion yuan (about 300 to 400 million dollars) to renovate their pharmaceutical manufacturing facilities. However, lacking product variety and marketing capability, these firms had very low utilization rate of manufacturing capacity. A lot of brand-new facilities were never used to manufacture products and some imported facilities were never even installed because of lack of new products to produce and obvious losses associated with producing old products. The low utilization rate of the imported facility brought almost all of the pharmaceutical companies a very high liability that constrained their further ability to reconstruct themselves in the 1ate 1990s.

The failure of the first round investment into biotechnology clearly reflects the path dependence of the Shanghai pharmaceutical companies. The overemphasis on manufacturing capability in the system was so strong that the relative insignificance of manufacturing in the biotech industry became a death trap to the first generation of Shanghai biotech firms set up around 1990. All five major biotech companies set up during the wave to develop the Pudong district were placed in the industrial parks in the Pudong area. These companies invested heavily and blindly in manufacturing facilities, most of which these companies never had a chance to use. Some of them finally were acquired by new startups. Since most investments were sunk in the manufacturing facilities, these companies had very limited capital to support marketing or R&D activities and finally their revenues could hardly cover the interests of the loans from the bank, not to mention the principal of the loans (Li, 2000).

**Joint Ventures**

In addition to importing manufacturing equipment, the Shanghai pharmaceutical companies also started to form joint ventures with foreign companies in the 1980s. The country was very careful in permitting the entry of foreign pharmaceutical companies into the Chinese market.

Therefore, joint ventures were not popular in the Shanghai pharmaceutical cluster during this period. Since the entry of foreign firms can usually boost the local gross products, the local government offices competed fiercely with each other for the foreign investment in the 1990s. The Shanghai pharmaceutical firms had some advantage in attracting foreign companies over other domestic firms because of their still high share of the Chinese pharmaceutical market, high-quality employees, and most importantly, the special political power of local Shanghai government in the Chinese political system.

Though the multinational firms introduced most of their competences including marketing into the industry, it turns out that the local companies learned very little from their foreign partners. The swiftly declining ownership of the local firms in these joint ventures is in evidence of this low degree of learning by local firms (Li, 1999). At the beginning, the central government required that the local firms own more than 51% shares of the joint ventures. However, by the end of the 1990s, most joint ventures with foreign firms were controlled by the foreign partners step by step and declined into manufacturing subsidiaries of the foreign companies. And with the changing environment in the late 1990s, most foreign companies set up fully owned companies, rather than joint ventures (Zhang, 1998).

There are several reasons for this lack of learning by local firms from joint ventures. First, though the Shanghai pharmaceutical firms were once the most advanced in manufacturing, they were still lagging far behind the multinational firms in manufacturing technologies. Second, the entry of multinational firms and formation of joint ventures with foreign firms were legitimized by the so-called strategy of ‘exchange of local market for foreign technologies’. But the most visible technologies to the local government officers often include the manufacturing equipment (Li, 1999). It is natural for the government officers to relate the multinational firms’ competence

with high-tech manufacturing equipment and justify the local firms' efforts in importing manufacturing equipment.

Third, the sales and marketing practices used by these foreign newcomers in the world pharmaceutical market had to be greatly modified for the local Chinese market. This need for modifications often made the local firms overlook the importance of marketing-related competences and attribute the success of multinational firms in China only to their highly profitable products with intellectual property rights (e.g., Zhang 1998). For example, the hospital sales representatives were first adopted by Bristol-Myers Squibb Company in 1984 to promote the products produced by its joint venture with a Shanghai company. However, Bristol-Myers Squibb Company found that the Chinese market for the high-tech prescription medicines was often too small to make the high-qualified hospital sales representatives cost-effective and that sales skills were much more important than knowledge about the products in improving sales performance in the Chinese market. But sales skills often have a negative label when they are related with nonprofit hospitals.

Fourth, there was and still is a wide gap in compensation policy between the local state-owned companies and the foreign firms. Attracted by the much high salaries and benefits, employees and executives have been flowing from the local state-owned firms to foreign firms. Most state-owned pharmaceutical companies found it difficult to retain or attract managers and researchers. According to a census in 1999, the Shanghai pharmaceutical industry lost more than 1,000 technologists since 1991 and in the Shanghai Pharmaceutical Group, even researchers with a graduate degree are still very few (Gu, 1999). Once entering the foreign firms, very few of them would like to go back to the local state-owned firms again. Without a flow of employees

from the foreign firms to the local state-owned firms, there is no transfer of competence to the local firms.

The step-by-step control of these joint ventures and the formation of wholly owned subsidiaries by the foreign firms greatly increased their share of gross regional products in the Shanghai economy. Before the 1980s, as a model of the centrally planned economy system, organizations in Shanghai were almost 100% state-owned. In 1999, the revenues produced by foreign companies were 280 billion yuan (34 billion dollars), 44% of the industrial revenues of Shanghai and close to those produced by the state-owed companies (48%). At the same time, the revenues of the locally owned private firms in Shanghai were only 68 billion yuan (8 billion dollars), representing only 11% of the revenues in the industrial sector. This can be compared to the share of locally owned private firms in Zhejiang, a province adjacent to Shanghai, while was around 65%. In 1999, the growth rates of revenues of the foreign-owned companies and private companies were 14% and 21%, respectively, while that of the state-owned companies was only 11%.

A nationwide manufacturing overcapacity together with limited intellectual property rights threw the whole pharmaceutical industry into high competition and limited supplier power towards the Chinese hospital system that controlled more than 80% of the medicine markets. The limited supplier power of the pharmaceutical firms can be shown in the always high ratio of receivables to sales revenues; most of these receivables could not be collected. Another sign of the low competence of the Shanghai pharmaceutical industry is that, by the end of the 1990s, the number of public firms in the industry was extremely low. With limited efforts in constructing new sales networks to replace the sharply contracting centrally controlled distribution channels, a more efficient manufacturing system could only produce more products that may never be sold.

Till the middle 1990s, when most Shanghai pharmaceutical firms became conscious of the importance of marketing and R&D capabilities, their poor performance, limited financial strength and lack of experience in commercializing technologies made it very hard for them to break the lock-in effects of manufacturing orientation. Only very few of these companies had the capability to evolve into original pharmaceutical manufacturers of multinational firms, such as Hualian Pharmaceutical Company and Sanwei. Right now, the very few pharmaceutical firms who are strong in marketing capability are often privately owned companies set up in the middle 1990s, such as Fuxin High-Tech Group (Li 1998). These companies concentrated much more on marketing capability, sales network, and property rights than on manufacturing facilities. They usually acquired the unexploited manufacturing capacity at very low price or just outsourced the needed manufacturing capacity around the country.

On the base of the above analyses, the overall receiver competence of the Shanghai pharmaceutical firms, such as in-house R&D, manufacturing competence and marketing strength, is relatively low because of the lock-in effects of their manufacturing orientation.

## SCIENCE BASE & MECHANISMS OF TECHNOLOGY TRANSFER

### R&D Organizations

The pharmaceutical and biotechnology R&D in Shanghai is carried out in research institutes, universities, hospitals, medical clinics, policy organizations and other institutions. Shanghai has the leading pharmaceutical and biotechnological research institutions and universities of the country. The Shanghai Academy of Life Science was one of the eight national research bases and the only national research center in life science set up by the Chinese Academy of Science in 1998. It was the result of merging eight research institutes (Shanghai Institute of Biochemistry, Shanghai Institute of Cell Biology, Shanghai Institute of Plant

Physiology, Shanghai Institute of Medicine Materials, Shanghai Institute of Physiology, Shanghai Institute of Neurology, Shanghai Institute of Entomology, Shanghai Research Center in Bioengineering) and two research centers (Shanghai Research Center in Life Science, and National Gene Research Center) in life science (http://www.sibs.ac.cn/jianjie.htm). Except the Chinese Academy of Science, various Ministries of China set up their research life research institutions in Shanghai. For example, Shanghai Research Institute of Biological Products is one of the six institutes in biotechnology of the Ministry of Health. Shanghai Institute of Medical Industrial Research is a major research institute of the National Medical Administration.

The number of universities in Shanghai is second only to that of Beijing. The Fudan University School of Life Science, the No. 2 Army Medical University, the East China University of Science and Technology, the former Shanghai Medical University (now the Fudan University Medical School) and the Shanghai No.2 Medical University are all major players in their research fields of pharmaceutical and biotechnology in the country. Most of these universities have one or more associated hospitals. The hospital system in Shanghai is also one of the most advanced and complete in China. Shanghai No.1 People's Hospital Ruijin Hospital, Huashan Hospital, Changhai Hospital, and Changzheng Hospital are among the best.

The number of senior research fellows, professors and members of the Chinese Academy of Science in Shanghai ranks No.1 or 2 among the 31 provinces or municipalities directly under the central government of China. In the Shanghai Academy of Life Science alone, there are around 1900 researchers and administrators, among whom there are 178 senior research fellows and 26 members of the Chinese Academy of Science or the Chinese Academy of Engineering (http://www.sibs.ac.cn/jianjie.htm).

As discussed earlier, before the middle 1990s, almost none of the Shanghai pharmaceutical companies had an R&D department. And according to the linear model of technology commercialization, the activities along the model were separated into different kinds of research institutions. The research universities such as Fudan University School of Life Research concentrated on basic research and teaching. Applied research institutes such as Shanghai Research Institute of Biological Products and Shanghai Institute of Medical Industrial Research concentrated on pharmaceutical engineering. Medical universities and their affiliated hospitals concentrated on clinical research.

Basic research institutes usually closed their research projects when their outcomes passed certain official evaluation processes or certain papers were published in academic journals. They rarely made efforts to pursue their research results to the later stages like applied research or industrial engineering since their professorship, salary and all other benefits are related with how many articles are published, how many classes they are teaching, and how many of their research projects win certain official prizes. Successful commercialization of a technology can do little to help develop their profession or earn reputation and therefore their research projects are largely academically oriented. These organizations receive grants largely from various official institutions such as National Natural Science Foundation, Ministry of Defense, etc., and their grants from industries are relatively small.

Some basic research institutions did make efforts to commercialize their technologies but they often found that they were lacking the needed capabilities. However, even the most prestigious basic research institutions, e.g., Fudan University School of Life Science, hardly had any knowledge beyond basic research. Knowing very little about the related engineering technology to change their decent research outcomes into commercial products, researchers of

the university often find that their cherished research outcomes are economically meaningless to the industries. Except several national laboratories and some research teams with strong leaders, the main function of Shanghai universities is to educate and train undergraduate and graduate students. From the industry perspective, their research results are of secondary importance to those of the application-oriented research institutions. However, because of their prestige and fame, these universities are still the first home of scholars who have studied and worked abroad. And because of their strong alumni networks all over the world and annual inflow of high quality undergraduate and graduate students, these universities are still a very important part of the problem-solving networks and informal networks of the pharmaceutical and biotechnology cluster. For example, when the New Huangpu Group invested 200 million yuan (around 24 million dollars) to construct a joint venture with Fudan University in gene engineering, the university's alumni network in the USA played an important role in formulating its strategy and finding alliance partners in the USA.

The applied research institutes played a much more important role in producing intellectual property rights and commercializing technologies than the research universities since their research was historically application-oriented and responsible for imitating the new drugs in the world and solving the technological problems for the manufacturing-oriented firms. From 1990-1996 the overall research grants received by the research institutes were as much as 3-4 times larger than those received by the universities (see Table 1.). In the centrally planned system these application-oriented institutions played a role similar to that played by the R&D departments of multinational companies. The major difference between them is that the application-oriented research institutions in China concentrated on imitating products of the western world, instead of inventing new drugs.

Since these institutions have the research facilities and human resources to do application research and are familiar with the long process to get approval from the appropriate authority for patenting, phase I and phase II trials, clinical testing, they will continue to be the major new drug creators in the Shanghai pharmaceutical system. From time to time, these institutions spin off firms or form joint ventures with various organizations. In the past few years, these institutions have tried hard to shift from a follower strategy to an innovation strategy. Most drugs with property rights in Shanghai were created by these organizations.

Under the centrally planned economic system, most research projects were often planned and started from basic research. Therefore, the Shanghai pharmaceutical industry invested a higher percentage of money into the early stage of technological research than their foreign counterparts. For example, according to the Shanghai official census data from 1981-1987, the relative investments into basic research, engineering research and manufacturing was around 1:1:10.6 while it is around 1:10:100 in the western countries (Dai and Zhuge, 1997). Since the overall investment into R&D of the system is very low, this ratio clearly shows that there was an overemphasis on basic research, a neglect of engineering research, and a lack of connectivity between basic research institutes and application-oriented research institutes in the Shanghai pharmaceutical industry.

Since the 1980s, the intellectual sector including universities and research institutions has been left under-invested. This can be partly seen from the low rate of annual government expenditure on education. The percentage of annual government education expenditure to Shanghai whole-society investment decreased sharply from 7.35% in 1978 to 2.46% in 1995 in Shanghai (Li, 1999b). The psychology of government officers is that investment in universities and research institutions was much less valuable than industrial investment projects to increase

gross regional products. Faculty members or research fellows, who could find good opportunities in the prospering industries or to study or work abroad, often chose to leave their faculty or research position with limited income and low benefits. The number of faculty members in Shanghai universities decreased sharply from 26,603 in 1988 to 21,522 in 1995 (Li, 1999b) and most of them will not return to these universities. Therefore, the strength of these universities to organize and conduct research was greatly weakened.

**Mechanisms of Technology Transfer**

Various formal and informal technology mechanisms are adopted by the R&D organizations. Formal mechanisms include sponsored research agreements, licenses or equity swaps. Informal mechanisms may involve personal networks or the hiring of students or part-time researchers.

Without a Chinese equivalent to the Bayh-Dole Act of 1980 in the U.S., property rights belong to organizations that financially support the R&D activities. In the centrally planned economy system in China, almost all research programs were supported by various government agencies, e.g., Shanghai Science and Technology Commission, Shanghai Economic Commission, and therefore research outcomes from these programs were also appropriated by these government agencies. However, this does not work when the system is transitioned to a market economy. First, a technology can be developed after years of work and during the process may be supported by various sources of funds. Therefore when the technology is transferred to a company, legally the company may have to negotiate with all these sources of funds to get the transaction down. It is relatively easy to transfer a technology to a state-owned company from a research organization since it is just a transfer of technology between state-owned organizations. However, when a private company tries to use a technology supported by government agencies

and developed by state-owned research organizations, the problem of losing state-owned properties to private companies arises. However, the private companies from the southern provinces are often more proactive in profiting from a technology.

Another problem with this technology appropriation system is that technology researchers can benefit little from technology transfer since technology belongs to various financiers and most research institutions or universities are under-invested. From the perspective of the user of technology, the involvement of the original researchers is critical to the economic success of a technology. The firms in Guangdong or Zhejiang provinces, often privately owned, are much more flexible in researcher compensation policy than those in Shanghai. So both private technology users and researchers would prefer informal mechanisms. A lot of researchers choose to patent their technologies by themselves or work part-time for the firms they feel comfortable to cooperate with. The fact that most research organizations do not support patent applications for their technologies at least partially facilitates the informal mechanisms of technology transfer. Probably it can be said that informal mechanisms are more popular than formal ones.

Among the formal mechanisms of technology transfer, licenses are relatively few. The reason could be largely attributed to the fact that very few licensors have extensive in-house R&D, manufacturing competitiveness, or marketing strength to make the technology profitable. Most R&D institutions demand a one-time payment for their technologies. Some others demand both a high down payment and an equity swap from licensees, which often deters potential licensees. Equity swaps are not popular because of lacking accountancy and finance transparency in most Chinese companies. Currently, sponsored research agreements are becoming increasingly popular because Chinese pharmaceutical companies are fed up with the fierce price competition and are conscious of the importance of property rights in competition. In 1996, 65%

of research grants received by the research institutes in Shanghai were obtained from various companies (Xu et al. 1998).

Due to lack of marketing competence of the Shanghai pharmaceutical firms, researchers in the Shanghai research institutions are inclined to transfer their technologies to the firms in Guangdong, Zhejiang or other provinces. A larger and larger share of technologies developed by the Shanghai R&D organizations are flowing out of Shanghai formally or informally to other provinces. For example, in 1999 there were 18364 technology transactions conducted through the Shanghai Technology Exchange Center and 4819 of these transactions involved flows from Shanghai to other provinces such as Jiangsu, Zhejiang, Guangdong, and Beijing etc. (Xu et al. 1998). What worries Shanghai officials most is that a transfer of technologies out of Shanghai is often followed by the researchers who developed these technologies.

However, it is worth noting that a lot of R&D institutions choose not to transfer their technology to the industries. They choose to set up wholly owned subsidiaries to commercialize the best technologies they develop. In fact it is common in Shanghai that research institutions use profits from these business subsidiaries to support their major operations. However, there are also problems inherent in this technology self-exploitation. First, financial support for these subsidiaries by their parent organizations is often limited. Second, these businesses can seldom develop into big ones because their profits are often channeled into parent organizations. Third, these subsidiaries have to balance between the often noneconomic objectives of their parent organization and the requirements of the business world and therefore a healthy governance structure is often hard to achieve. Spin-off or introduction of other investors is rarely regarded as an option by the R&D organizations because these R&D organizations are not willing to lose control of these profitable businesses (Guangming Daily, Feb. 8, 2000). The unwillingness to

share the most promising technologies with external investors is at least partially responsible for the fact that, in the past few years, very few pharmaceutical or biotechnological companies evolved into large ones in Shanghai, the most technologically advanced district of the country.

## SYSTEM CONNECTIVITY

In the centrally planned system, manufacturing is the primary system function. Therefore, the components and their relations to the whole system were organized to enhance the manufacturing function. Since 1996, innovation is promoted to be the central function of the system and various strategies are adopted to shift the system toward this function.

### Networks

There are three kinds of actor networks, namely, user-supplier relations, problem-solving networks, and informal/personal networks; the problem-solving networks are the most important since they are channels to the flows of knowledge and competence, and therefore often define the boundary of a technological system (Carlsson 1995, 1997).

The evolution of the problem-solving networks of the Shanghai pharmaceutical cluster could be separated into three stages. Before 1978 problem-solving networks were mainly organized by government and some scientists were put together when from time to time some technological problems arose during the manufacturing process. Usually researchers and scientists worked together under an umbrella called “Technology Breakthrough Plan” designated by government. The Technology Breakthrough Plan series once helped Shanghai achieve most of its success in science and technology.

Between 1978 and 1992, with redefinition of the role of government and changes in the environment, such government-centered technological plans were much less applicable and the firms became more important in the process to organize R&D activities. The relations between

research institutions and industries, which were based on arbitrary government requirements, are now in the process of being transformed into contract-based relations. The research institutions receive more and more grants from the firms, instead of from the state or local governments. Thus while the independent research institutions received 35% of their grants from firms in 1985, this share increased to 65% in 1992. The Shanghai R&D system evolved from one dominated by state-owned research institutions to one in which universities, state-owned research institutions and firm-affiliated R&D institutions played similar roles. In 1992, the rate of the numbers of these three kinds of research institutions was 3:2:5, respectively. Since 1993, the privately owned firms began to play an important role in the Shanghai innovation system. The private firms are more active and flexible in organizing R&D research teams (see Table 1).

The informal networks established through professional conferences, meetings, publications and so on are emerging but still largely undeveloped in Shanghai or even all over the nation. Most professional associations are poorly organized due to vagueness in mission and lack of financial support. Vagueness in the roles of professional associations is obvious since the whole intelligentsia sector in China is lagging behind in the process of Chinese economic and political reform. The activities of these professional organizations are largely restricted to publishing one or two journals and routine meetings about distributing the decreasing resources from the traditional official channels (personal interviews, Chinese Bio-engineering Association in Beijing). Holding an annual meeting is still a painstaking process for most professional associations because of difficulties in getting financial support from industries.

**Intermediary Institutions**

From the perspective of network theory, in the centrally planned system, government agencies were the overwhelmingly important bridging institutions and other traditional bridging

institutions, such as industrial associations, were often regarded as redundant and therefore lost the reason to exist. Every organization had its supervisory government unit, which was the primary source of information and was responsible for coordinating the organizations along the linear manufacturing model. What an organization needed to do was to follow its supervisory government unit. Its relations with other organizations in its vertical supplier-buyer chains or other networks were secondary and contingent on government plans. Therefore the supplier-buyer networks of an organization in a centrally planned economy disappeared swiftly since these relations were not organized according to market prices and not economically effective when the whole economy shifted towards a market economy.

In recent years, the local governments in China started to avoid being a player in the industry. The economic progress in China and promotion of alliance strategy require significant connectivity that a single administrative government is hardly able to supply. The importance of intermediary institutions like associations and service companies is increasingly acknowledged. There are four major industrial associations in the Shanghai pharmaceutical sector: the Shanghai Pharmaceutical Industrial Association, the Shanghai Traditional Chinese Medicine Association, the Shanghai Medical Equipment Association, and the Shanghai Pharmaceutical Business Association. The firm membership coverage of these associations is relatively high. For example, the Shanghai Pharmaceutical Industrial Association has 142 firm members, which is about 92% of the local pharmaceutical firms (Li, 1998).

These industrial associations were all set up in the late 1980s, while experiments in extending their roles were not officially permitted until the late 1990s. These experiments were initiated by the Chinese Economic and Trade Commission in May 1997 and Shanghai happened to be one of the four cities that were allowed to do the experiments. The basic functions of these

industrial associations include three aspects: early-stage investigation into the applicants for manufacturing licenses, medicine pricing and price adjustment, and monthly and annual industrial census. Each of these functions was appointed by specific documents from the Shanghai Medical and Pharmaceutical Bureau. In other words, these industrial associations are closely affiliated with the local governments and are assuming functions separated from the downsizing local government. Affiliated with the supervisory government departments, these industrial associations have a relatively high credibility among the firms. In the long run, some of these associations can evolve into prestigious bridging institutions. But their limited roles and dependence on the government determine that they can hardly act as bridging institutions to proactively channel foreign knowledge into local companies in the near future.

A lot of service firms have emerged in recent years, including consulting firms, law firms, patent agents, marketing analysts and image designers. Service firms are also important bridging institutions in a technological system. However, most of these service firms are very small. The state-owned service companies often occupy monopoly positions in various service sectors. One of the reasons is that legitimization of service organizations is often based on the capability and reputation of individual professionals (Henderson & Mitchell 1997). Most of these service companies are managed by part-time professionals with low knowledge specification and therefore can hardly get their legitimacy beyond their own small circles. When professionals with high individual capability are lacking, the government endorsement becomes the central legitimization mechanism of service companies. Government background often represents easy access to the resources and channels still largely controlled by various government agencies. Although the indispensable roles of intermediary organizations in promoting technology commercialization have been acknowledged by the Shanghai government officers, they have

found it extremely difficult to cultivate highly diverse intermediary organizations. The poorly developed capabilities of individual professionals and the fact that the government is the only source of legitimacy for service companies, together formed the lock-in effects in developing intermediary organizations.

In general, from the technological system perspective, the connectivity in the Shanghai pharmaceutical system to promote knowledge creation, diffusion and exploitation is low. The transition from a manufacturing-centered system to an innovation-oriented system has proved to be difficult because of the low trust and path-dependence effects.

## PUBLIC POLICY AND OTHER INFRASTRUCTURE

The Shanghai Municipal Government is well known for its ability and proactivity in adjusting its policies with the changing environment.

### The 'Three Centers' and in-house R&D

As discussed earlier, in the centrally planned system, the basic business functions such as R&D, marketing, and manufacturing are separated into different organizations; and similarly, the R&D function are also separated into research institutes or universities within the Academy system (for fundamental research), for each industry sector (for applied research and development) and for the design of manufacturing facilities and the import of technology (the project design organizations) (Amann et al., 1979). This separation of business and R&D is one of the central problems of the Chinese innovation system.

One of the major strategies adopted by the country to solve this problem is setting up enterprise technology centers, engineering research centers and engineering technology research centers (the so-called 'three centers') that concentrate on technology commercialization. These centers are certified and partially supported by government and are operated by companies,

research institutions or universities with R&D strength. Since 1995, six technological research centers or engineering centers were set up in the Shanghai pharmaceutical industry. The overall investment of these centers was about 110 million yuan (13.2 million dollars) and updated most of the R&D facilities of the related research institutions[4]. Among these six centers, those operated by application-oriented research institutions are much more successful than those operated by academically oriented research institutions in terms of revenues and products introduced into market (Dai and Zhuge, 1997). These centers have begun to spin off technology-based firms in the last few years or evolved into business groups.

At the same time, the government is encouraging mergers and cooperation of firms and research institutions. The public companies or business groups often find that cooperation with these application-oriented research institutions is closer to the market and therefore less risky than that with the academically oriented universities. Also, application-oriented research institutions are more welcomed by the firms to merge with than the academically oriented research institutions.

**Venture Funding System**

In China, sources of capital for new ventures are limited. The first private commercial bank in mainland China since the 1950s, China Mingsheng Banking Corp., was set up in January 1996. It was not until in 2000 that private institutions were encouraged to set up commercial banks. And it is also only recently that the state-owned banks started to make loans to the locally owned private firms. Private offerings are still illegal. The government-supported investment companies were the major sources of capital. The Shanghai government started to set up venture funding companies in 1984. Most of these companies were supported by funds from the local government agencies (See Table 2). In 1998, these seven major companies managed around 0.5

billion yuan (around 60 million dollars). There are several fundamental barriers to the effective operation of these government supported venture funds. First, all of these funds are operated by former government officers, most of whom have no business experience. Second, the fundamental new venture harvest channels, like IPO, still do not exist. Third, most of these government funds are assumed to be for profit and a certain degree of profitability is used as measure of performance. To ensure this degree of profitability, the former-government-officer executives of these companies are often so risk-averse that these companies seldom invest in the early-stage technologies. Instead, they often picked mature technologies with relatively low yield. Therefore, it is natural that most of these funding companies have evolved into diversified firms and one of them even went bankrupt during the process (See Table 2).

The venture capital industry has been emerging since 1998 but is still in very early stage in China. At the end of 2000, there were 90 local venture capital companies with around 7 billion yuan (around 800 million dollars), among which only less than 1 billion yuan is used to invest in new ventures (Chongqing Morning Newspaper, Oct. 16, 2000). The foreign venture capital companies in China manage around 300 million dollars. The industry lacks experienced venture capitalists and successful cases. Without involvement of local private capital, most existing venture capital companies are based on government funds. Furthermore, the industry has to wait for some new laws to pass and some fundamental changes in the existing business laws, security laws, etc. Before these laws are in place, the exit market for the industry will not come into existence. Some researchers worry that a poorly regulated IPO market will be manipulated by speculators so that the new ventures can hardly benefit from the market (e.g., Xu et al. 2000, Li 2000).

**Business Incubator System**

A business incubator system supported by the local government has emerged in Shanghai since the early 1990s. Till now, there are 13 business incubators, among which there are two specialized incubators, three national incubators, and one international incubator. The Shanghai Municipal Government is trying to develop the Zhangjiang Incubation Base into a Medicine Valley with a hope that it can play an important dual role as a "bridging institution" between local academic research institutions and the Chinese researchers all over the world as well as the local industry. To facilitate the incubation of pharmaceutical startups, the government directly or indirectly has invested in modern new buildings and installed advanced facilities from which the startups can get easy access to the Internet. Startup companies can have office space for free, and pay for the actual cost of most office services. Startup companies can get one-stop government service like business registration, certification of high-tech firms, and patent application. The incubator has also attracted some branches of large service institutions as long-term tenants, such as bank branches. Except getting access to different facilities at very low cost, startup companies who move into or even just register in the incubator can get long tax holidays from the local government. Also, the incubator is affiliated with some venture foundations that concentrate on financing startup companies.

Major Shanghai pharmaceutical research institutions are encouraged to move into the region or construct new subsidiaries there. Right now there are already one research institute and six technology centers. These organizations are responsible for operating and maintaining the laboratory facilities and equipment that were largely supplied by the state or local municipal government. The startup companies can complete most R&D work and tests needed to get approval from the appropriate authority in these technological centers at a very low cost.

There are several major problems in the Shanghai incubation system. First, the incubators are almost all managed by people with government background. These incubator managers know well how to get access to and fully exploit the government resources since in Shanghai the local government still plays a central role in the business world. For example, the Zhangjiang Incubator managed to open two bus lines between itself and the two major universities, Fudan University and Shanghai Jiaotong University, to facilitate the students or researchers to come back and forth (personal interview, Zhangjiang Incubation Center). However, these incubator managers can do very little to help the startups in channeling business support and consultation by networking the entrepreneurial support system (Hansen et al 2000). Because there was a serious lack of small entrepreneurial firms in Shanghai before 2000, the incubators concentrated on attracting more entrepreneurial companies and don't care much about the quality of the startup companies. There are no formal recruitment, evaluation or graduation processes in the incubators at all (Li 2000).

Second, directed by an industrial economics perspective, the incubators are modeled after industrial parks. After more than ten years of practice, local government officials know how to attract multinational companies or business groups of other provinces by giving easy access to land, long tax holidays and transportation convenience and other supports. However, the differences between industrial parks and incubators have never been clearly distinguished by policy researchers and implementers. Basically, Shanghai is adopting its policies in industrial parks into its emerging incubation system. In fact some incubators are internalized as an unimportant part of the industrial parks because of their limited ability in producing gross regional products and their preferential tax treatment policy is almost the same. The incubator managers' performance is evaluated on the base of the number of tenants recruited and the

overall revenues produced by these tenants (personal interview, Shanghai Science and Technology Commission).

Third, the government officials or incubator managers find that it is too risky for them to invest directly into a startup with limited unproved competence since they have to be responsible for increasing the value of the state-owned properties they are in charge of. Without knowledge in business management, they can find no ways to bridge the gap between the local government's goal in developing high technology industries and the inevitable weakness of startups. For example, during the process of setting up a venture fund affiliated with an incubator, a government officer is not willing to sign a well negotiated investment contract unless the money is made available to the incubator as a loan. Most incubator managers choose to invest their incubation funds in profitable firms or even stock markets rather than into the entrepreneurial firms (Li 2000). Some senior bankers even concluded that it is more profitable to invest in real estate than to invest in the high-tech entrepreneurial firms (Li 1998). The problem of seed capital and startup capital for the entrepreneurial companies is still largely unresolved.

Fourth, technological competitiveness is regarded as the primary standard in evaluating the quality of entrepreneurial firms in which to invest. The Shanghai Municipal Government was among the first local governments in China to certify the high-tech projects and high-tech firms, which partially helps to improve the image and legitimacy of startup companies. Dominated by technologists, a lot of entrepreneurial companies with sound technologies make little progress in sales revenues and generally volatile in performance (Li 2000). Such factors as management capabilities, that are regarded by U.S.A. venture capital firms as at least no less important in achieving entrepreneurial success than technological capability, are superficially acknowledged but generally overlooked in local investment decisions. Most preferential government policies

are guided towards research entrepreneurs with high-tech projects. Some pharmaceutical firms with strength in marketing and sales networks found it hard to be accepted as successful (personal interview, Shanghai Science and Technology Commission).

There are many other institutional factors which may continue to negatively influence the entrepreneurship of the pharmaceutical system in Shanghai: the overwhelming buyer power of the hospital system, the difficulty of separating medical treatment and medical retailing, the high segmentation of the Chinese pharmaceutical market (Li, 1999b), the too high standard of General Manufacturing Processes (Zhang, 1999) and the outdated while transitional medical reimbursement system etc.

Chinese society happens to be one with low social capital (Fukuyama, 1995). For example, most venture capital companies in China find that they should own more than 50% share of their invested entrepreneurial companies to ensure their interests while their American counterparts seldom pursue more than 40% shares. A lot of entrepreneurial companies in the Shanghai business incubators are not willing to accept external investment because they worry about loss of control over their firms (Li, 2000). Most pharmaceutical companies internalized related business as much as possible. Middle size pharmaceutical companies are relatively few in Shanghai.

## CONCLUSIONS

This paper has concentrated on answering the question ‘why the Shanghai pharmaceutical system lost its leadership in a transitional economy’. The analysis yields several answers. First, the pharmaceutical system is lacking critical actors such as competent venture capitalists and exit markets, which makes the system incomplete in its critical functionalities. Second, the local

state-owned firms are largely locked into an overemphasis on manufacturing competence, and their ability to receive knowledge and competence and to take successful innovations to industrial scale production is very limited. Third, since various R&D institutions are historically separated according to different stages of the traditional linear model of innovation and therefore largely isolated from market, their ability to understand economic competence and reorient their R&D activities towards potential market demands is extremely limited. Fourth, because government is still the overarching bridging institution of the system, the overall connectivity among the players is too low to promote innovations.

Overall, the Shanghai pharmaceutical system is still largely running on the basic assumptions of a centrally planned system: that the actors, especially the government, have perfect information about the whole system; and that the demands of a system can be treated as given and the whole system can be hyperrationally organized and manipulated to satisfy these known demands (Carlsson 1997; Freeman 1995). The local Shanghai government itself is innovative in formulating government policies and promoting institutionalization of new actors such as incubators. However, it is so dominant in the system that it over-selects the system and fundamentally destroys the variation-creation mechanisms of the whole system. The overruling local government restricts the roles of most critical actors in the system and constitutes the single greatest obstacle for the Shanghai pharmaceutical cluster in forming balanced variety-creation and -selection mechanisms which are critical for a technological system to evolve successfully.

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Table 1. R&D expenses of the industrial sectors in Shanghai between 1990 and 1996 (in 100 million yuan)

| | *1990* | *1991* | *1992* | *1993* | *1994* | *1995* | *1996* |
|---|---|---|---|---|---|---|---|
| Independent research institutes | 6.04 | 8.42 | 9.73 | 10.31 | 9.99 | 13.27 | 15.61 |
| Large & medium industrial firms | 1.77 | 1.35 | 3.25 | 5.65 | 10.58 | 9.06 | 12.79 |
| Small industrial firms | NA | 0.25 | 0.71 | 1.17 | 0.40 | 0.60 | 0.68 |
| College & universities | 1.95 | 2.09 | 3.06 | 3.73 | 3.63 | 4.24 | 4.69 |
| Locally owned private firms | NA | NA | 0.14 | 1.45 | 1.64 | 3.17 | 4.24 |
| Others | 0.37 | 0.53 | 0.59 | 0.73 | 1.37 | 2.26 | 3.09 |
| Total | 10.13 | 12.64 | 17.48 | 23.04 | 27.61 | 32.60 | 41.10 |

Source: Lin et al, 1998. Research on forming Shanghai R&D system, in Xu et al, Research on Shanghai Innovation System (ed.), unpublished research report of Shanghai Important Technology Consultation Project.

Table 2. Venture funding institutions set up by local government agencies since 1984

| *Name of Institution* | *Year of Founding* | *Government Agency Involved* | *Investment (In Million Yuan)* | *Outcome* |
|---|---|---|---|---|
| Dongfang Company | 1984 | Shanghai Municipal Government | 10 | Bankrupt |
| Industrial Technology Development Foundation | 1986 | Shanghai Economic Commission | 20 | Business Group |
| Science & Technology Enterprise Center | 1988 | Shanghai Science & Technology Commission | 20 plus some loans | Changing from a high-tech business group to high-tech incubator |
| Gaochuang Technology Development Company | 1991 | Shanghai Education Comission | 1 | Business group |
| Technology Investment Company | 1992 | Shanghai Science & Technology Commission | 300 | Diversified Conglomerate |
| Xinxing Technology Enterprise Company | 1994 | Caohejing Development Zone Company | 13 | Incubator |
| Pudong High-tech Enterprise Development Company | 1996 | Zhangjiang Development Zone | 50 | Venture capital company |
| Zhongxin Technology Consultant Company | 1996 | Shanghai Science & Technology Commission | 10 | Consultant company |

Source: Dai et al, 1998. Research on constructing Shanghai Technological Venture Investment System, in Xu et al (ed.), Research on Shanghai Innovation System (ed.), unpublished research report of Shanghai Important Technology Consultation Project.

## Endnotes

[1] This paper is based on data collected in previous studies (Li, 1998, 1999 a, 1999b, 2000). These data are supplemented with the personal experience of the first author with various organizations in Shanghai, such as firms, government agencies, investment banks and venture capitalists, industrial associations, business incubators, industrial parks, university Office of Science and Technology, researchers etc. when he worked as a general manager of a Shanghai venture capital company. During the time of writing this paper, data were further collected via interviews through international phone calls and visits to the websites of the related organizations.

[2]The Chinese firms are often large when measured by the number of employees. But they are very small when measured by revenue. It is because a lot of institutes, such as kindergarten, middle schools or even retailers, are incorporated as part of the firms.

[3] In China, most hospitals are state-owned and the hospital system in a large or medium city often supplies more than 85% of the local medicine market. At the same time, a medicine has to pass some official evaluation procedures every year to be listed on the Catalogue of Reimbursable Pharmaceuticals (CRP). Therefore, the various governments can intervene in their local medicine market when necessary. For example, in 1997, some fundamental change of the Catalogue of National Fundamental Pharmaceuticals, on which CRP is based, sharply decreased the market shares of the imported pharmaceuticals since a lot of imported pharmaceuticals were excluded from the catalogue because of their high prices. The imported pharmaceuticals in 1997 were only 950 million dollars while those in 1996 were 1,267 million dollars.

[4] To get an impression of the magnitude of this amount of investment in Shanghai the following data may be of interest: the overall R&D expenses in Shanghai is 3.26 billion yuan (see Table 1.); the overall expenses in developing a drug named a1b IFN between 1984-1994, the first biotech product to which China has independent property rights, were about 10 million yuan (1.20 million dollars) altogether (Dai & Zhuge, 1998).