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Le Transfert de Technologies de l'Université vers l'Industrie dans le Système National d'Innovation Chinois

Technology Transfers from University to Industry in the Chinese National Innovation system

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General introduction

“The universities are not just a creator of knowledge, a trainer of young minds and a transmitter of culture, but also a major agent for economic growth: the knowledge factory, as it were at the center of knowledge economy.” (Cf. Sharma *et al*., 2006: p.110).

This viewpoint has been widely accepted by scholars and policymakers (Lundvall, 1992, 2007; Nelson, 1993, 2000; OECD, 2002; Mowery and Sampat, 2005; Edquist, 2005; Xue, 2006). Some scholars and an international organization explore the viewpoint and point out that the commercialization of university technology is an effective measure for universities to promote social economic development (Nelson, 2001; OECD, 2002; O’shea *et al*., 2005; Sampat, 2006; Meyer, 2006) and national competitiveness (Edquist, 2005).

In practice, the governments in many countries have taken measures to motivate universities in releasing their economic energy, such as decreasing public research funding allocation, granting universities to hold intellectual property rights arising from publicly sponsored research, establishing university incubators and so on. Consequently, the widespread set-up of university technology transfer offices, significant expansion in university patenting activities, a marked rise in the number of university spin-offs, the emergence of science parks around universities have placed universities in the process of commercializing academic research achievements.

Chinese universities are nonexclusively influenced by the global trend of commercial knowledge exploitation. The rise of university incubators and university spin-offs in the 1980s and university technology transfer offices (TTOs) in the 1990s display the fact that Chinese universities have actively got involved in commercial activities since 1980s. China’s further economic development requires universities to accelerate the capitalization of knowledge. This thesis analyzes empirically and theoretically how universities transfer technology to industries in the Chinese national innovation system (NIS).

The concept of NIS was officially adopted by China in 1998. Chinese policy makers attempt to understand and implement the concept of NIS in order to build national innovation and technological competitiveness. Lack of innovative entrepreneurs and weak absorptive capability of domestic firms are the typical characteristics of the Chinese innovation system. Universities are expected to overcome these weaknesses and promote the innovation system through technology transfers.

University technology transfers can be divided into three mechanisms: open science, semi-open science and market-based science[1]. The mechanism of market-based science has captured the attention of business leaders, policy-makers, and academics as they look at the examples of highly successful economic regions like the Silicon Valley and the Route 128 area around Boston and Cambridge (Florida and Cohen, 1999; Shane, 2004). They have concluded that the university has played a fundamental role in developing the technological innovations and in driving regional economic growth. Numerous studies concentrate on market-based science transfer mechanisms (Henderson *et al*., 1998; Schmoch, 1999; Liu and Jiang, 2001; Gregorio and Shane, 2003; Xue, 2004; Sharma *et al*., 2006), namely patent licenses and university spin-offs. In China, university transfers technology through open science (i.e. training and education) in order to compensate the shortage of R&D personnel in domestic firms. The catch-up history of Japan and South Korea has demonstrated that training skilled scientists and engineers is one of the critical elements to improve the national innovation system. Our thesis analyzes university training and education and focuses on the university technology transfer mechanisms of market-based science.

In terms of market-based science transfer mechanisms, Chinese universities focus on the creation of spin-offs whereas its western counterparts emphasize on licensing. This

[1] According to Cohen *et al*. (2002), open science means publications & reports, informal interaction, meeting & conferences and employment of graduates; semi-open science means consulting, contract research, cooperative R&D projects and personnel exchanges; and market-based science means patents and licenses. In our opinion, market-based science is equivalent to commercial science.

difference results from a country-specific context and the characteristics of university technology. Western education focuses on creative and multi-disciplinary background talent training. The skilled human capital strengthens the absorptive and innovative capabilities of western firms. Firms are accustomed to getting know-how through licensing agreements with university technology transfer offices (Jensen and Thursby, 2001; Mowery and Sampat, 2005). The licensing agreements facilitate academic technology transfer by codifying technology and reduce the potential prosecutions on intellectual property resulting from transferred technology. Inventors, faculty and universities share the licensing revenues and gain a certain degree of prestige through licensing activities. Licensing transfer is a traditional and effective way to promote university technology transfer in western countries (Nelson, 2001; Chapple *et al.*, 2005).

In China, examination-oriented education hampers the training of innovative, international visions and problem-solving graduates. The shortage of human innovators creates an obstacle for firms to absorb licensed technology. This is because licensing transfer is usually bounded to sponsored researches. Firms need R&D investment to develop their embryonic technology. The insufficient absorptive capabilities make firms reluctant to sign licensing agreements with universities. Although the establishment of university technology transfer offices (TTOs or equivalent) and the expansion of university patenting activities promote licensing technology transfer, it is not the most important technology transfer mechanism in China. When universities cannot find the appropriate firm to sell their technology, they create spin-offs to commercialize research outputs with potential market value. University incubators are instituted to support the growth of university spin-offs. They seek to link talent, technology, capital, and know-how to leverage entrepreneurial talent, accelerate the development of new ventures, and speed the commercialization of technology (Smilor and Gill, 1986).

Licensing, spin-offs, university technology transfer offices or university incubators are all used as instruments to overcome market failures in terms of externalities, uncertainty and limited rationality. These market failures are associated with the characteristics of university technology, which distinguish its marketability from other ordinary commodities.

Firstly, university technology is considered as a public good. Universities are publicly financed organizations and their output is characterized as a non-rival and non-excludable public good. The public good creates free-rider problems (externalities) which destroy the incentive of knowledge generators (Arrow, 1963; Dijk, 1994; Geroski, 1995). Knowledge will be underproduced and will receive insufficient investments (Dosi *et al*., 2006).

Secondly, university technology embodies non-codified and tacit know-how which is difficult to transfer. Tacit knowledge, especially technical knowledge, is implicit, and is largely the outcome of individual judgment, skill and practice (Polanyi, 1967). Unlike other tangible commodities, know-how does not exist independently and is usually embodied in human being.

Thirdly, university technology associated with uncertainty is difficult to estimate (Teece, 1980; Geroski, 1995; Cf. Bercovitz and Feldmann, 2006). Uncertainty may arise either from the changing environment (Arrow, 1963), marketable technology itself or from moral hazard of traders. This is because converting university technology into new products or services takes a certain amount of time and the market reaction to such new products and services is difficult to predict. For example, before such new products and services are presented to the market place, consumers may have changed their tastes or other rivals have already marketed similar products or services. Formal technology-transfer agreements are negotiated prior to the research being completed at a time when the commercial value of the end results is not known (Bercovitz and Feldmann, 2006). The market failure in terms of uncertainty may cause the contractual value to deviate from the actual value.

Additionally, the emergence of moral hazard causes asymmetric information distributed to buyers and sellers, which may prevent traders from estimating the technology value correctly. Indeed, collecting full and relevant information is costly in terms of time and money so that buyers and sellers are not sure to get enough information to make a right decision, especially under an uncertain and complex setting. The limited rationality of traders increases the difficulty of assessing the consequences of decision-making and specifying contractual terms (Coase, 1937; Malmgren, 1961; Simon, 1961; Arrow, 1973; Williamson, 1975; Ouchi, 1980; Arora *et al*., 2001).

Given the above market failures in terms of externalities, uncertainty and limited rationality hinder the marketability of university technology. Policy makers and university administrators conduct institutional and organizational innovations to surmount such market failures.

Because of the externalities of university technology, policy makers introduce a patent system to balance the wedge between social and private return (Mansfield, 1969; Dijk, 1994). The US Bayh-Dole Act of 1980 is one example of such a patent system. It initially authorizes universities to hold intellectual property rights stemming from publicly financed research and to enjoy economic incomes arising from licensing activities. Universities then have the exclusive but temporary right to create new technology. The exclusivity of a patent provides universities with a legal monopoly power, resulting in pecuniary income, necessary to cover the R&D costs. Universities thus are motivated to generate more new technology. The social benefits of inventors' information disclosure are that it prevents them from duplicating R&D and makes it possible for other firms to build further on it (Dijk, 1994). Witnessing a significant increase in university patenting and licensing activities led by the Act, many OECD and non-OECD countries have emulated the US Act since the late 1990s (Nelson, 2001). China followed the global trend and implemented its own version of the "Bayh-Dole Act" in 2002.

Concerning uncertainty and limited rationality linked to the price mechanism and decision making, the only way to maximize utility and profits of traders may be to collect sufficient information. University inventors may know more about the technological value of inventions but less about the commercial value than buyers. Buyers may have more experience in estimating the commercial value of inventions but have difficulties in estimating the technological value, especially when inventors are reluctant to disclose sufficient information about the invention. Thus, it needs a creditable organization which can facilitate the information exchange between universities and buyers so as to accelerate the technology transfers from universities to industries. University technology transfer offices are used as an instrument to overcome the mentioned market failures in terms of uncertainty and limited rationality.

The creation of university technology transfer offices (TTOs) is a direct consequence of the implementation of the "Bayh-Dole Act". TTOs mainly deal with licensing technologies. Although universities hold the ownership of science and research findings, the private return to inventors can be achieved by sharing the profits arising from contractual technology transfer activities. Since inventors and TTO staff belong to the same university, they know each other and their behaviors are constrained and monitored by organizational rules and regulations. A common university background facilitates the transparency of information disclosure between faculty inventors and TTO officers. Universities usually give the public a positive creditable image and TTOs subordinated to universities can gain trust from potential buyers. The information exchange based on trust decreases the possibility of asymmetric information, moral hazard, opportunistic behaviors between inventors, TTO officers and clients. Furthermore, TTO officers with commercial experiences are helpful to defend the profit of inventors and universities when negotiating with clients. TTOs often have a broad communication network with other institutions, such as technology markets, technology evaluation agencies, financial institutions, firms and so on. The wide network of TTOs helps collect more information and reduce the transaction cost for traders.

However, because of the tacit property, a large part of the tacit knowledge and technology cannot be transmitted directly by licensing contractual agreements. The successful transfer of the tacit component of the new knowledge generally requires close and ongoing interactions between the inventor and the purchaser. This is particularly true if the recipient has limited direct experience with the technology (Cf. Bercovitz and Feldmann, 2006). Other factors, like the capability of the recipient, the reward structure facing individuals, or the professional skills of technology licensing officers, also influence the success of university technology transfer (Geroski, 1995). Successful licensing transfer can bring pecuniary income but not for all TTOs. In fact, the majority of the licensed technology cannot create enough income to cover the expenditures of technology licensing offices (Mowery *et al*, 1998; Mowery *et al*., 2002; Mowery and Sampat, 2005; Bercovitz and Feldman, 2006; Geuna and Nesta, 2006). Most contractual licensing agreements concentrate on biotechnology and software technology generated by leading universities.

In underdeveloped technology markets, problems of moral hazard, asymmetric information and opportunistic behavior are not always successfully avoided (Arora et al., 2001). The rising cost to assess the value of technology and commercial conflicts between TTOs and clients delay the licensing transactions.

The weakness of licensing transactions pushes universities to license or transfer intellectual property rights to new firms created by university professors and students. The direct involvement of inventors facilitates tacit knowledge transfer, especially in the early stage of start-ups (Becker and Gassman, 2006; vonZedtwitz and Grimaldi, 2006). University incubators are created to nurture these university spin-offs. They can overcome the market failures linked to small start-ups, such as access to capital, knowledge, technologies, staff recruiting, marketing, advertising, public relations, and administrative and legal affairs (vonZedtwitz and Grimaldi, 2006).

A diverse set of services is available in university incubators: space, infrastructure, facilities, as well as access to technical and managerial expertise, assistance in business plan development. The ultimate objective of university incubators is to train entrepreneurship, reduce the costs of doing business, increase their chances of survival and generate wealth and jobs. Many countries, ranging from North America, continental Europe and Asia, have seen significant growth and interest in university incubators. University incubators have been considered as one of the policy tools to promote the commercialization of university S&T findings.

China follows the global trend in terms of university technology transfer mechanisms. It has set up the Chinese version "Bayh-Dole" Act, university TTOs and university incubators to promote university technology transfer. Our thesis focuses on these three institutional innovations to analyze how universities transfer technology to industries in the Chinese NIS.

Chapter 1 discusses the role of universities in the Chinese national innovation system (NIS). It outlines the NIS approach, analyzes the building-up of the Chinese NIS along two dimensions (i.e. technology imports and endogenous innovation), and then discusses the role orientation of universities in the NIS. Adopting previously theoretical and practical research on the possibilities for technologically lagging countries to develop a proper national innovation system, this chapter aims to explain how the Chinese NIS evolves and how university plays a role in promoting the innovation system.

Chapter 2 focuses on the Chinese "Bayh-Dole Act" and national technology transfer centers (NTTCs, equivalent to TTOs) in six Chinese universities. The Act and NTTCs are used as political tools to encourage endogenous innovation. This chapter assesses whether the Act has a positive impact on the growth of university patenting and licensing and whether the establishment of NTTCs is an efficient political tool to promote the commercialization of academic research findings.

Chapter 3 discusses the development of university incubators. The chapter firstly focuses on Chinese university incubators, and then broadens to make a cross-nation comparison of university incubators in China and in France. The purpose of this chapter is to show how knowledge is transferred from universities to new start-ups and to provide university incubator managers and academic entrepreneurs with some practical and theoretical implications. The Chongqing University incubator, the Caohejing Technology Business Incubator (non-university incubator) and the SEMIA incubator (Alsace university incubator) are used as case studies in this chapter.

The final part of this thesis summarizes the key research findings found in the three chapters and presents our future research projects.

Chapter 1

The role of universities in the Chinese national innovation system (NIS)

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University activities, such as knowledge generation and dissemination and innovation, are helpful to strengthen a nation's competitiveness. The recognition of universities as important institutional actors in a national innovation system was identified by scholars, policy makers and businesses in industrialized countries in the 1970s (Mowery and Sampat, 2005). Governments in the industrialized world are active practitioners of the concept and launch numerous initiatives to stimulate university innovation activities linked to industrial needs.

The same concept has been later spread to many developing countries, such as Russia, Brazil, South Africa, China and India (Lundvall, 2007). Policy makers in these developing countries try to understand and implement the concept of NIS for building national innovation competitiveness so as to catch up with developed countries. In the literature on economic growth, many economists emphasize the role of foreign direct investment, institutions and market liberalization, science and technology, human capital, and ability to create or adopt new technologies in catching-up economies (Romer, 1986, 1987; Lucas, 1988; Chow, 2005). China seems to be influenced by this growth theory. Since the 1980s, the Chinese government has begun to restructure the socialist system of innovation. A series of measures have been carried out to link science with industry and market and to encourage both technology import substitutes and endogenous innovation. As domestic firms have weak absorptive and innovative capabilities, the role of universities in the Chinese NIS is highly stressed by policy markers.

This chapter centers on the role of universities in the Chinese NIS. It is composed of three sections. Section 1.1 first outlines different understandings of NIS, then reviews research literature, and finally puts forward our research question after introducing the Chinese NIS and Chinese university system, namely the role of university in the Chinese NIS. This section tries to demonstrate that the understanding of NIS and of the role of universities in NIS help policy makers in catching-up economies design and implement appropriate polices for promoting overall competitiveness.

Section 1.2 analyzes how the Chinese NIS is built to help China catch up with the industrial world. The building of Chinese NIS is mapped along two dimensions. On the one hand, a wide range of institutional reforms have been carried out for technology importation. On the other hand, the infrastructure of knowledge generation, commercialization and diffusion has been set up for endogenous innovation. The outcome performance of these two dimensions is discussed in this section.

Section 1.3 emphasizes the role of universities in the Chinese NIS. It shows the current absorptive and innovative capabilities of Chinese firms, then discusses the linkage between university's missions and firm's competitiveness and finally analyzes how university can improve firm's competitiveness.

Section 1.1 Introduction

The research on national innovation system (NIS) ranges from a single country to a group of countries. In the 1990s, research focused on advanced countries and newly industrialized countries either individually or collectively. Nowadays the research focus of NIS is shifting to some catching-up countries, like China, Brazil and India. This section aims to provide catching-up economies with theoretical and empirical evidence that understanding NIS and the importance of universities in NIS is the pre-conditions for catching-up. Section 1.1.1 introduces various definitions of NIS and some important notions embedded in the concept of NIS. Section 1.1.2 reviews research literature on NIS and raises our research issue.

1.1.1 Understanding the concept of NIS

According to Lundvall (1992), Friedrich List (1841/1959), a German economist, was the first one who attempted systematically and theoretically to focus on NIS but only sketched industry-government linkage in the system. Christopher Freeman (1987), a British economist, was the first one who used explicitly the concept of NIS. He viewed NIS as a network of institutions which engaged in technological activities. Research followers broaden List and Freeman's concepts of NIS (Lundvall, 1992, 2007; Nelson and Rosenberg, 1993; Edquist and Lundvall, 1993; Noisi *et al*., 1993; Patel and Pavitt, 1994; Metcalfe, 1995; OECD, 1999). Next section 1.1.1.1 shows the exploration of the concept of NIS.

1.1.1.1 Various definitions of NIS

A literal meaning of NIS is composed of three components: innovation (technology advancement), system (connection of related parts) and geographic boundary (within a country/national). Indeed, many existing definitions of NIS encompass all or almost all of three components. Institutional interactions and technological development within a country are positioned at the core of the conceptualization of NIS (see Table 1.1).

Table 1.1: Different definitions of National Innovation System

Authors	Definitions of NIS
Freeman (1987/88)	The network of institutions in the public- and private- sectors whose activities and international initiate, import, modify and diffuse new technologies.
Lundvall (1992)	The elements and relationships which interact in the production, diffusion and use of new and economically useful knowledge… and are either located within or rooted inside the borders of a nation state.
Nelson and Rosenberg (1993)	The set of institutions whose interactions determine the innovative performance of national firms.
Edquist and Lundvall (1993)	Constituted by the institutions and economic structures affecting the rate and direction of technological change in the society.
Noisi et al. (1993)	A system of interacting private and public firms (either large or small), universities, and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, in as much as the goal of the interaction is the development, protection, financing or regulation of new science and technology.
Patel and Pavitt (1994)	The national institutions, their incentive structures and their competences, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country.
Metcalfe (1995)	That set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provide the framework within

	which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies.
OECD (1999)	The market and non-market institutions in a country that influence the direction and speed of innovation and technology diffusion.

Sources: OECD (1999) and Niosi (2002, p.292).

Lundvall concludes the above definitions as follow (2007: p.14):

"Different authors may mean different things when referring to a national system of innovation. Some major differences have to do with the focus of the analysis and some with how broad the definition is in relation to institutions and market."

Do these definitions of NIS make sense to developing countries? The question is addressed by Juma *et al.* (2001, p.633) as "technology policy should be demystified. It does not need to be a business just for developed countries nor seen as a kind of unnecessary and wasteful luxury for poor countries". For developed countries, the research on NIS started in the late of 1980s and the study focus is not the building of NIS but correcting the mismatch of interactions among national institutions. The corrected NIS will help them maintain or improve an already established level of competitiveness and growth (Feinson, 2003), whereas developing countries, like Brazil, China, India, have recently conducted research on NIS and the understanding of NIS is very important for them from the starting point. During the course of building NIS, these later comers can combine advanced countries' experiences with their specific histories, cultures and institutional contexts to design and implement a nation-specific innovation system.

We agree that national institutional and technological changes are key determinants in NIS, which is emphasized in the above definitions of NIS. However, the above definitions do not clearly explain what institutions mean (are they organizations, like universities, research institutes, firms and governments, or regulations, policies, laws and routines?) and what is the source of diffused technology (imported or endogenous). As our research focus is related to institutional and organizational changes and source of technology in a transitional country, we define institutions as policies, laws, finance and infrastructure of knowledge commercialization and diffusion. Technology in our analytical context means imported technology and domestic technology. Thus, we outline the concept of NIS as followd:

It is a system of related organizations (government, university, industry, research institutes and intermediary institutions[2]) which interact with each other to acquire/absorb imported technology and to encourage/facilitate endogenous innovation in a country. These interactions are influenced by the country's organizational and institutional changes, i.e. changes in policies, laws, finance, R&D infrastructure as well as supporting infrastructure of knowledge generation, commercialization and diffusion.

We center our analysis on institutional and organizational changes in the Chinese NIS and discuss the effect of these changes on the acquirement of imported technology and on endogenous innovation.

1.1.1.2 Some important notions embedded in the concept of NIS

In order to get a good understanding of the concept of NIS, we analyze the components of NIS one by one as follows:

1) **<u>The notion of innovation</u>**

[2] Intermediary institutions refer to those organizations which serve to strengthen science-industry linkage and accelerate innovation process.

"Innovation" is perhaps the most frequently cited word in knowledge-based economy[3]. Innovation has been linked to rising productivity, to emerging new high-tech industries, to increasing economic growth and to strong competitiveness in export market and trade (Utterback, 1979). Many arguments of innovation focus on whether innovation is equal to invention and whether it is endogenous.

Innovation v.s. invention

Some people view innovation as a creative act synonomous with invention (Utterback, 1979). Invention is an unexploited knowledge with potential economic value. In other words, if innovation is equal to invention, innovation means an idea usually expressed in patents which have not been used, produced, nor sold yet. This perspective focuses on the originality and newness of innovation. But the widely accepted concept of innovation is distinguished from inventions. Inventions only become innovations when they are sold or used to make marketable products (McKelvey, 1997). Many researchers regard innovation as new combinations (Schumpeter, 1939; McKelvey, 1991, 1997; Lundvall, 1992), namely process innovation, product innovation, organizational innovation and market innovation. Shumpeter defines innovation in a much broader way:

We will simply define innovation as the setting up of a new production function. This covers the case of a new commodity as well as those of a new form of organization such as a merger, of the opening up of new markets, and so on… Recalling that production in the economic sense is nothing but combing productive services, we may express the same thing by saying that innovation combines factors in a new way, or that it consists in carrying out ***New Combinations*** *(Shumpeter, 1939: p.87-8).*

[3] Knowledge-based economies refer to economies which are directly based on the production, distribution and use of knowledge and information (OECD, 1996).

McKelvey (1991) follows Schumpeter's concept of innovation, but strongly emphasizes the process of technical changes[4], non-technical novelties of institutions and the process of creating, diffusing or using these various changes in the context of the production system and of social and economic institutions.

Nelson and Rosenberg (1993) conceive innovation in a narrower way. They first restrict innovation to technical innovation, then broaden innovation to 'the processes which firms master and get into practice product designs and manufacturing processes that are new to them, whether or not they are new to the universe, or even to the nation' (Nelson and Rosenberg, 1993: p.4-5).

Whether broad or narrow, the concept of innovation illustrates the fact that innovation is linked to technical novelty[5] and things which are sold to market. The use of the above alternative conceptions of innovation depends on various purposes in the study of innovation. The conceptual tools used should, for instance, be influenced by whether we want to study only technological process innovation or include product innovation and/or organizational innovation (Edquist, 1997).

In our research, we center innovation on institutional and technological changes at a national level. These changes accelerate the process of knowledge generation, capitalization and dissimilation. China's long-term planned economy separated science from industry and market, which destroyed its innovation capability. China needs systematically institutional changes to facilitate interactions between knowledge generators, knowledge exploiters, and knowledge diffusers on the one hand, it also needs technological changes to catch up on the

[4] Dividing the process of technological change into three stages – invention, innovation and diffusion – illuminates the difference between making an initial idea a technical reality (invention) and commercializing it (innovation) and spreading that technology to potential users or final consumers (diffusion). However, technological development is a process without clear lines between the stages because both producer and user continue to improve the product (Rosenberg, 1982, ch.6).
[5] Technical novelty refers to a combination of knowledge, techniques (ways of doing things), and technologies (things) (Mckelvey, 1997: p.201).

other hand. In the Chinese-specific context, technological changes depend not only on domestic R&D activities but also on imported technology embedded in FDI.

Exogenous v.s. endogenous

In pre-industrial societies, innovations are seemed to occur as rare and exogenous events. They come from the outside and temporarily disturb the general equilibrium. After a period of adjustment, a new state of equilibrium is set up (Lundvall, 1992). Given innovations are identified as exogenous events, nations may hold either an active, passive or neutral attitude to adapt to the effect rooted in innovation. Some nations may continue to be competitive or even stronger if they adjust their behaviors promptly and actively in response to innovations, some may lag behind if they are passive to meet the challenges of innovations when innovations emerge, others may stay at the same place because they partially follow the tendency of innovations. In short, none of these nations themselves can control the direction and speed of innovations because innovation is an exogenous phenomenon. The choice of nations is only to adapt to innovations.

However, the reality shows that policy makers use innovation as a political tool to keep or build national competitiveness and they actively shape the process of innovation. Moreover, firms themselves in the modern economy take deliberate, concerted actions following a strategy for competition, survival and growth. The government, firms, research institutes and universities and other organizations, all can be innovators and decide which types and what range of innovative activities they engage in, and hence they directly influence the types of technical or non-technical novelty they are likely to generate. Thus, innovation is endogenous rather than exogenous.

The understanding of the endogenous character of innovation is important for catching-up economies. It provides them with theoretical support that a nation's innovation capability can be built through national actions on purpose. But these actions should put firms into the central consideration. Because firms are the core to conduct and manage innovation activities (Utterback, 1979; McKelvey, 1997) and active learning and deliberate R&D investments of firms manage to influence the process of innovation (Lundvall, 1992).

2) The notion of system

The meaning of a "system" seems to be related to a specific boundary and never refers to one element. According to Lundvall (1992), a system is composed of numerous elements and of the relations between these elements. Later, Lundvall (2007) explores the concept of system by identifying the complex relations between production structure (hardware), institutions (software) and knowledge. Nelson and Rosenberg (1993) stress the institutional actors and the effect of these actors on innovative performance in the "system" concept. But these scholars (Lundvall, Nelson and Rosenberg) do not identify the boundary and the function of a system. Ingelstam (2002: p.19) complements their definitions and describes the system concept with more sense:

a) A system consists of two kinds of constitutions: There are, first, some kinds of components and second, relations about them. The components and relations should form a coherent whole (which has properties different from the properties of the constituents).

b) The system has a function, i.e. it is performing or achieving something.

c) It must be possible to discriminate between the system and the rest of the world; i.e. it must be possible to identify the boundaries of the system. If we, for example, want to make empirical studies of a specific system, we must, of course, know their extent[6].

[6] Only in exceptional cases is the system closed in the sense that it has nothing to do with the rest of the world (or because it encompasses the whole word). Like the system of innovation approach, the "general systems theory" might be considered to be an approach rather than a theory (Edquist, 2005: p.204).

Actually, the identification of the boundary, components and function of a system depends on our research issues. Supposed that a research study is centered on innovation, we should specify the boundary of the system as the innovation system. The components of the system are most probably identified as institutions[7] and organizations. And the function of the system should be orientated towards building or enhancing the innovation capability.

Moreover, when analyzing the system of innovation, we should notice its dynamic and evolutionary perspectives. Here we use the word 'dynamic' because the system is in movement rather than in stagnancy. Some components of the system may disappear and be replaced by new ones, some may stay at the original stage, others may be changed to adapt to new settings. A new combination of these components leads to new interactions between them. Supposing a new system is about to replace an existing one, the conflicts between new components and old ones may cause uncertainty of the system. Before a new system functions smoothly, the substitution process of components might be a painful experience.

As for the word 'evolutionary', it originates from Charles Darwin (1809-1882)'s theory on natural selection of the origin of species. Economists adopt the evolutionary theory in biology to explain social, economic and technical changes. According to Nelson (1987), the concept of evolution encompasses the principles of changes, specifically generation of novelty, selection among diversity, as well as retention and transmission of information. He shows interest in technical changes. For him, novelties mean innovations and selection among diversity depends on market. Information is maintained and transmitted by firms' routines. Considering the impact of firms' behavior on technical changes distinguishes Nelson from some pure evolutionary economists, like Lundvall (1992, 2007) and McKelvey (1997), who

[7] Institutions: North (1990) conceptualizes institutions as the rules of the game in society. The game rules include two types: formal ones (constitutional, property-rights rules, and contracts) and informal ones (norms and customs). Edquist and Johnson (1997) define institutions as sets of common habits, norms, routines, established practices, rules, or laws that regulate the relations and interactions between individuals, groups, and organizations. Aoki (2000) views institutions as a salient, common component of the player's subjective game models. The process of institutional change is the coordination process between players which leads to the shift of equilibrium one after another.

employ merely the evolutionary theory to explain how technical changes take place in systems of innovation. Nelson combines institutional theory with evolutionary theory to analyze the systems of innovation.

Freeman (1987) and Porter (1990) seem to be pure institutional economists because they emphasize how social behaviors influence the identification of the techno-economic paradigm and the competitiveness of a national industry, such as institutional structures, government policies and firm's organizations. These economists' propensity to institutional theory[8] or evolutionary theory or mixed theory can be found in the previous definitions about national innovation system (p.22-23).

3) <u>The notion of 'national'</u>

The rest in the NIS concept is the notion of 'national'. The geographical dimension for analyzing the system of innovation (SI) can be diversified at the sectoral, regional, national as well as international level. How to specify the geographical dimension of the system of innovation relies on the research purpose (Edquist, 1997), in spite of the recent mainstream study on 'national'. The general idea of research aims at understanding the systems of innovations at different levels. Carlsson *et al*. (1992) talk about 'sectoral' systems of innovation and they use specific technology fields to determine sectors. Nelson and Rosenberg (1993) argue for a sectoral approach, then doubt whether it is useful to examine the geographical dimension of SI when considering the activities of multinational companies exploring abroad. They write:

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[8] Institutional theory: It focuses on how rules, norms, and routines, become established as authoritative guidelines for social behavior. It inquires into how these elements are created, diffused, adopted, and adapted over space and time; and how they fall into decline and disuse (Scott, 2004).

On the one hand, the concept may be too broad. The system of institutions supporting technical innovation in one field, say pharmaceuticals, may have very little overlap with the system of institutions supporting innovations in another field, say aircraft. On the other hand, in many fields of technology, including both pharmaceuticals and aircraft, a number of the institutions are or act transnational. Indeed, for many of the participants in this study, one of the key interests was in exploring whether, and if so in what ways, the concept of a "national" system made any sense today. National governments act as if it did. However, that presumption, and the reality, may not be aligned.

In fact, research on SI goes beyond the sectoral boundary. Saxenian (1994) takes Silicon Valley in California and Route 128 in Massachusetts as examples to analyze 'regional' system of innovation. Sigurdson (2004) studies three major economic regions existing in China – Pearl River Delta, Yangtze River Delta and Bo Hai Rim and analyzes how the regional innovation systems in these areas achieve success. Either 'sectoral' or 'regional' research seems to be constrained in a sovereign nation. Following the expansion of the European Union, Soete and Caracostas (1997) show their research enthusiasm on a supranational/international system of innovation, namely a European Union's SI. They demonstrate:

The core of a system of innovation at the European level is made of those organizations and institutions regulating the creation, distribution and use of knowledge and know-how in cooperation across member states' boundaries; that is, organizations and institutions dedicated to research, innovation, and education and training.

Compared with a SI within one single sovereign state, the European SI requires more coordination among member countries. The process of building cross-border institutions takes a long time on the basis of negotiating and bargaining and each country is reluctant to give up sovereignty if its national SI conflicts with the supranational SI. Considering that generalized

European institutions have been established, it is difficult to evaluate the performance of these institutions because of existing divergences in the social, economic and political context in the Union. But it is meaningful to carry out research on supranational SI when various countries integrate into each other culturally, economically and politically, as the European Union does.

Another viewpoint for specifying the SI 'international' results from the exploration activities of multinational companies. They establish plants abroad and conduct R&D activities in the host countries. Their behaviors are embedded in the host countries of national innovation systems. Hence, the boundary of SI is not constrained by the 'national' but 'international' concept.

Although the concept of 'national' is controversial, the widely recognized focus is laid on 'national' (Mckelvey, 1991; Lundvall, 1992, 2007; OECD, 1997, 1999). Mckelvey (1991) insists that nations constitute a valid analytical category because many internationalization activities are monitored and supervised by the regulations, rules and governmental policies of host nations. The integration of foreign firms into local markets should respect local cultures and customs. Lundvall (1992, 2007) does not deny the process of regionalization and globalization challenging sovereignty to some degree but he stresses that national innovation systems still play a key role in supporting and directing processes of innovation and learning, because the same national environment shares common cultural, ethnical and linguistic characteristics and facilitates the flow of knowledge and technology among various players involved in the innovation system. It is very interesting to find that OECD also prefers studying SI at the national level although it is an international organization. The first phase of OECD research projects on SI focuses on country-specific studies (2002).

To sum up, the specification of the boundary of SI depends on what we want to study. For example, if we are interested in innovative clusters, sectoral and regional SI may be the appropriate approach; if we stress national competitiveness in terms of innovation, NIS seems to be a good analytical tool; if we study cross-nation learning and innovation, it is appropriate to put the international or supranational SI on the researchers' agenda. The boundary of SI at different level is not absolutely separated from each other. In our opinion, the sectoral or regional SI is a sub-system of NIS whilst international or supranational SI is an extension of NIS.

In our research, we consider innovation as an endogenous process which includes knowledge generation, exploitation and diffusion stages. Policy makers can design or restructure institutions to influence the process of innovation, and firms can conduct and manage innovation activities by themselves. Concerning the determinants of SI, we identify institutions as the key components of SI because our research issue emphasizes the effect of institutional changes on China's innovation capability building. As institutional changes spread all over the country and are nationally influential, we specify the boundary of SI as 'national' instead of 'sectoral', 'regional', 'international' and 'supranational'. Of course, we do not forget to put foreign companies into the analysis of Chinese NIS due to their important role in Chinese technological progress.

1.1.2 Research literature and research focus

From the initially explication of the concept of NIS raised by Freeman (1987) to the present time, research on NIS has been systematically and theoretically conducted in both developed countries and developing countries. This section first reviews existing research literature, and then puts forward our research focus: the role of universities in the Chinese NIS. The Chinese NIS and the Chinese university system are analyzed in the research focus.

1.1.2.1 Research literature on NIS

Our overview of research literature on NIS emphasizes the policy implications from previous research findings for developing countries. These research results provide us an analytical tool to discuss the Chinese NIS and the importance of universities in the NIS.

Freeman (1988) argues that every country can integrate into the technological revolution if the country uses the new techno-economic paradigm[9] in its own areas of comparative advantage and specialization. His idea is supported by the Nordic case studies in the Electronics Industry done by Dalum *et al.* (1988). The four Nordic countries (Norway, Finland, Sweden and Denmark) keep their competitive advantage in specialized multidomestic industries, such as telecommunication, electromedical equipment and other electronic instruments where economies of scale are less important. Concerning the underdeveloped countries, he considers that these countries have the possibility to jump out of the vicious circle of technological and economic 'dependency' precisely at times of paradigm change. The exploitation of such a 'window of opportunity' however heavily depends on supporting infrastructure like science and technology policies and on the capacity for institutional change at both macro and micro level.

Perez (1988) supports the importance of identifying the new techno-economic paradigm to catching-up but highlights the endogenous technological development. It takes a long time for the new paradigm to crystallize and diffuse thoroughly in the whole productive system. If developing countries can identify the paradigm and learn the new concepts as everybody else does, and implement a set of policy instruments in response to the paradigm before the window of opportunity closes, catching-up can be realized in these lagging

[9] The expression of 'techno-economic paradigm' implies a process of economic selection from the range of the technically feasible combinations of innovations ; and indeed it takes a relatively long time (a decade or more) for a new paradigm to crystallize and still longer for it to diffuse right through the system. This diffusion involves a complex interplay between technological, economic and political forces. The impulse to the development of a new techno-economic paradigm arises from the perceived constraints on the further development of productivity, profitability and markets within the hitherto existing dominant mode (Freeman, 1988, p.74).

countries, which are either early imitators or originators of new products or process. But Perez does not explain how developing countries can develop endogenous technological capability.

Lundvall (1992) centers on the analysis of components of NIS and points out that institutional learning, user-producer relationships, industrial networks and public policies impact on a nation's competitiveness. However, his research boundary in 1992 is limited in developed countries rather than developing ones.

Nelson (1993) increases the number of sampled countries and studies seventeen countries – from large market-oriented industrialized ones to several smaller high income ones, including a number of newly industrialized states as well, to analyze the national systems of technical innovation of these countries. These studies highlight institutions and mechanisms which support technical innovation, showing similarities, differences, and their sources across nations. The research on the NIS of newly industrialized economies provides empirical evidence to developing nations that technology followers can become competitive players in fields that used to be the preserve of only a few high-income countries if a nation builds the technological capabilities of domestic firms (Neslon and Rosenberg, 1993: p.3).

Radosevic (1997) focueses his research interest on the system of innovation in transitional countries, namely Eastern Europe. He describes the socialist system of innovation: it was characterized by low innovative capabilities, lacked dynamic efficiency and interinstitutional learning, the separation of technology and production as well as by their closeness. The way to restructure the system of innovation depends on the process of enterprise formation, their relation to the innovation infrastructure (universities, other public research institutions) and government policies (openness, regulations). The research output of Radosevic provides a theoretical remedy to transitonal countries including China. But for adopting his proposition, it is necessary to take specific-location, institution, social culture into consideration.

Kim and Nelson (2000) analyze in detail how firms in newly industrialized economies acquire technological capabilities and how public policies shape the process of technological progress. Their study indicates that if technologically backward and poor countries implement proper public policies to support innovation activities and domestic firms creatively learn from advanced innovators, it is possible for the later comers to create the economic miracle as newly industrialized countries did in 1980s.

Fagerberg and Godinho (2005) discuss the role of inward foreign direct investments (FDI) to some successful catching-up economies, like Hong Kong and Singapore, and stress how Asian catch-up gets an access to foreign technology through 'original equipment manufacturing' (OEM)[10] . They recognize the importance of firms in the catching-up process and identify four institutional instruments which need to be improved to meet the requirement of firms in developing countries:

- links with the technology frontier,
- links with markets (and sophisticated users),
- supply of needed skills, services and other inputs,
- the local innovation/network.

In fact, the four institutional instruments combine Lundvall's idea about producer-user interactive learning with Freeman/Perez's idea about identification of a new techno-economic paradigm. However, they do not explore how European and Asian catching-up economies implement these institutional instruments and to what extent firms are influenced by these instruments.

Tylecote (2006) agrees with Fagerberg and Godinho's opinion in terms of tracing technology frontier but he explains explicitly what kind of NIS catching-up economies need. He argues that less developed countries need twin national innovational system: system with upper level to engage with advanced technology and develop industries which use it and a

[10] OEM: it is a situation in which a company consigns another company to manufacture a product with a specification, then buy the finished product from the producer and sell them with its own brand.

lower level to help to improve the economy's existing traditional technology. In order to improve the technological level of the whole nation, the development of intermediate technology is needed to bridge advanced technology and traditional technology. In other words, developing countries should build a middle-level of NIS to promote the diffusion of advanced technology resulting from the upper level toward the traditional technology resulting from the lower level. But he does not discuss whether the different levels of technology need to depend on imported technology or on endogenous innovation.

In short, the past and recently research results on NIS signal that it is possible for both technologically backward countries, big or small, to become competitive and affluent nations in knowledge-based economies if these countries can coordinate the science-industry relationships, shape appropriate institutional set-ups to support innovation activities and promote interactive learning at national, regional, firms and individual levels (Freeman, 1988; Perez, 1988; Nelson, 1993; Radosevic, 1997; Kim and Neslon, 2000; Fagerberg and Godinho, 2005; Tylecote, 2006). However, they do not place emphasis on the role of universities in the NIS.

Being a transitional country, China has the weaknesses rooted in the command economy as Radosevic (1997) mentioned. Following its shift to a market-oriented economy, the Chinese policy makers have implemented a wide range of institutional and organizational reforms to promote technology development and innovation. Due to weak innovation capability of domestic firms, universities have become more and more important players in the Chinese NIS. They act not only as knowledge creators but also as active knowledge exploiters.

The concept of Chinese national innovation system (NIS) was originally introduced by the Chinese Academy of Sciences in 1998 to the central government. Many studies on the Chinese NIS focus on either China's S&T system reform (Fang 1999; US embassy 2002) or

S&T programs (Bao *et al*., 2002; Chen, 2003; Suttermier *et al*., 2004; Huang *et al*., 2004; Yan, 2005; Bach *et al*., 2007). Very few researches emphasize the institutional and organizational changes of the Chinese NIS, expect Liu and White. Liu and White (2001) study China's NIS in a transitional context and discuss how organizations and distribution of fundamental activities[11] change in the innovation process before and during the transition period. However, they do not link these changes to China's catching-up objective.

Since the above fruitful literature provides us with theoretical evidence about the possibility of catching-up, we center our analysis on how the Chinese government carries out institutional and organizational changes in the NIS to catch up with a dynamic, evolutionary and institutional perspective. In our analysis, institutions refer to policies, laws, financial system and supporting infrastructure of knowledge generation, commercialization and diffusion. Organizations refer to firms, the government, universities, public research institutions and intermediary institutions. In the following section 1.2 and section 1.3, we analyze how the Chinese NIS is constructed along two dimensions to help China catch up and how universities play their role in the NIS.

1.1.2.2 Research focus

Although firms are the core in the NIS, the set-up and performance of firms cannot be divorced from the investment of human resources. Universities are responsible for training scientists and engineers who would form the foundations of absorptive and innovative capabilities for firms. The catch-up story of Japan and of South Korea has demonstrated that the Japanese (in the 1960s and 1970s) and Korean (in the 1980s and 1990s) universities have enhanced the absorptive capability of industrial firms by providing well-trained graduates on a large scale (Eun *et al*., 2006). In comparison with Japanese and Korean firms, many

[11] Fundamental activities: Liu and White (2001) identify five fundamental activities as the core of the NIS framework. These activities are composed of R&D, implementation, end-use, education and linkage.

Chinese firms are less active innovators. Their insufficient assimilation capability hampers them from acquiring the source of innovation through open science (e.g. academic meetings and published academic papers). Universities play a very important role in building up firms' absorptive and innovative capabilities. As long as domestic firms set up such capabilities, China's overall competitiveness will be advanced. Thus, we put our research focus on the role of universities in the Chinese NIS in this Chapter. To understand the research issue, it is necessary to have some basic knowledge about the Chinese NIS and the Chinese university system. Hence, we outline the Chinese NIS in section 1.1.2.2.1 and the Chinese university system in section 1.1.2.2.2.

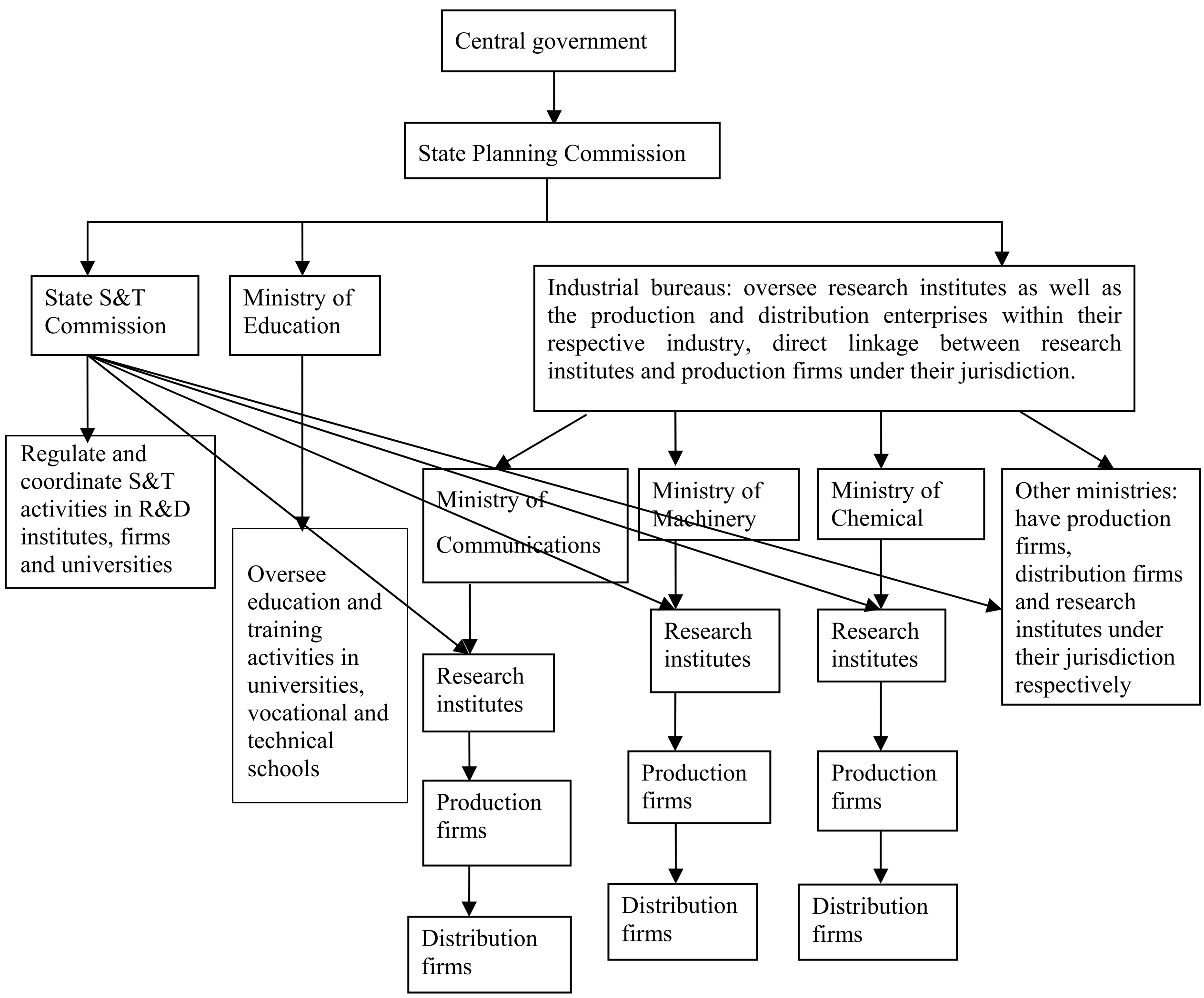
1.1.2.2.1 The Chinese NIS

Ancient China was an invention country and its S&T was far advanced as compared to other countries. But missing the opportunity of the industrial revolution, suffering world and civil wars as well as improper public policies in the Chairman Mao's period made China lag behind compared to the industrialized countries.

During Mao's time, the Chinese S&T system was built on the basis of the Soviet Model. Production, distribution, research, student enrolment, materials & funds allocation, even job assignment, all these activities were planned and controlled by the central government. The central government created a range of governmental sectors. The State Planning Commission (SPC) was most influential, with ultimate control over economic plans, resource allocation and oversight. It issued annual and 5-year plans including new R&D and production project selection, capital and labor allocation, production levels, price-setting, distribution and others (Liu and White, 2001). Under SPC, there were administrative bureaus in charge of carrying out the plans. For example, the State Science and Technology Commission (SSTC, it has been called Ministry of S&T since 1998) regulated and coordinated S&T activities in R&D institutes, production enterprises (manufacturers) and research centers in universities. According to the education plans made by SPC, the Ministry of Education supervised education and training activities in the higher education system. Other related ministries, like the Ministry of Communications and Posts, the Ministry of

Machinery and the Ministry of Chemical Industry, were subordinated to industrial bureaus. These ministries had their production and distribution firms as well as research institutes. When receiving these production and distribution plans from the State Planning Commission, these ministries transferred the information to affiliated firms, together with the corresponding resources allocation (see Figure 1.1).

Figure 1.1: System structure under command economy



Source: done by the author on the basis of Liu and White's paper (2001).

Figure 1.1 shows that the top-bottom information flow mechanism separated both production from market and science from industry. Producers were close to customers but had no right to make production decision whereas policy-makers were “far away” from the market (they did not approach customers), they determined what firms should produce, how to produce, how many they produced and where they should sell. The centrally planned production guaranteed the survival of firms and firms had no incentive to conduct innovation activities. Universities and public research institutes carried out R&D activities but had a very weak linkage with industry. The command economy hampered technology development and innovation.

After DENG Xiaoping took over the central government’s power, he launched a series of reforms which gave institutional actors more autonomy. Industrial firms become decision-makers and self-reliance organizations. Research institutes and universities are responsible for funds allocation and human resources assignment. To compensate for the decreasing budget, research institutes and universities try to collect research funds from industry. From the industry side, market competition pushes them to link up with science for acquiring new technology. The institutional changes in the Chinese NIS have strengthened science-industry linkage and provide a favorable environment for technological innovation.

The Chinese NIS can be viewed in two dimensions. One dimension is engaged with technology importation, the other dimension with endogenous innovation. Witnessing the contribution of foreign direct investment (FDI) to the rise of newly-industrialized economies, the Chinese government implemented open policies and laws to attract FDI which encompasses technology. It also reformed financial system and R&D infrastructure to support the acquirement and absorption of imported technology. Imported technology is used as a short cut way to improve China’s competitiveness in the world market.

The other dimension deals with endogenous innovation[12]. The government constructs complex supporting infrastructures for knowledge generation, commercialization and diffusion to develop China's independent innovation capability. HU Jintao (2007), the actual president of China, stresses the importance of endogenous innovation to China's sustainable development during his speech at the 17th Party Congress:

"*enhancing China's capacity for independent innovation and making China an innovative country is the core of our national development strategy and a crucial link in enhancing the overall national strength… We need to keep to the path of independent innovation with Chinese characteristics and improve our capacity for independent innovation in all areas of modernization…*"

These two dimensions are complements rather than substitutes. The institutional and organizational changes are the determinants of the two dimensions. Institutions and organizations are shaped to transit China from a low value-added manufacturing country to an innovation country. Details about the two dimensions of NIS are explained in section 1.2.

1.1.2.2.2 The Chinese university system

China's university system is characterized by three components: regular higher education system, adult higher education system and private higher education system.

The regular higher education system was built, on the basis of the centralized Soviet educational model since the foundation of the People's Republic of China, responding to the

[12] Endogenous innovation: it is originally called "***zizhu chuangxin***" in Chinese. It has been differently translated as "independent", "indigenous", "home-grown" innovation, or "self-motivated" innovation (Jakobson, 2007, p.xxii). Bai and Jakobson (2007: p.5) explain that ***zizhu chuangxin*** reflects a goal with threefold dimensions: (1) genuinely original innovation, (2) integration of existing technology, a process, (3) re-innovation, in other word assimilation and improvement of imported technology. In this chapter, we center innovation on the first dimension as genuinely original innovation. It means that innovation depends on domestic R&D investment and the intellectual property rights resulting from R&D outputs are held by domestic organizations. In other words, domestic organizations are genuinely original innovators of technology and they do not depend on imported technology.

state' need of industrialization. Students are required to have full-time studies in these universities after succeeding in the national unified enrollment of examination.

The adult higher education system was designed to meet the education need of the generation whose higher education opportunities were delayed by wars before 1949 or by the Cultural Revolution (1966-1976)[13], and the needs of those who failed in the national higher education entrance examination (Cf. Xue, 2006). It provides full-time, part-time and postal courses in response to the demand of students.

The private higher education institutions emerged in the 1980s to compensate the shortage of public higher education supply. Since 1999, public universities have been allowed to establish affiliated so-called second-tier, for-profit colleges offering degree programs with less stringent entry requirement (Jakobson, 2007: p.17).

According to China's National Bureau of Statistics, in 2006 there were 1867 regular higher education institutions, 444 adult higher education institutions and 1590 private higher education institutions. The total enrollment of students amounted to 25 million in these higher education institutions and the higher educational attainment of total population aged 18-22 reached 22%. China's higher education has evolved from elite education to popular education.

The fast development of higher education results from administrative and financing decentralization of universities. Since 1985, many universities originally subordinated to governmental ministries have been delegated to provincial and municipal governments. And the central government decreases the financial budget for universities and grants universities more autonomy to seek other sources of funding. Many universities gain more autonomy in terms of charging tuition fees, enrollment of students, curricula design, employment of teaching staffs, scientific research and so on. Universities are no longer "ivory towers" devoted to mere knowledge generation and they are exposed to accelerate the

[13] Cultural Revolution: it was a political movement launched by the first president of People's Republic of China, Mao Zedong, in august of 1966 at a Plenum of the Central Committee when he called for Red Guards (usually young people with a red armband) to challenge Communist Party officials for their bourgeoisness and lack of revolutionary zeal. During the Cultural Revolution, millions of young people were sent to the countryside for re-education by the peasants and schools were closed. http://www.sjsu.edu/faculty/watkins/cultrev.htm

commercialization of research outputs under political pressure. University-affiliated enterprises, university science parks and university incubators have emerged around campus since the 1980s. Professors and students with applied science background have got more and more involved in commercial activities.

At the same time, a lot of mergers and acquisitions among universities have appeared after 1998. By 2006, 1465 universities were merged to create 431 new universities. The mergers and acquisitions facilitate the development of cross-disciplinary science and strengthen universities' research capacities. In recent years, Universities have become active patenters. To seek for economic return and to meet the government's requirement, universities accelerate the process of patents capitalization: either they generate spin-offs or sell patents to industry. Challenged by more and more market competition, firms go closer to universities for technology seeking than before.

In total, the higher educational reform has influenced the behaviors of universities. Universities have ended up the divorce with industry and turn to establish or enhance university-industry linkage.

1.1.3 Conclusion

Although the understanding of the NIS's concept depends on the research purpose, innovation is widely accepted as an endogenous phenomenon and policy makers can take actions to shape the process of innovation. Organizational and institutional changes are the important components of NIS.

Our overview of the research literature on NIS confirms our understanding of NIS. Previous research findings provide sound theoretical and practical evidence to Chinese scholars and practitioners that it is possible for technology backward countries to catch up if they implement proper policies to develop domestic firms' competitiveness.

Our research issue focuses on how universities help firms build up competitiveness in the Chinese NIS. We identify ‘national proper actions’ as ‘national institutional and organizational changes’ in our analytical context. We conclude that the Chinese NIS is a system of related organizations which interact with each other to acquire/absorb imported technology and to encourage/facilitate endogenous innovation. These interactions are influenced by China’s institutional and organizational changes. The importance of universities in the Chinese NIS is found to set up domestic firms’ absorption and innovation capabilities. Due to a constrained budget, political pressure and fruitful research achievements, universities have actively taken part in commercial activities. Consequently, the university-industry linkage is closer than before. Details about the Chinese NIS and the role of universities in the NIS are discussed in section 1.2 and section 1.3.

Section 1.2 China's National Innovation System

The meaning of 'catch-up' usually refers to the ability of a single country to narrow the gap in productivity and income vis-à-vis a leader country (Fagerberg and Godinho, 2005). Although China was the world fourth biggest economy behind the USA, Japan and Germany in 2006, its level of GDP per capita was much lower than many other countries. To narrow the average income gap vis-à-vis developed countries, the new growth theory[14] emphasizes the role of science & technology, human capital and FDI in economic growth (Romer, 1986, 1987; Lucas, 1988). The NIS theory highlights the importance of innovations in catching-up economies. For developing countries, innovations mean upgrading export product structure, improving productivity, strengthening firms' competitiveness and bringing economic growth (Lundvall, 1992).

The previous research findings in section 1 have theoretically and practically proved that developing countries can catch up if they implement proper public policies to build the technological capabilities of domestic firms. We combine the new growth theory with the NIS theory to analyze how China builds its NIS along two dimensions (FDI and endogenous innovation) and tries to catch up in this section. It consists of two parts. Each part represents one dimension of the Chinese NIS. Section 1.2.1 discusses a set of institutional changes which are engaged with technology importation. Open policies and legal system are set up to attract FDI, whereas the financial system and R&D infrastructure are restructured to both acquire and absorb imported technology. Section 1.2.2 argues how supporting infrastructure of knowledge generation, commercialization and diffusion is constructed to facilitate endogenous innovation. The performance of the NIS along these two dimensions is discussed in section 1.2.1 and section 1.2.2.

[14]The new growth theory differs from the early post-Keynesian growth model which emphasizes savings and investment, and from the neoclassical models which highlight technical progress (Solow, 1957).

1.2.1 One dimension: institutional changes for technology imports

Foreign direct investment (FDI) is defined when an investor based in one country acquires an asset in another country with the intent to manage that asset (IMF, 1993; IMF and OECD, 2000). Although the effect of FDI on economic growth of host countries is debatable (Ran *et al*., 2007), many developing countries believe that the inflows of FDI is helpful to narrow their technological gap with developed countries. China is a practitioner of this view. Since the economic reform in 1978, China implemented a package of policies to attract FDI, expecting the spillover effects of FDI to facilitate technological progress of domestic firms. FDI enters China in fours ways: joint-venture enterprises (JVEs), cooperative operation enterprises (COEs), foreign investment enterprises (FIEs) and cooperation development (CD) (Yi *et al*. 2004).

1.2.1.1 Opening-up policies

Chinese governmental policies toward openness followed a pragmatic approach. The geographic openness to FDI was firstly limited in four special economic zones and then gradually spread almost all over the country. The sectoral openness to FDI follows the "Foreign Investment Industrial Guidance Catalogue" in which industries foreign investors are encouraged, restricted and prohibited (see Appendix 1.1, p.311). At the same time, the government decentralizes the technology import power. Firms gain autonomy to make technology import decisions.

1) Enlarging geographic openness to FDI

In 1978, China's open policy replaced the Maoist doctrines of 'self-reliance'. In the 1970s, the economic depression spread in western countries and firms in these countries were forced to explore new markets abroad. On the contrary, China's geographic neighbors were emerging as newly industrialized economies[15]. Constrained by their small domestic markets, they sought to develop overseas markets, especially Japan. The appreciation of the Japanese currency in the 1980s accelerated the expansion of Japanese firms. China's open policy met the hungry appetite of these foreign companies.

In 1980 the Chinese government created four special economic zones (SEZs) as open economic areas in four coastal cities[16]. SEZs perform under a more liberal environment, isolated from the prevalent hierarchical system of order (Lerais *et al.*, 2006). After receiving the government's positive appraisement, various derivatives of SEZs emerge as open areas to FDI[17], spatially distributed almost all over the country. The expansion of geographic openness is expected to spread FDI's externalities at a national level rather than a regional level.

2) Increasing sectoral openness to FDI

The WTO (World Trade Organization) membership integrates China into the global market but also requires China to liberalize domestic trade border. Since 2006, high value-added industries (e.g. telecommunication, banking and insurance) have been gradually open to foreign investors. Protected industries, i.e., automobiles, chemicals, and electronics, are not allowed to enjoy the tariff and non-tariff protection. More export-oriented products can enter domestic market (Jiang, 2002).

The liberalization of industries promotes the emergence of new combinations: new commodities, new markets and a new form of organization. FDI brings new technology (may

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[15] Newly industrialized economies refer to South Korea, Singapore, Hong Kong and Taiwan.
[16] Four coastal cities: Xiamen, Zhuhai, Shantou and Shenzhen. Xiamen is in the Fujian province, the other three cities are in the Guangdong province.
[17] Derivatives of SEZs: 14 open coastal cities (1984), 54 economic & technical development zones (1984), 53 high technology development zones (also called S&T industrial parks, 1988). Details see Tseng, W., Zebregs, H., 2002 and Llerena, P., Tang, M.F., 2007.

be not cutting-edge but new to China) and organizational models to produce new commodities in China. Chinese partners explore overseas markets which is a potentially powerful mechanism of technological learning. Those firms, which are not linked to FDI, have to face the challenges from FDI. They either conduct and manage innovation for surviving or drop out of the market. The successful entry of Chinese manufacturers in the local mobile phone industry, which was originally dominated by foreign multinational companies, provides evidence to support this point (Zhu *et al*., 2006). Their success mainly lies in the exploration of new markets in the small villages and towns, which are neglected by foreign firms. Thus, the openness of industries to FDI indeed creates an innovative environment.

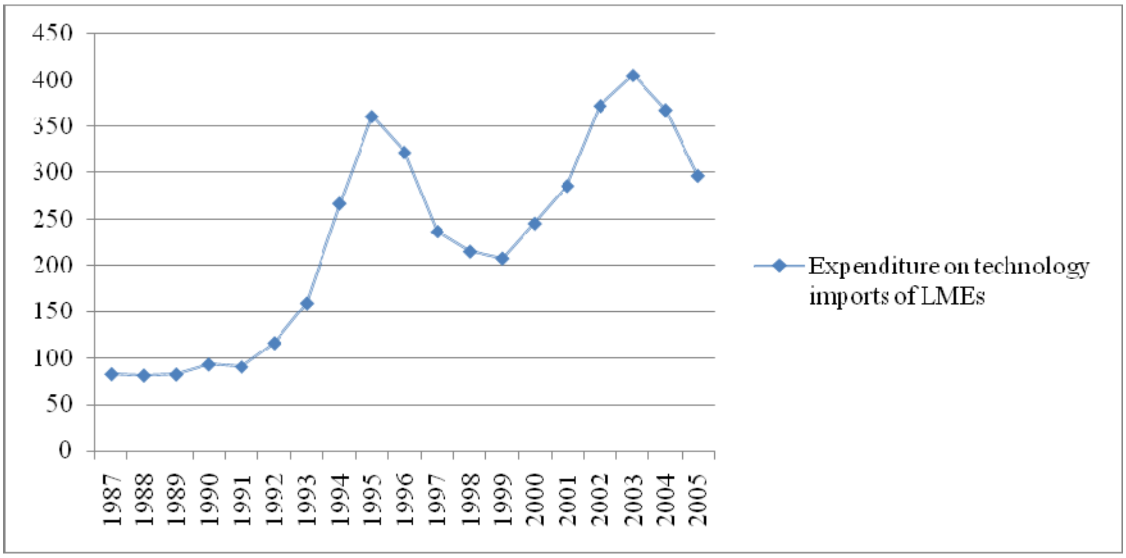
Moreover, China has not opened all industries to FDI overnight. Local firms get an opportunity to technological learning and experience accumulation. Incumbent foreign firms may need local firms' cooperation to surmount the entry barriers, and fresh foreign entrants may need local firms' assistance to get familiar with the Chinese market. In spite of a growing tendency of wholly-foreign-owned enterprises, the externalities of FDI still exist but depend on sectors, local firms' absorptive capability and location. Therefore, it is possible for local firms to learn new technology by cooperating.

3) Decentralizing technology import power

The Chinese history shows that many flourishing dynasties appeared in power-centralized dynasties, e.g. *Qin* dynasty (B.C.221-206), *Xi Han* dynasty (B.C.202-A.D.8), *Tang* dynasty (A.D.618-907) and *Qing* dynasty (A.D.1644-1911). Emperors used the centralized political system to govern the increasingly enlarging territories and to defend outside invasions. After the foundation of the People's Republic of China, the government followed the governance tradition and centralized policy-making.

The State Commission for Imports and Exports[18] (SCIE) was set up to manage technology imports in 1979. The imported technology from order to delivery was wholly planned. Up to the 1990s, firms were authorized to take responsibility for the technology imports (Greeven, 2004). Large-medium industrial enterprises (LMEs) were the main beneficiaries of the decentralization of technology imports power. The expenditure of LMEs on technology imports increased slowly during the period of 1987-1991 but became very impressive between 1992 and 1995. From 1996 to 1999 it decreased but rebounded to increase between 2000 and 2003. Starting from 2004, the expenditure of LMEs decreased again (see Figure 1.2).

Figure 1.2: Expenditure of large-medium industrial enterprises (LMEs) on technology imports in China (1987-2005), money unit: 10 million €



Source: data collected from National Bureau of Statistic of China.

Note: 100RMB = 10EURO

The expenditure changes of LMEs reflected the entry modes of FDI to China. In the 1990s, many technology imports were closely related to FDI and concentrated in

[18] State Commission for Imports and Exports: it was created in 1979 and renamed three times on the basis of merging with other organizations, namely Ministry of Foreign Economic and Trade in 1982, Ministry of Foreign Trade and Economic Cooperation in 1993 and Ministry of Commerce in 2003.

manufacturing, mining and construction industries (Dahlman and Aubert, 2001; Tseng and Zebregs, 2002; Greeven, 2004; Chen, 2005). Until 1992, the inward FDI was small and cooperative operation enterprises (COEs). Cooperation development (CD) dominated the technology entry modes. It means that LMEs purchased imported technology and modified it with foreign partners to meet local customer tastes. The joint searching and exploring is a process of learning. Learning may result in new products, new techniques, new forms of organization and new markets (Lundvall, 1992). But during the period between 1996 and 1999, LMEs decreased technology import expenditure. It might result from more technology-based equity investment from foreign firms so that Chinese partners did not need to spend much money in importing such technology.

Later, the amount of foreign investment enterprises (wholly-foreign-owned firms) increased to a share of almost 50% of total FDI whereas the share of COEs and CD declined (Yi *et al*., 2004). The divorce between foreign firms and domestic firms led to the increase rebound of technology imports from 2000 to 2003. But the upward tendency has quickly dropped since 2004. It may be related to the growing endogenous innovation of LMEs.

In short, the decentralization of technology imports power makes domestic firms import more market-oriented technology. The direct interactions with foreign suppliers promote technological learning and experience accumulation.

1.2.1.2 Legal system

Due to market diversity within or beyond the boundary of a country, innovators can benefit from a temporary monopoly income for a long time if their intellectual property rights (IPRs) are protected. Foreign firms, especially multinational firms (MNCs), are recognized as a major source of technology and know-how channelling to developing countries. To sustain their profitability, foreign companies require the host country to build up and implement a legal system on IPRs protection. Countries without IPRs policy and its enforcement would decrease the gains to an innovator. Sooner or later, competitors will be able to imitation, or invent around, or develop a better version of, the initial innovation (Nelson, 1987). Indeed, the destination of FDI is influenced by the legal framework and the rule of law in the recipient country (Report, 2003).

To attract FDI and also to motivate domestic innovators, China has made great progress in developing a comprehensive legal system on FDI (see Appendix 1.1, p.311) and IPRs[19]. The established legislative framework on FDI was set up by the central government. But local governments to a certain extent are given autonomy to formulate their preferential treatment towards foreign investors. Governments at local levels center more on economic growth and revenue increase in their jurisdictions when attracting FDI, whilst the central government pays much attention to transferring technology and managerial skills from foreign firms (Shi, 2001).

The protection of IPRs is criticized as not being effective, but it signals that the infringement activities of IPRs are to be punished under the law.

1.2.1.3 Financial system

The financial system is an important component of a national innovation system (Lundvall, 1992; Nelson, 1993; Mckelvey, 1997). Like Japan and South Korea, Chinese financial system has contributed to the build-up of China's innovation capability[20]. Between 1949 and 1978, the Chinese banking system was wholly controlled by the People's Bank of China, which bore the double responsibilities of a central bank and a commercial bank (Dai, 2003). Following the economic reform in 1978, the commercial business was split into four

[19] IPR legislation: more details can be found in the following chapter 3 section 2.2.2.
[20] Innovation capability: it is defined as the skills and knowledge needed to effectively absorb, master, and improve existing technologies, and to create new ones (Kynge, 2000).

specialized state-owned banks[21] and the People's Bank of China retained the role of central bank. The banking system was overwhelmingly dominated by the central bank and the big four state-owned banks until the mid-1990s when some non-state banks and joint-stock banks were allowed to run business throughout the country. The Big Four and their local branches had their own servicing niches, ruling out any possibility of free competition.

As state-owned enterprises (SOEs) and state-owned banks were both controlled by the government, SOEs were privileged borrowers and banks extended loans to SOEs on the basis of fulfilling the national and regional production plans, regardless of profitability (Wong and Wong, 2001). The ratio of total bank debt to total assets of the SOEs was about 10% in 1980 and increased to 85% in 1995. About 50% of the SOEs had more debt than assets at the end of the nineties (Chen, 2005). These financial loans largely supported SOEs' technical renovation, technology importation and absorption. At the same time, the exchange rate of domestic currency against foreign currency was artificially high to facilitate technology imports.

However, the political lending resulted in huge volumes of non-performing loans and loss-making. Following the liberalization of the banking system, joint-stock commercial banks, local commercial banks as well as foreign banks have entered the banking sector. Former stated-owned banks have to reduce non-performing loans and boost profitability so as to compete with other banks. The bank loans for funding S&T activities dropped from 16.13% in 1992 to 5.27% in 2005. Nowadays enterprise funds dominate the funding of S&T activities.

[21] Four specialized state-owned banks: they are Bank of China, Construction Bank of China, Industrial and Commercial Bank of China and Agricultural Bank of China.

1.2.1.4 Research & Development (R&D) Infrastructure

To help domestic firms absorb foreign technology, the government set up over 400 research institutes (RIs) in the early stage of industrialization (Liu and White, 2001). In the 1980s, the science & technology reform restructured RIs to promote the efficiency of R&D infrastructure. The Chinese Academy of Sciences (CAS), the National Natural Science Foundation of China (NNSFC) and the Chinese Academy of Engineering (CAE) are very important components of the current Chinese R&D infrastructure.

The Chinese Academy of Sciences (CAS) was founded in 1949. It is China's foremost natural science and technology research institute, administrating some 100 research institutes. CAS keeps close contact with international S&T communities to trace the world frontier knowledge and technology under various forms: sending Chinese researchers abroad; attracting overseas Chinese scholars to return to China; organizing international academic conferences; joining R&D alliance with foreign multinational companies… In 2005, CAS established 6 joint research centers with companies from South Korea and the Unite Kingdom. To diffuse the acquired foreign knowledge and technology, CAS provides advanced graduate education programs to students, undertakes national science and technology programs and strengths linkage with Chinese firms.

The National Natural Science Foundation of China (NNSFC) was established in 1986 to promote and finance basic research. It develops cooperation and exchanges with foreign scientific organizations and runs a Sino-German Center for Research Promotion. However, NNSFC does not directly support R&D activities of firms but provides grants to brilliant researchers in universities and research institutes.

The Chinese Academy of Engineering (CAE) was set up in 1994. It functions as an advisory institution in matters related to engineering and also supports technical research projects financially. It does not own research institutes but carries out research through engineering departments at universities.

These three government-based research institutes cooperate with international science & technology communities. The wide-ranging network with foreign partners facilitates the inflow of technological information. The mobility of researchers at home and abroad also contributes to the circulation of knowledge. CAS has employed 52 foreign academicians and CAE 35 ones[22]. CAS, NNSFC and CAE emphasize the importance of human capital. Human resource development may be a most basic and crucial determinant of technological capability (Kim, 1993). Hence, these public R&D institutes are directly or indirectly helpful to Chinese firms for acquiring, identifying, assimilating and adapting imported technology.

1.2.1.5 Attained objective?

After almost three decades, have the above institutional changes helped China to acquire imported technology and improve its innovation capability? We use the quantity of inward FDI and the types of inward technology to measure the acquired foreign technology, and use innovation motivation, R&D expenditure in high-tech industry and high-tech trade balance to measure the innovation capability linked to FDI.

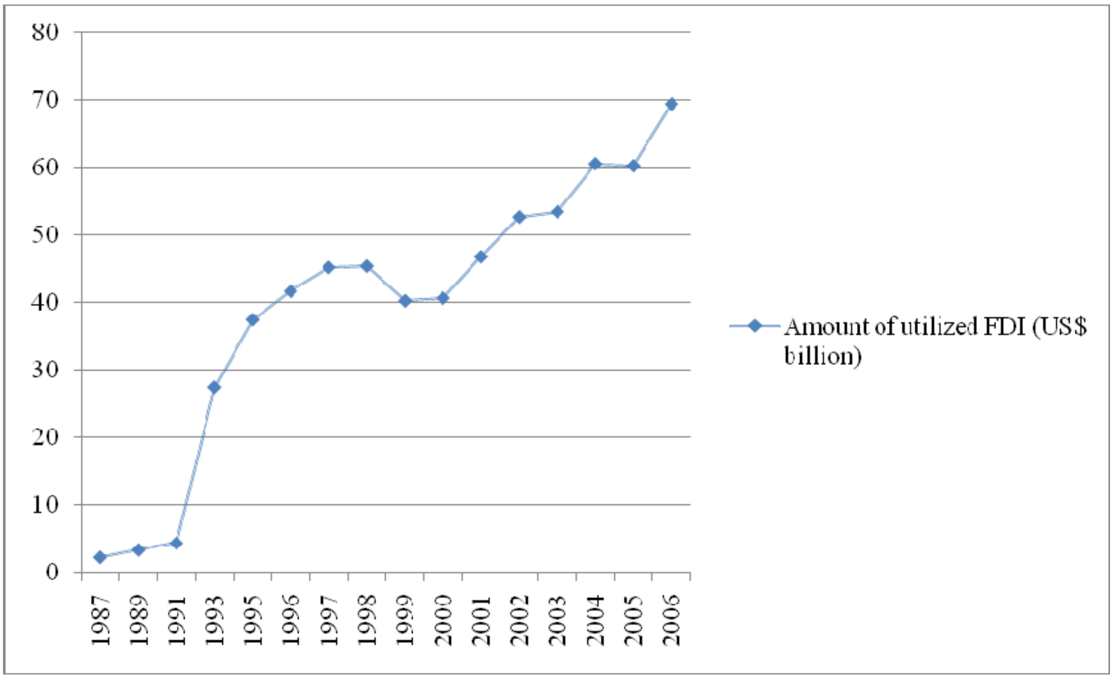
1) Acquired foreign technology

Given that the impact of the Chinese legal system on the inflows of FDI is not conclusive, China's open policy is widely accepted to have played a positive effect on the growth of FDI in China. Deng Xiaoping's discourse during his south tour in 1992 and China's access to WTO in 2001, both events stimulated new foreign entrants and foreign

[22] The data collected from CAS and CAE's website respectively. The data of CAS represents the number of employed foreign academicians by 2004 and the data of CAE by 2005.

incumbents to invest or reinvest in China. In 1999, China was the third biggest recipient country of FDI in the world, behind UK and the USA. It hosted over a third of the foreign affiliates of multinational corporations (Dahlman and Aubert, 2001). Following China's adhesion to WTO, the inward FDI increased very fast (see Figure 1.3). China overtook the United States in 2002 and became the world largest recipient of FDI (Bajpai and Dasgupta, 2004). Starting from 2006, high value-added sectors (e.g. banking, insurance) have been gradually open to foreign investors. More FDI is predicted to flow into China in the years to come.

Figure 1.3: Utilized FDI inflows to China, selected year (US$ billion)



Source: data from 1987 to 1993 collected from World Bank Report, September 2000. Data from 1995 to 2006 collected from Ministry of Commerce of PRC. Because of the reconstruction of governmental bureaus, the Ministry of Commerce of PRC has replaced the Ministry of Foreign Trade and Economic Cooperation since 2003.

The inward FDI can be divided into three categories: investments from Hongkong, Macau and Taiwan affiliated enterprises, from newly industrialized economies (NIEs) affiliated enterprises (e.g. South Korea, Malaysia), and from advanced country affiliated enterprises. The former two categories normally transfer mature & standardized technology and general purpose equipment, and the third category, especially western multinational companies, mainly transfer product technology and processing technology rather than their core technology in R&D (Shi, 2001). Many imported technologies are embedded in equipments and facilities. The performance of imported capital goods improves productivity, and reduces production cost and materials consumption. Moreover, imported technology rarely takes the form of licensing agreements which is supposed to be more efficient for technology diffusion than physical goods import. Licensed technology import represents comparatively limited spending: less than 0.5% of merchandise imports in China's case, against 0.7% for India, 2.2% for South Korea and 3.2% for Japan (Dahlman and Aubert, 2001).

2) Innovation capability of domestic firms

FDI is a potentially powerful channel for integrating a system of innovation into global networks and influencing its structural change. The effect of FDI on a host country is still arguable, good or bad. The host country may increase its dynamic capability but also takes risk of 'vicious circles' of deterioration where a country or a sector has its initial comparative advantages (Radosevic, 1997). A large literature on inward FDI in China shows that FDI plays a positive impact on the productivity of Chinese industry and on upgrading Chinese export segments (Zhang and Song, 2000; Li *et al.*, 2001; Shi, 2001; Lemoine and Kesenci, 2004; Luo, 2007; Ran *et al.*, 2007; Yao and Wei, 2007). Some scholars find that FDI decreases the R&D expenditure of its Chinese partners (Fan and Hu, 2007) and it may cause economic inequality (Ran *et al.*, 2007). However, they do not discuss whether domestic firms have improved their innovative capabilities after FDI inflows to China. We now focus on this point at a general level: the innovation motivation of Chinese firms, R&D expenditure in high-tech industry and high-tech trade balance.

- **Innovation motivation**

Chinese enterprises are divided into state-owned enterprises (SOEs) and collective-and-private-owned enterprises. Multinational companies tend to cooperate with SOEs, especially with large SOEs. Smaller firms from Hongkong and other East Asian NIEs are more likely to seek collective-and-private-owned enterprises as partners.

SOEs lack incentives to carry out innovation activities (Li *et al*., 2007). Before all foreign firms turn to be domestic market-oriented, SOEs can continue to survive because of the diversity of a vast market and usage of imported technology (even not cutting-edge technology). In cases when SOEs carry out innovation, they depend largely on imported equipments and facilities to conduct process innovation rather than product innovation, because product innovation costs more time, money and is more risky in contrast with process innovation. Besides, the faster achievements arising from process innovation influence the tenure of chief executive officers (CEOs)[23] in SOEs. The passive attitude of Chinese SOEs toward product innovation is quite different from South Korea's big family-based enterprises, Chaebols[24]. The latter actively develop organizational and technical resources to acquire both explicit and tacit knowledge at a high international level, then expand and deepen industrial R&D activities in the shortest possible time. Lastly, they approach the technological frontier (Kim, 2000).

The Chinese automobile industry is the case. The industry was built in 1950s but until now none of the state-owned automobile companies are capable of designing the entire

[23] CEO of SOE: chief executive officers of state-owned enterprises are appointed by the Chinese government. Indeed, it is an indirect control of SOE. The government's criteria for evaluating CEO include not only performance or capability, but also many political factors. This suggests a negative influence of government control on innovation (Li *et al*., 2007).

[24] Chaebols : refers to family-controlled and government supported large Korean corporate. They were created by Korean government intentionally in the 1960s as an instrument to bring about the economy of scale in mature technologies and in turn to develop some 'strategic industries' (plywood, textiles, consumer electronics and automobiles) and to lead exports and economy (Kim, 1993).

passenger car and reach massive-production of 1 million units while Ford Company attained an output of over 2 million units in 1926. The heavy dependency on imported technology, the government's protection policies and a booming domestic automobile consumer market make these state-owned auto makers mainly stay at the level of assembling imported automobile parts instead of actively learning from imported technology and conducting endogenous innovation. On the contrary, in South Korea, private auto producers' (chaebols) strong entrepreneurship and active learning attitude toward imported technology, together with other factors like formation of highly trained human resources, government coherent supports and continuous inflow of foreign technology, all these elements made 'Korea-made' automobiles competitive in the international market in the 1980s. Hence, we should say active learning is one of the determinants to the success of innovation.

Collective-and private-owned enterprises are considered more market-oriented and dynamic than SOEs. They are generally small sized and have low R&D expenditure and technological capability. However, they are more motivated to learn and imitate than SOEs (Li *et al.*, 2001), especially private domestic enterprises. These enterprises learn foreign technology through subcontracting or participate in foreign firms' global production chain as component suppliers. Foreign partners often provide detailed design specifications and technical assistance in production, management, and quality control to ensure that the commodities they buy are delivered on time and meet international quality standards (Dahlman and Aubert, 2002). This interaction between users and producers is a learning and technology diffusion process (Lundvall, 1992). But the efficient learning is based on simple and standardized technology. On the one hand, it is very difficult for these small enterprises to absorb sophisticated technology, due to insufficient financial capital and skilled human resources. On the other hand, foreign firms are reluctant to transfer cutting-edge technology to Chinese firms.

- **R&D expenditure in high-tech industry**

Inward FDI has a strong presence in some Chinese high-tech industries, such as electronic and telecommunication equipment, computer and office machinery. FDI accounts for over half of the total firms, in spite of its low R&D intensity in China (Lerais *et al.*, 2006). To survive in the high-tech market, SOEs spend substantial funds in importing technology but much less in assimilating it (see Table 1.2). We focus on SOEs because they are the most important R&D spenders in high-tech industry.

Table 1.2: Spending structure of state-owned enterprises on high-tech industries (million €)

	1995	1998	1999	2000	2001	2002	2003
Spending for technology import	228.66	51.62	41.86	120.49	120.43	142.92	152.77
Spending for the purchase of domestic technology	36.85	11.42	13.66	14.25	10.72	23.27	12.19
Spending for assimilating technology	16.12	24.99	20.63	15.20	6.58	10.65	13.19

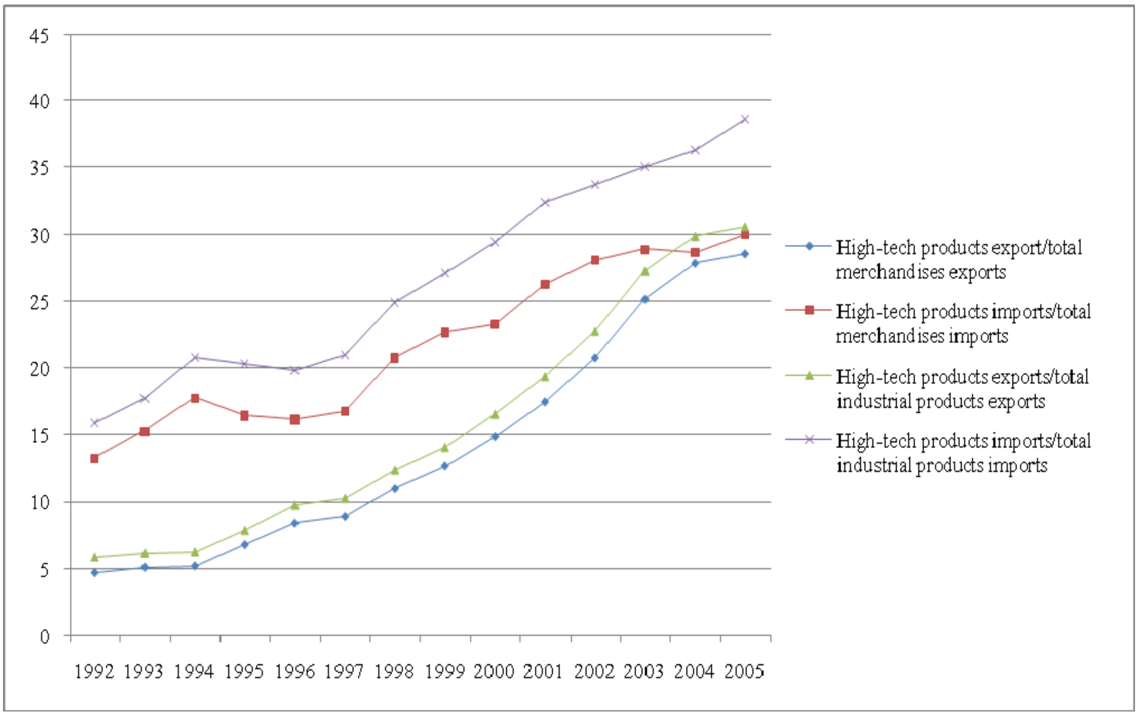
Source: China Statistics Yearbook on High Technology Industry 2004, China Statistics Press.
Note: here the spending is related to five high-technology industries, namely manufacture of medical and pharmaceutical products, manufacture of aircraft and spacecraft, electronic and telecommunications equipment, manufacture of computers and office equipments and manufacture of medical equipments and meters.
Exchange rate: 100 Euro = 1038.39 RMB (Bank of China, 31/7/2007)

Table 1.2 indicates that SOEs spend much more funds in buying foreign technology than domestic technology. For example, in 2003, it reached a factor of 10. Concerning the expenditure on technology assimilation, during the period of 1998- 1999 SOEs spent a large sum of money in absorbing technology, equivalent to almost 50% of the value of purchased technology. It may result from the integration of public R&D institutes into SOEs in the 1990s. However, the high ratio was not sustained in the following years. Between 2000 and 2003, SOEs only invested on average 8.4% of the cost of purchased technology. It seems that SOEs emphasize the usage of acquired technology rather than innovation. From this viewpoint, it reflects SOEs lack innovation motivation. Recent research supports our analysis that the net effect of FDI on indigenous R&D effort is negative (Fan and Hu, 2007).

- **High-tech trade balance**

In recent years, China's high-tech exports and imports have largely increased. The high-tech exports grew from 13.3% of all merchandise exports in 1992 to 30% in 2005 and the share of all industrial exports increased in parallel from 15.9% to 38.6%. The progress of high-tech trade is directly associated with China's integration in the international segmentation of the production process. Export-oriented foreign firms played a very important role in helping China integrate the global production chain. But the growth was based on the processing and assembling trade. The balance of high-tech trade remained deficit over a decade (see Figure 1.4).

Figure 1.4: High-tech trade as share of merchandise trade and industrial trade (%)



Source: National Bureau of Statistics of China.

The deficit of the high-tech trade shows that China's export-oriented high-tech industry relies heavily on imported technology. China's endogenous innovation capability is weak in the high-tech industry. Actually, foreign firms dominate high-tech trade in electronic and telecom equipment and in computers and office equipment. In 2005, 88% of China's high-tech exports were produced by foreign owned firms (Jakobson, 2007: p.2). And the spillovers of FDI are limited in those domestic firms linked to foreign partners and they do not extend to the rest of Chinese firms (Lemoine and Kesenci, 2004; Ran *et al*., 2007).

After about three decades of institutional reforms, the Chinese national innovation system has succeeded in attracting FDI. Technology embedded in FDI has improved productivity, upgraded export product structure and economic growth. China has become the world's second biggest holder of foreign reserves, the third biggest import-export economy and the fourth biggest economy in the world. These achievements indicate that China's national competitiveness has improved.

However, the progress depends largely on imported technology. China's heavy dependency on imported technology hampers domestic firms' motivation for endogenous innovation. In the short term, imported technology upgrades Chinese firms' production productivity and facilitates economic growth. But in the long run, the dependency on high-tech imports rather than in-house R&D activities pushes domestic firms away from acquiring key upstream technologies. Without core technological know-how, domestic firms cannot become competitive players in those industries which are traditionally dominated by advanced countries. China's current position as a labor intensive manufacturing country goes against China's medium and long term S&T development target: building "an innovation-oriented country" by 2020 and a "world's leading science power" by 2050. Moreover, the nowadays economic and political environment is quite different from the past settings. Imitation becomes more and more expensive and the protection of IPRs is much stronger than before.

Thus, China needs another driving engine to catch up: endogenous innovation.

1.2.2 The other dimension: supporting infrastructure construction for endogenous innovation

A numerous literature explains the importance of endogenous innovation for catching-up countries (Freeman, 1988; Perez, 1988; Kim, 1993; Fagerberg and Godinho, 2005; Gu and Lundvall, 2006). Some scholars emphasize endogenous technological innovation (Perez, 1988; Nelson, 2000), others focus on organizational and institutional innovation (e.g. Fagerberg and Godinho, 2005).

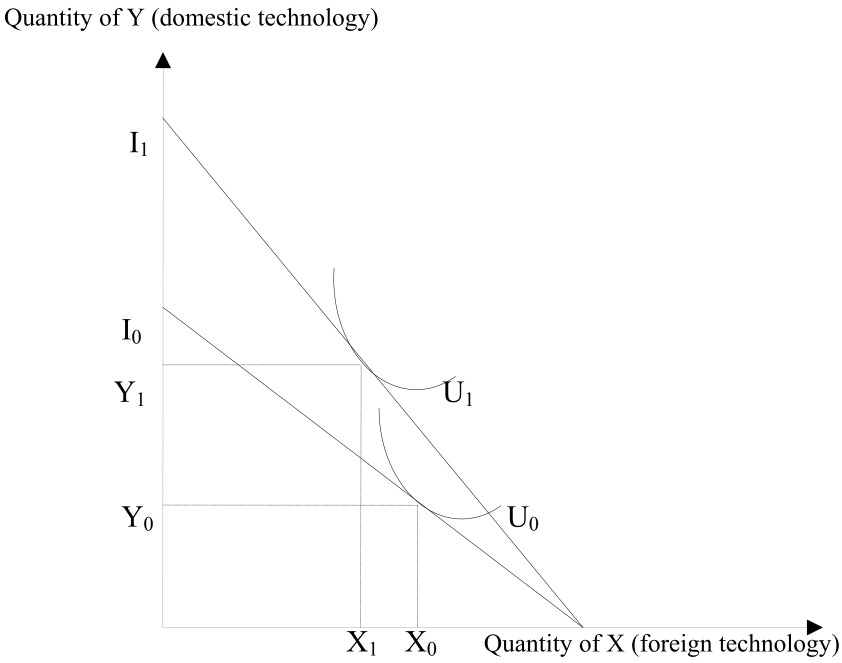
Perez (1988) considers that a catching-up strategy cannot be achieved based solely on importing mature technology but through acquiring the capacity for endogenous technological development. Her opinion is consistent with what Nelson (2000) said:

"*A nation that wants its firms to be strong over the coming years in the downstream industries had better not let foreign firms control the key upstream technologies*".

Fagerberg and Godinho (2005) point out that the successful catching-up story of the United States, Germany and Japan, has historically been associated not merely with the imitation of the more advanced technologies already in use in the leading countries but also innovation, particularly developing new ways of organization production and distribution.

China is a practitioner of the above theoretical research. Policy makers use endogenous innovation and technology imports as political tools to catch up. As we have discussed technology imports in section 1.2.1, we here continue to place organizational and institutional innovation at the core of our analysis but add some discussion about technological innovation, because China's national S&T programs are associated with endogenous technological innovation. Endogenous technological innovation to some degree can generate a "substitute" effect on imported technology (see Figure 1.5).

Figure 1.5: The 'substitute' effect of endogenous technological innovation on imported technology



Source: author herself

Axis X represents the quantity of foreign technology and Axis Y represents for the quantity of domestic technology. The propensity of domestic firms to buy domestic or foreign technology depends on the price of technology on sell, supposing that there is no big difference in quality. Given that Chinese firms carry out endogenous technological innovation, they succeed in presenting new technology to the market. The increased supply of domestic technology leads to the decrease of price P_y. The fallen P_y pushes the budge constraint to shift outward from I_0 to I_1 and the quantity of domestic technology Y chosen has increased from Y_0 to Y_1 as a result of the decline in P_y. On the contrary, the demand of domestic firms for foreign technology X_0 drops to X_1 as a result of the substitution effect.

In this situation, foreign firms are forced to sell higher technology or sell the same level of technology at a lower price to maintain the Chinese market share. From this viewpoint, the ‘substitute’ effect arising from endogenous technological innovation facilitates the upgrading of imported technology and the diffusion of technology.

Besides, at times of new-tech economic paradigm changes, endogenous technological development could lead to radical innovation and make later comers become leaders in some specialized sectors.

Chinese policy makers have recognized the importance of technological and non-technological innovation[25] and built knowledge generation, commercialization and diffusion infrastructure for promoting endogenous innovation.

1.2.2.1 Infrastructure of knowledge generation

Universities and public research institutes are principal knowledge generators. To encourage them to generate more knowledge, the Chinese government has launched various national S&T programs, reformed university and public research institutes, and carried out high-quality talent training and recruitment program since 1985. This section 1.2.2.1 focuses on these four points to analyze China’s knowledge generation infrastructure.

1.2.2.1.1 Major national S&T programs

Innovation sometimes results from cumulative knowledge, and sometimes needs to take enormous R&D investments which may result in radical breaks from the past (Lundvall, 1992). China’s national S&T programs focus on enhancing China’s technological competence

[25] There are two explanations about non-technological innovation. One is that the major types of non-technological innovation are likely to be organizational and managerial innovations (Oslo Manual, 2005: p.88), the other is that non-technological innovation refers to the novelties of an organizational, social, institutional nature (McKelvery, 1991). In our context, we consider organizational and institutional innovations as non-technological innovations.

through searching and exploring[26] activities. These activities increase the stock of knowledge and provide sources to radical technological innovation.

China's current two S&T programs, National Natural Science Foundation of China (NNSFC in 1986) and Key Basic Science R&D Program ("973" Program in 1997), emphasize the build-up of a genuinely original innovation capability in basic research. Universities and research institutes are the main actors to carry out the NNSFC and "973" Program. The Key State Laboratories Program (1984) aims to promote research and advanced training in the 182 established laboratories (2005 data), subordinated to the Ministry of Education (53.3%) and Chinese Academy of Sciences (32.2%). These laboratories employ 8532 full-time personnel and host 3214 guest researchers. The research fields of 182 laboratories cover life science, engineering, information, chemistry, geoscience, mathematics and physics. By 2005, these key state laboratories with 6 state laboratories (in the course of establishment) undertook 12965 research projects among which 22.9% were conducted jointly with industry (Key State Laboratories Report 2005).

Additionally, three S&T programs encourage enterprises to be major technological innovators. Firstly, the Key Technology R&D Program (1983) concentrates resources on key and common technologies linked to industrial need and social sustainable development. For example, the 11th five-year plan (2006-2010) gives top priority to technology connected to energy-water-saving and environmental friendliness. Secondly, the High Technology R&D Program ("863" program in 1986) identifies the emerging new-tech paradigm and helps China integrate into the new paradigm. In 2004, 35.3% of all R&D expenditure for the "863" program were allocated to enterprises which undertook 23% of the total program. Universities got 25.5% expenditure for carrying out 39.4% projects. Research institutes share almost the same percentage in terms of funds received and programs undertaken, 31.3% and 31.1%

[26] Searching and exploring: the most important difference between exploring and searching is that 'exploring' is less goal-oriented than profit-oriented search. Exploring will sometimes result in breaks in cumulative paths and create the basis for new technological paradigms (Lundvall, 1992: p.11).

respectively ("863" Program Annual Report 2004). Thirdly, the National New Product Program (1988) supports mainly high-technology-based firms. In 2005, 1751 projects were financed among which 1620 were conducted by enterprises, accounting for 92.53%. 1106 projects were granted intellectual property rights (National New Product Program Annual Report 2006). In order to map these various research programs more clearly, we put them in the following Table 1.3.

Table 1.3: China's current science & technology programs

Program	Initiating year	Objective	Main operators
National Natural Science Foundation of China (NNSFC)	1986	Support basic research train scientific talents	Universities and research institutes
Key Basic Science R&D Program ("973" Program)	1997	building the capability of original innovation in the domain of basic research	Universities and research institutes
Key State Laboratories Program (182 established laboratories, 2005 data)	1984	Promote the basic & applied research and advanced training	Universities and research institutes
Key Technology R&D Program	1983	Concentrates resources on key and common technologies linked to industrial need and social sustainable development.	Universities, research institutes and firms
High Technology R&D Program ("863" program)	1986	Identifies the emerging new-tech paradigm and helps China integrate into the new paradigm.	Universities, research institutes and firms
National New Product Program	1988	Support the development of new products from high-technology -based firms	Firms

Source: Huang *et al.*, 2004; State Key Laboratories Report 2005; "863" Program Annual Report 2004; National New Product Program Annual Report 2006.

The funding mechanism of these programs is distributed on the basis of projects competition replacing the former planned allocation. The carriers of such projects have autonomy to organize their research teams and manage the funding obtained (Huang *et al.*, 2004; Xue, 2006). The government supervises the process of these projects, and assigns specialized institutions to evaluate the research results arising from the publicly funded projects when they are accomplished. The management of S&T programs pushes executors of S&T programs to take the quality of research into consideration seriously.

1.2.2.1.2 University

In addition to the implementation of national S&T programs, the government decreases the budget for universities but compensates it by granting them more autonomy. The aim of cutting-down government grants is to force universities to generate and commercialize more industry-needed knowledge. Many universities choose to set up new specialties to increase the enrollment of students. These new specialties are characterized by multi-disciplines and market-orientation, such as public relationships management, digital media technology, energy engineering and automation, software engineering and so on. The opening-up of new specialties requires professors to learn new knowledge first, and then transfer it to students. At the same time, universities provide more and more option courses for students. Professors are pushed to widen their knowledge boundaries to meet the changing education system. Some professors reenter universities to refresh their knowledge, others learn by themselves.

And the reward system in universities is in favor of professors who work more and better. Professors can take less teaching workload if they engage in more research projects. If professors get great research achievements, universities, local governments even the central government, will provide them with moral and material awards. The incentive measures motive professors to generate new knowledge.

1.2.2.1.3 Research institutes

The reform of research institutes is another measure that the Chinese government embraced in an effort to enhance knowledge production. These institutes were inactive knowledge generators under planned economy. The State Planning Commission designed research projects and allocated related resources to research institutes. The State Science and Technology Commission (replaced by the Ministry of Technology and Science since 1998) managed S&T activities in these institutes. The rigid funding and R&D management hindered researchers' active participation in innovation.

After 1985, the R&D funding system was reformed to a project-based competition one. Research institutes were forced to be competitive so as to obtain more government grants. As they gained more autonomy in terms of personnel, finance, property management and international cooperation, research institutes introduced the remuneration differentiation policy which motivated research staff and encouraged the mobility of human resources. At the same time, these institutes, especially those doing experiment and development were pushed to merge into enterprises. The government concentrated its funding on the unchanged institutes that primarily conduct basic research (Huang *et al.*, 2004). By 2001, over 300 research institutes were merged into enterprises, over 600 ones changed to become profitable firms and a few were integrated into universities (Gu and Lundvall, 2006). The reform forces those institutes, who seek to profits, to generate new knowledge and commercially explore research outputs.

1.2.2.1.4 Human resources

Human resources build undoubtedly the fundamental of an innovative society (Jakobson, 2007). To become an innovation leading country in the world, the Chinese government has actively taken measures since the 1990s to mobilize researchers with potential competence and attract overseas Chinese who obtained higher education degrees and career experiences abroad. For example, NNSFC has created several funds to send selected young scholars abroad for training and also attract overseas Chinese scholars to return to work in China. Similarly, CAS has launched "Hundred Talents Program" to recruit promising scientists. Between 1998 and 2004, the program of CAS succeeded in bringing back 778 foreign-based Chinese researchers (Jakobson, 2007).

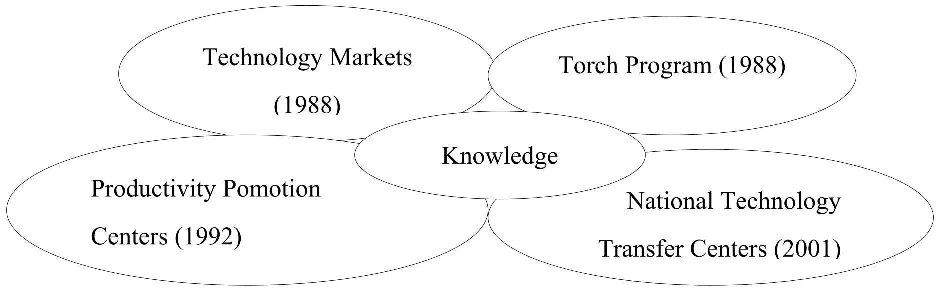
During the period of 2000-2005, the total number of returned overseas Chinese attained over 119, 000[27]. These returnees enjoy preferential policies in terms of remuneration, job assignment, housing, school entrance for their children and in some cases a bulk of funds to initiate research programs. They are expected to help China identify the world new tech-economic paradigm and push Chinese technological progress to approach or reach the world forefront.

1.2.2.2 Infrastructure of knowledge commercialization and diffusion

In line with knowledge generation infrastructure, the government set up technology markets, Torch Program, productivity promotion centers and national technology transfer centers to commercialize and diffuse knowledge. Technology markets and Torch Program were launched in 1988 to facilitate the technology transfer from academy to industry. Productivity promotion centers, established in 1992, were partially the results of the transformation of research institutes. They specialize in consulting services for technology-based small-medium firms. National technology transfer centers were founded in 2001 to commercialize university-specific research outputs (see Figure 1.6). The following parts discuss these four components of knowledge commercialization and diffusion infrastructure in detail.

[27] Data collected from China Statistics S&T Data Book 2006.

Figure 1.6: Infrastructure of knowledge commercialization and diffusion



Source: author herself

1.2.2.2.1 Technology market

Technology markets play an important role in capitalization and diffusion of knowledge. It makes R&D outputs tradable at market prices. The marketable technology is traded in four categories of contracts on the market: technology development, technology transfer, technology consultation and technology service. Enterprises, research institutes and universities are the main players in technology markets.

Technology development contracts dominate transactions on technology markets in terms of contract value. They are usually traded between university and industry. Enterprises entrust universities with technology tasks, or combine with universities to do some research for a specific topic, or even to set up an entity with universities for long-term research in a special field (Xue, 2006). Technology transfer contract is associated with patent licensing. Both industry and academy have expanded patenting activities in recent years, but patent licensing-based technology transfer in China is not as efficient as in developed countries because of the uncertainty of technology and the weak absorptive capability of domestic firms. Technology consultation and service contracts are probably much more flexible ways of transferring knowledge and technology. Such contracts often contain technology information supply, talent training and equipment maintenance. Technology service is the most frequent contract traded in the market.

To sum up, technology development is related to creating new knowledge with much uncertainty. Technology transfer deals with existing knowledge but its commercial potential is uncertain. The other two categories are linked to existing knowledge and the results arising from the contracts are often predictably positive.

Concerning market players, technology trade agencies, research institutes and universities are active technology sellers. And enterprises have gradually dominated technology purchase and sale transactions. This is probably in part due to the transformation of research institutes into enterprises which strengthens enterprise R&D outputs, but maybe also to the growing number of high-technology companies that spinout from research institutes and universities (Bach *et al.*, 2007). Moreover, the change in ownership regime of state-owned companies into limited ownership companies may push limited companies to seek technology from the market.

The overall development of technology market can be measured by the total number and the total value of transaction (Bach *et al.*, 2007). During the period of 1988-2005, the total number of traded contracts fluctuated between 206748 (1990) at the lowest level and 281782 (1998) at the highest level, then it dropped to 265010 in 2005. But the value of transaction remained an upward tendency in parallel with the R&D expenditure in the Chinese system. The average value of contract in 2005 was 21 times more than that in 1988, namely €58.5K against €2.73 K[28]. During the same year, the total value of traded technology contracts in technology markets accounted for 63% of the total R&D expenditure in China. The 63 percent included the ratio of two catogaries of knowledge-intensive contracts (technology development and technology transfer) to the overall R&D spending, namely 36 percent[29]. These figures indicated that the measurable effort towards acquisition and adaption

[28] Foreign exchange rate between RMB and Euro is calculated as: 100RMB = 10EURO.

[29] According to China Statistics S&T Data Book (2006), the total R&D expenditure was 245,000 million RMB in 2005. The total value of traded technology contracts in Chinese technology markets amounted to 155,137 million RMB and the value of technology development and technology transfer contracts was 86,976 million RMB in 2005. (http://www.sts.org.cn/KJNEW/maintitle/MainMod.asp?Mainq=12&Subq=6)

of exisiting domestic technology is around 35% of the effort devoted to creating new technologies.

Technology markets facilitate the circulation of technological information and guide universities and research institutes to generate market-oriented knowledge. Enterprises can use purchased technology from the market to replace in-house R&D activities in case of their weak R&D capability, whereas those technology generators can gain revenues through the commercialization of research outputs in the market. Technology markets have become an important instrument for knowledge diffusion.

1.2.2.2.2 Torch Program

The Torch Program (1988) is a key component of knowledge commercialization and diffusion infrastructure, devoted to the promotion of national innovation through nurturing new technology-based firms. Three institutions were created to carry out the program: Science and Technology Industrial Parks (STIPs), Technology Business Incubators (TBIs) and Innovation Fund for Technology-based Small-Medium Enterprises (Innofund). Market failure problems arising from technology markets, e.g. information asymmetry about the technology, difficult estimation of the value of tradable technology, potential moral hazards of contract executors, can be partially overcome by incubation programs of Torch.

1) Science and Technology Industrial Parks (STIPs)

From the establishment of ***Zhongguancun*** (the first STIP created in 1988 in Beijing) to nowadays, 53 national STIPs and many provincial STIPs have been set up almost throughout China. These STIPs are expected to form clusters of innovation and cooperation between science, industry and education, and to support the start-up creation, the incubation and development of high-tech and knowledge-based business companies. The ultimate objective is to upgrade China's endogenous technological capabilities and fill up the technological gap with advanced countries.

However, the development of China's STIPs seems to be biased against its original target. Its increasing production of export oriented high-tech manufactures and heavy reliance on foreign investment set China's STIPs apart from developing endogenous innovation capabilities. The majority of companies in STIPs are domestic share-holding companies but they have low productivity and export capacity. On the contrary, a small number of foreign and joint ventures have a strong presence in production and exportation. For example, foreign companies represented only 15% of all companies in 2005, but their production output approached 50% of the total and their share of total exports in STIPs reached 85%. Compared with foreign companies in STIPs, domestic firms seem to target more the Chinese market. Share-holding companies amounted to 38% of the total production but 10% of total export[30]. The other companies in STIPs (e.g. state-owned enterprises, collective-owned enterprises and others) were smaller producers and exporters. The differences are probably due to a lack of competitive high-technology of Chinese companies.

The failure of high-tech industrialization with Chinese own S&T resources in STIPs may be compensated by the performance of technology business incubators (TBIs).

2) Technology Business Incubators (TBIs)

Technology Business Incubators (TBIs) are another important institutional innovation under Torch to capitalize research findings. They create a favourable environment for nurturing new technology-based firms to commercially exploit R&D achievements arising from universities, research institutes and enterprises.

The actual performance of TBIs shows that TBIs foster not only endogenous technology-based firms but also imported technology-based firms. University incubators are typical ones to foster domestic technology-based firms. Entrepreneurial professors and students bring their R&D results from laboratories and create new innovative firms in university-affiliated incubators. These technologies may not necessarily be at the world frontier but as least they are new to them or to China. In case of successful performance, these start-ups generate a demonstration effect on other professors and students. More university

[30] All these percentages of 2005 were calculated by author herself and the original data is collected from Source: http://www.sts.org.cn/sjkl/gjscy/data2006/2006-3.htm

research outputs would go out of laboratories and be transferred into new products and services in incubators. From this viewpoint, university incubators promote academic innovation. When these new firms finally fail in the market, entrepreneurs gain at least some experiences which belong to tacit knowledge. Other new entrepreneurs can learn from their experiences. The exchange of experience is a mechanism of knowledge transfer. More details about university incubators will be analyzed in chapter 3.

Incubators for overseas scholars and international business incubators tend to foster foreign-technology-based firms. These incubators are usually subordinated to STIPs so that incubation and high-tech industrialization can be linked together in a same park. Incubated firms bring new foreign technology into China and generate at least demonstration spillover effects on other firms.

The domestic and foreign-technology-based firms assist China in identifying and integrating current new techno-economic paradigms. A set of preferential incubation instruments (e.g. specific business services, networking, financing…) has been implemented to help these incubated firms grow. Various national S&T projects, especially projects financed by Innofund (Innovation Fund for Technology-based Small and Medium Enterprises) are open to new firms. The participation of S&T projects provides new firms with financial access and innovation opportunities.

3) Innovation Fund for Technology-based Small-Medium Enterprises (SMEs)

Innofund represents the main governmental financial support for technology-based SMEs to market innovation. It can accompany SMEs from the incubation stage to the production stage. Innofund is also used as a leverage to attract other investments for the development of SMEs. It helps SMEs solve the problem of market failure linked to difficult financial access.

The selection criteria of Innofund emphasize innovativeness, R&D resources and Chinese ownership of SMEs. It indicates that Innofund prioritizes endogenous technological innovation of SMEs. Indeed, technology-based SMEs have become a very important innovation force in the Chinese NIS. It is consistent with what an officer from the National Development and Reform Commission said (2007):

"*Over 75% innovative products are provided by SMEs (in China) and these firms hold over 80% patents of the total*".

1.2.2.2.3 Productivity Promotion Centers (PPCs)

Productivity promotion centers are deemed to be a bridge between universities, firms and research institutes. They are composed of a group of intermediary and consulting organizations, established since 1992 throughout the country to support small-medium innovation-based firms. Some centers are transformed from public research institutes. The Ministry of Science and Technology together with local S&T Commissions manage these centers in terms of macro-policies and business guidance. These centers provide consulting services in terms of management, technology, the applications of S&T projects and technology-based services (e.g. technology promotion, diffusion and product testing, information collecting services, human resource services, training services and incubation services to enterprises) (see Table 1.4). According to the Chinese Association of Productivity Promotion Centers, there were 1331 PPCs distributed spatially in 31 provinces, autonomous regions and municipalities in 2006. Among them, 79 PPCs were sectoral PPCs. Local governments are the major financial supporters for PPCs, accounting for 86% of total funds.

Table 1.4: Services provided by Chinese productivity promotion centers in 2006

Items	Contents	Quantity
Consulting services	Management, technology and others	155100 (times)
	assistance in S&T project applications	12900 (units)
Information services	Various information provisions	69.61(million items)
Technology services	Technology development, diffusion Products testing etc.	30000 (times)
	Introduce technology into firms	2924 items
	Organize technology transaction activities	1912 times
Training services	Talents training	2.47(million persons)
Human resources services	Introduce talents for firms	10571 persons
Incubation services	Support and foster technology-based firms	9029

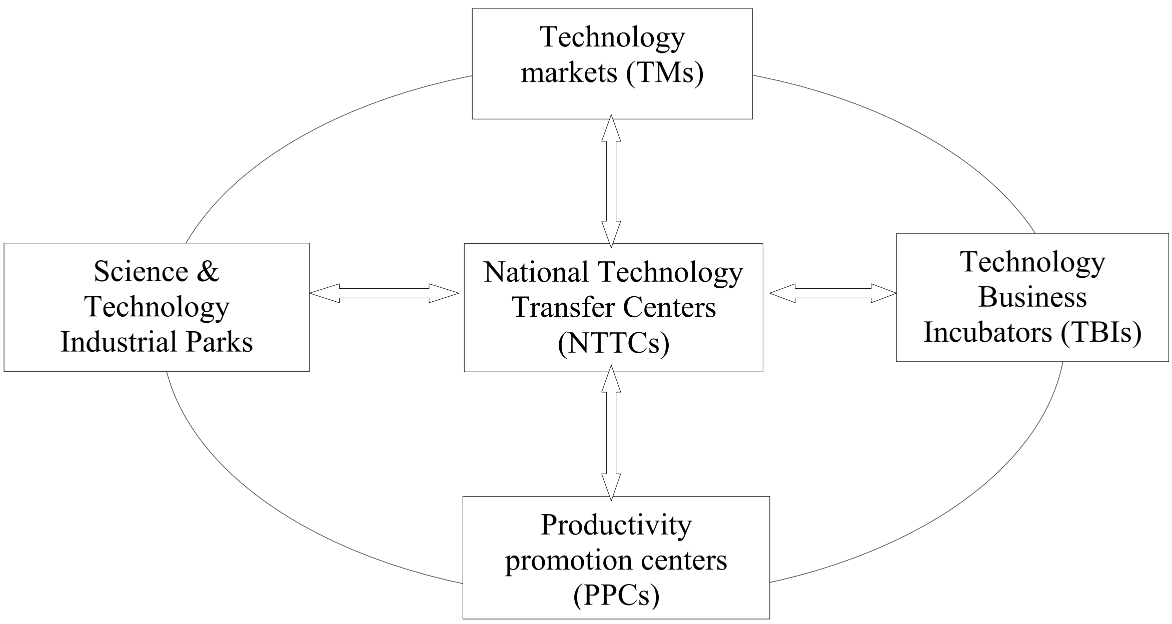
Source: http://www.cppc.gov.cn/zxkx/200742084829.htm

Table 1.4 shows that the services of PPCs are diversified but focus on information provision for firms. Small medium-sized enterprises (SMEs) usually go to PPCs for problem-solving solutions. PPCs take advantages of their wide networks with universities and research institutions and introduce experts in responsive to the demands of SMEs. PPCs are helpful to reduce SMEs' transaction cost, because the comparatively complex services of PPCs basically meet SMEs demands and SMEs do not necessarily ask for innovation assistance from other institutions. PPCs are a complementary institutional innovation for technology business incubators and technology markets to capitalize and diffuse knowledge. They promote the growth of technology-based SMEs.

1.2.2.2.4 National Technology Transfer Centers (NTTCs)

The co-existence of technology markets, Torch Program and productivity production centers does not necessarily mean there are institutional interactions among them. The emergence of national technology transfer centers (NTTCs) in 2001 facilitates the connection building between these three components of knowledge commercialization and diffusion infrastructure (see Figure 1.7).

Figure 1.7: Networking of the components of knowledge comercilization and diffusion infrastructure



Source: author herself.

Following the western model, NTTCs were created to manage univeristy intellectual property rights issues and technology transfer activities. NTTCs establish connection with TM, TBIs, Innofunds, STIPs and PPCs. The connection keeps the related institutions informed about research outputs so as to facilitate the marketability and diffusion of academic achievements. Indeed, NTTCs act as intermediaries between university, industry and market.

Chapter 2 will analyze the performance of NTTCs in details.

1.2.2.3 Endogenous innovation improved?

China's national innovation system has evolved to promote endogenous innovation for about two decades. How about China's endogenous innovation now? Hereafter we address the question in terms of published academic papers, patentability and high-tech outputs. Publications are used as an indicator of S&T output, whereas patents and high-tech industries are indictors to measure the innovation capability.

1) Scientific publications

In recent years, more and more Chinese authors' names appear in international academic journals. Chinese academic papers demonstrated an exponential increase (see Table 1.5). The number of Chinese scientific publications collected by SCI (Science Citation Index), ISTP (Index of S&T Proceedings) and EI (Engineering Index) reached 153374 pieces in 2005, approaching 7% of the world's total, behind the USA (29.8%), the UK (7.2%) and Japan (7.1%)[31]. About 30% of these publications resulted from China's major national S&T programs[32]. Elite research institutes and universities were major publishers, such as the Chinese Academy of Sciences, Tsinghua University, Beijing University and so on. China has become the fourth leading nation in terms of its share of the world's scientific publications.

[31] See China S&T Statistics Year Report 2006. http://www.sts.org.cn/zlhb/2007/3.1.htm#4

[32] According to National Statistics Bureau of China, NNSFC published 13610 academic papers in overseas journals, 8218 for "973 Programs", 1637 for Key Technology R&D Program and 9830 for "863 Program" in 2004.

Table 1.5: Chinese academic papers collected by three international indexes and ranking

	2000		2001		2002		2003		2004		2005	
	N.	R.	N.	R.	N.	R.	N.	R.	N.	R.	N.	R.
Collected by SCI	30499	8	35685	8	40758	6	49788	6	57377	5	68226	5
Collected by ISTP	6016	8	10263	6	13413	5	18567	6	20479	5	30786	-
Collected by EI	13163	3	18578	3	23224	2	24997	3	33500	2	54362	2
Total	49678		64526		77395		93352		111356		153374	

Source: http://www.sts.org.cn/KJNEW/maintitle/MainMod.asp?Mainq=12&Subq=1
N.: the number of papers
R.: China's ranking in the world

Along with the exponential increase of scientific publications, the citation rates of Chinese publications are increasing exponentially as well (Zhou and Leydesdorff, 2006). Six disciplinary publications were placed in the world top 10 in terms of the citation rate of papers during the period of 1996-2005, namely material science, chemistry, mathematics, synthesis, engineering technology and physics. According to the SCI database, China ranked world 13th in terms of citation rate between 1996 and 2005 which was advanced as compared to world 19th between 1992 and 2001[33]. The growth of publications and of citation rate indicates that China's knowledge generation infrastructure is efficient to facilitate the creation of new knowledge.

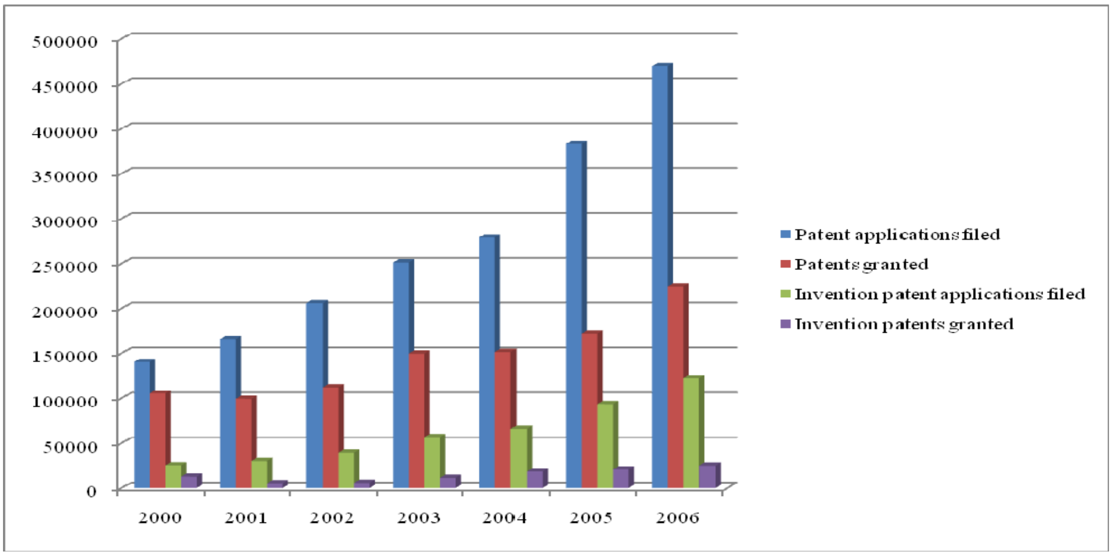
2) Patentability

In terms of patentability, China has increasingly expanded its patenting activities in the State Intellectual Property Office of China (SIPO, see Figure 1.8). The annual average growth of filed patent applications attained over 20% between 2000 and 2006. The number of filed patent applications and granted patents in 2006 were over 3 times and twice as compared to the corresponding patenting in 2000, namely 470,000 units and 224,000 units respectively. Domestic firms have dominated the patentability. During the period 2001-2006, the growth of on-duty invention applications filed by domestic enterprises amounted to 43.2%. In 2006, they acquired 51.3% of all invention patents granted to domestic patenters (MOST, 2007).

[33] See China S&T Statistics Year Report 2006. http://www.sts.org.cn/zlhb/2007/3.1.htm#4

Some technology-based Chinese firms, like ***Huawei*** and ***Zhongxing***[34], are active and competitive innovators but the majority of Chinese enterprises have weak R&D capabilities. Universities follow the growth of firms' patentability. Their R&D expenditure accounted for nearly 10% of the total but they acquired over 30% of all invention patents granted by SIPO in 2005[35]. Universities have become a very important source of innovations. On the contrary, affected by a decreasing budget and the number of units, the R&D outputs of research institutes have decreased in recently years.

Figure 1.8: The evolution of China's patenting activities in SIPO, unit (10 000 pieces)



Source : data collected from China S&T Statistics Data Book 2002, 2004 and 2006.
Note: data of 2006 collected from S&T Statisitcs Report, Vol.14, n.405, the Ministry of Science and Technology, 2007.

Figure 1.8 shows that the growth of China's patentability focuses on less-R&D-intensive utility model and design patenting. Design patents and these modifications may have meaning in the marketplace, but they do not represent significant innovations (Liu and

[34] In 2006, three domestic enterprises were in the top 10 firms in terms of invention patents applications filed in China and the rest were foreign invested firms. Huawei and Zhongxing, two domestic telecommunication equipment manufacturers, took the first and the second top places respectively (MOST, 2007).

[35] The percentage was calculated by the author on the basis of the data which were collected from China S&T Statistics Data Book 2006.

White, 2001). Foreign firms still dominate invention patenting activities, holding about 88%[36] of all granted invention patents. The slow increase of invention patents mismatches with fast growing scientific publications. China ranked 12th among 39 countries in terms of patents granted by triadic patent families (OECD, 2007). The ranking is much lower than China's world 4th ranking in scientific publications. It shows that Chinese enterprises have weak a absorptive capability from open science on one hand, and on the other hand universities and research institutes may not generate much market-oriented knowledge to meet industrial needs.

With respect to overseas patentability, China displays a remarkable growth although its world position is moderate. Its patent applications to the European Patent Office (EPO) increased from 743 units in 2003 to 1403 units in 2005 at the aggregate level. About 27% of these applications were foreign co-invested. The granted patents in triadic patent families[37] to China attained 433 units in 2005 compared to 177 units in 2003, which lagged far behind 16368 USA, 15239 Japan and 6266 Germany. China occupies rank 1 place among all non-OECD countries but only rank 12 among 39 sampled countries by OECD (OECD, 2007).

The expansion of patentability shows that China has strengthened its awareness of IPRs protection and improved its S&T capability. But the slow growth of invention patents and the large gap of patentability with developed countries reflect that China needs to restructure its supporting infrastructure for endogenous innovation.

3) **High-tech industries**[38]

High-tech industries are linked to knowledge-capital-intensive investments, innovation and high-added value so that they can be used as one of the indicators to measure a nation's innovation capability in a knowledge-based economy.

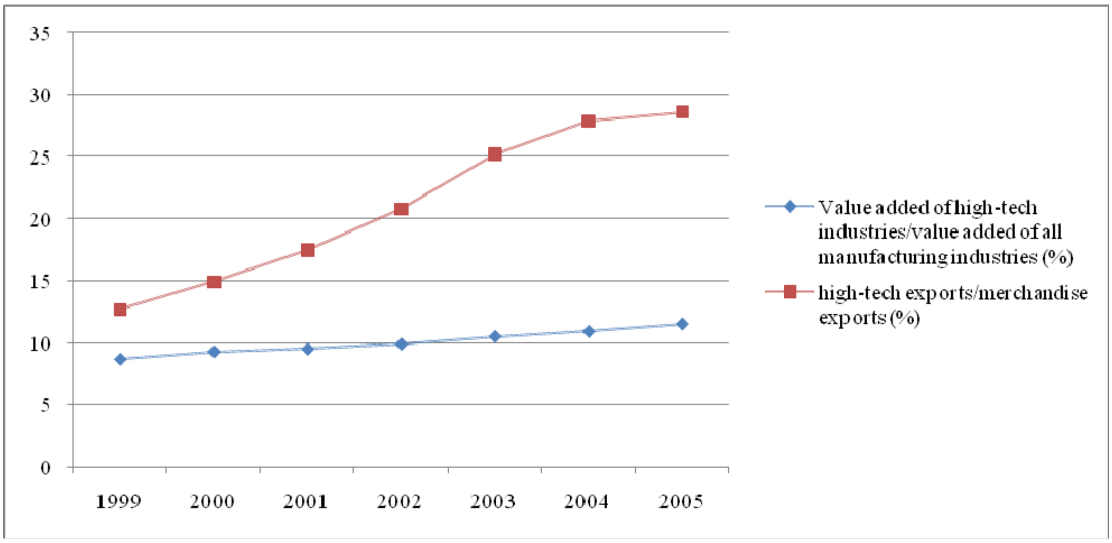
[36] The percentage was calculated by the author on the basis of the data which were collected from China S&T Statistics Data Book 2002, 2004 and 2006.

[37] Patents applied for at the European Patent Office (EPO), the Japan Patent Office (JPO) and granted to the US Patent & Trademark Office (USPTO), estimations for priority year 2005. The priority date corresponds to the first international request for protection.

[38] According to OECD (2007), high-tech industries refer to aerospace; office and computing equipment; drugs and medicines; radio, TV and communication equipment; medical, precision and optical instruments.

China's high-tech industries have achieved progress since 1990s. Their development upgrades manufacturing industries at a general level and improves the export structure of merchandises. The ratio of value added of high-tech industries to that of all manufacturing industries grew from 8.7% in 1999 to 11.5% in 2005. The percentage of high-tech exports to total merchandises exports also increased from 12.7% to 28.6% (see Figure 1.9). Indeed, Chinese high-tech products have presented a strong performance in the world market. Considered the third biggest world high-tech manufacturers, China's high-tech manufacturing industries acquired 18.4% of the export market of all OECD behind USA 19.5% (OECD, 2007).

Figure 1.9: Chinese high-tech industries between 1999 and 2005



Source: China S&T Statistics Data Book 2006.

The progress resulted from the strong presence of foreign firms in electronic and telecommunication equipments and computers and office equipments manufacturing. Foreign firms created 65.5%[39] of the total value added in 2005. SOEs had the similar scale as foreign firms by the end of the 9th five-year plan (1995-2000) but lagged behind foreign firms and other domestic firms in 2005. The embarrassing situation of SOEs can probably be explained by the lack of core technology. The current R&D intensity[40] of Chinese high-tech industries is merely 1.05%, much lower than the level of the USA, Canada, the UK and Japan which is over 10% (CSTSAR, 2007). The growth of other domestic firms in high-tech industries is

[39] See China S&T Statistics Annual Report (CSTSAR) 2006. http://www.sts.org.cn/zlhb/2007/3.1.htm
[40] R&D intensity refers to the ratio of R&D expenditure to added value of products.

most probably due to the integration into foreign firms' global assembling process chain. When identifying a new tech-economic paradigm and benefiting from China's comparative advantage in manpower and assembling specialization, foreign firms present high-tech products labeled 'Made in China' to the world market. From this viewpoint, the effect of supporting infrastructure on endogenous innovation is not as efficient as on imported technology.

1.2.3 Conclusion

This section has analyzed the construction of China's national innovation system (NIS) and the output of its performance. The Chinese NIS is found to be built along two dimensions. One dimension is characterized by technology importations, the other dimension by endogenous innovation. The effect of institutional changes under the NIS on technology imports has proved a great success. A large bulk of FDI has flowed into China and embedded foreign technology has improved production productivity but limited to those Chinese firms linked to foreign partners. These Chinese firms gain short-term profit but probably loose long-term competitiveness due to heavy reliance on foreign technology. Further non-technological innovation is necessary to stimulate Chinese firms, especially state-owned enterprises to become dynamic and active learners.

The effect of supporting infrastructure on endogenous innovation is probably viewed as semi-efficiency. China has made great progress in world scientific publications, patenting activities and high-tech industries. However, numerous academic publications contrast with the slow growth of invention patents. China's patentability centers on less-knowledge-intensive utility model and design. Domestic firms have a weak innovation capability in spite of some moderate progress. The development of Chinese high-tech industries is found to be associated with a strong presence of foreign firms in electronic and telecommunication equipments and computers and office equipments manufacturing.

All these facts indicate that the supporting infrastructure is efficient to facilitate knowledge generation but not conclusively efficient to promote knowledge commercialization and diffusion. The inefficiency is related to the weak capability of domestic firms to absorb research outputs arising from open science. It is also probably in part due to insufficient connection between the technology market, the Torch Program, productivity production centers and national technology transfer centers. A further reform of the Chinese NIS is needed to strengthen firms' absorption and innovation capability and to strengthen interinstitutional interactions. Next section 1.3 discusses how universities play their roles in building up the competitiveness of domestic firms in the Chinese NIS.

Section 1.3 The role of universities in the Chinese national innovation system

Universities are broadly viewed as important players in the national innovation system (Lundvall, 1992, 2007; Nelson, 1993, 2000; OECD, 2002; Mowery and Sampat, 2005; Edquist, 2005; Xue, 2006). The existing literature confirms the contribution of universities to national innovative and competitive performance but argues that the influence of university research depends on industrial sectors. Pharmaceutical industry is proved to be the largest beneficiary of university research (Nelson, 1986; Jaffe, 1989; Klevorick *et al*., 1995).

Cohen *et al*. (2002) demonstrate university research importantly affects industrial R&D across much of the US manufacturing sector through different channels. According to them, industry can benefit from university research through open science (publications & reports, informal interaction, meeting & conferences, employment of graduates), semi-open science (consulting, contract research, cooperative R&D projects, personnel exchanges) and market-based science (patents and licenses). Among these three channels, open science holds the predominant place to provide R&D information to industry. This most probably results from the strong absorptive capability of American firms. These firms have the capability to absorb the new ideas and methods generated by universities and turn them into new products.

In China, many domestic firms can not directly benefit from scientific publications because of weak absorptive capacity to exploit academic research outputs. Their technological capability remains at a low level. In this sense, collaboration with universities, which posses a relatively higher level of technology, is an effective way to achieve competitive innovation capabilities (Motohashi and Yun, 2007). Moreover, as firms are the central players in a national innovation system, the upgrading competitiveness of firms reflects the advancement of a nation’s competitiveness. The role of universities in the Chinese NIS is oriented to improve domestic firms’ competitiveness, namely absorptive and innovative capabilities. Adopting Cohen *et al.*’s research findings, we analyze how universities can contribute to the upgrading of Chinese firms’ competitiveness through training and education (open science), R&D collaboration (semi-open science) and creation of spin-offs (market-based science) in this section.

This section 1.3 is composed of two parts. Section 1.3.1 analyzes current competitiveness of Chinese firms. Section 1.3.2 discusses the contribution of universities to the improvement of firms' competitiveness.

1.3.1 Current competitiveness of Chinese firms

To analyze current competitiveness of Chinese firms, we should understand what competitiveness means. As we consider competitiveness as absorptive and innovative capabilities, we explain the meanings of absorptive and innovative capabilities first, and then use related indicators to evaluate these capabilities. After the analysis, we get a general picture of current competitiveness of Chinese firms.

1.3.1.1 Notions and indicators

The most widely cited definition of absorptive capability is given by Cohen and Levinthal (1990) as a firm's ability to develop and improve its new products through the adaptation and application of the external technology stock. It also includes the ability to internalize technology created by others and modify it to fit the firms' specific applications, processes and routines (Cf. Narula, 2002). The absorptive capability emphasizes the ability to advance the existing technology originally coming from outside.

Concerning innovative capability, it is defined as the skills and knowledge needed to effectively absorb, master, and improve existing technologies, and to create new ones (Kynge, 2000). To build up innovation capability, several elements are required to be integrated into firms, such as management ability, R&D ability, manufacturing ability, reserve ability and marketing ability (Cf. Li *et al*., 2007). In contrast with absorptive capability, innovative capability emphasizes both generating in-house new technology and upgrading external technology.

To assess absorptive capability, R&D intensity and education intensity are used as measurement indicators (Eun *et al*., 2006). To measure innovative capability, there are three major established indicators: R&D expenditure, patents and complexity of product design

(Oslo, 2005). Following these proposed indicators, we determine our analytical indicators as below:

a) Indicators to measure firms' absorptive capability: R&D intensity (GERD), business enterprises R&D (BERD) and education intensity[41].

b) Indicators to measure firms' innovative capability: R&D personnel and new products[42].

We add new products to assess firms' innovation capability because the emergence of a new product depends on not only firm's R&D capability but also other abilities, like management, marketing and production skills. Innovation does not merely mean technological advancement but also organizational and institutional improvement. R&D and patenting activities indicate more the capability of firms to generate new knowledge but reflect less firms' ability of practicing knowledge, like production, management and marketing ability. New products resulting from new generated knowledge can better reflect the overall innovation capability of firms. Remember that innovation is distinguished from invention because innovation turns new ideas into products or service whereas invention retains ideas.

After understanding the related notions and indicators, we discuss the current absorptive capabilities of Chinese firms first, and then go on to discuss their innovative capabilities.

[41] GERD (%) = Gross domestic expenditure of R&D/GDP
Business enterprise expenditure on R&D (BERD): it covers R&D activities carried out in the business sector by performing firms and institutes, regardless of the origin of funding. The business enterprise sector includes all firms, organizations and institutions whose primary activity is production of goods and services for sale to the general public at an economically significant price, and also includes the private and non-profit institutes mainly serving them (OECD Science, Technology and Industry Scoreboard 2007). http://titania.sourceoecd.org/vl=3103434/cl=12/nw=1/rpsv/sti2007/a5.htm
Education intensity (%) = Government budgetary expense for education/GDP (%)

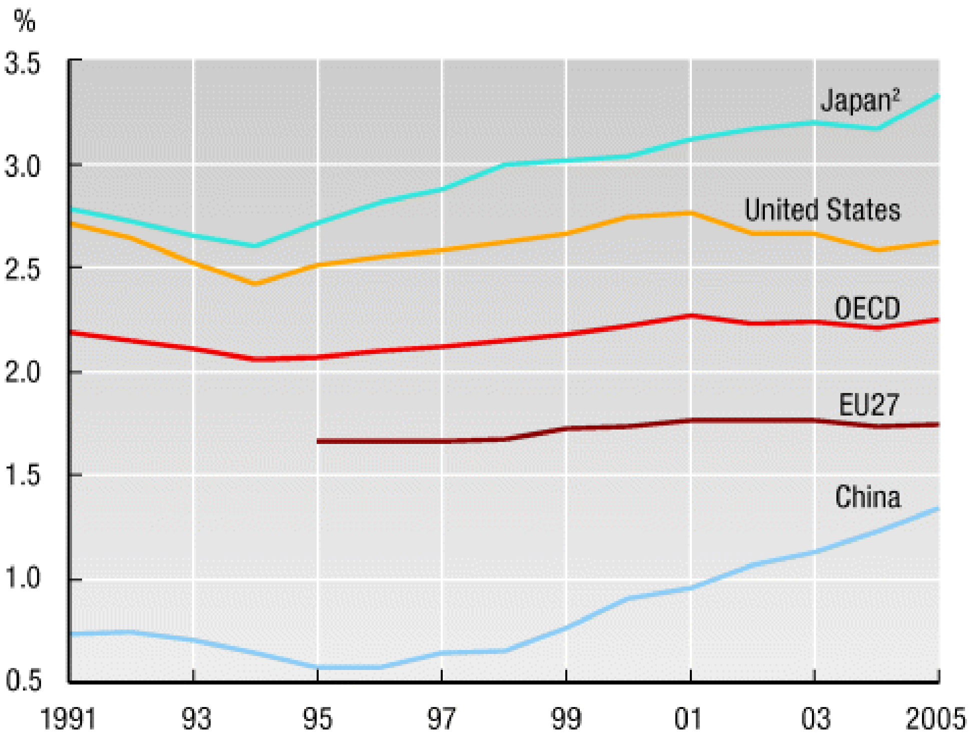
[42] Patents should be used to measure innovation capabilities of firms. As we have discussed it in section 1.2.2.3, we do not talk about it again here.

1.3.1.2 Absorptive capabilities of firms

1) R&D intensity

R&D intensity displays a country's absorptive effort. China's GERD gives evident of growth in recent years, attaining 1.34% in 2005. The progress is associated with firms', especially LMEs' growing R&D expenditure. But it is still lower than European and OECD countries' level and much lower than some strong innovators like USA and Japan (see Figure 1.10). The R&D intensity of Japan was about 2.5 times than that of China in 2005.

Figure 1.10: Trends in R&D intensity [1] by area, 1991-2005
As a percentage of GDP

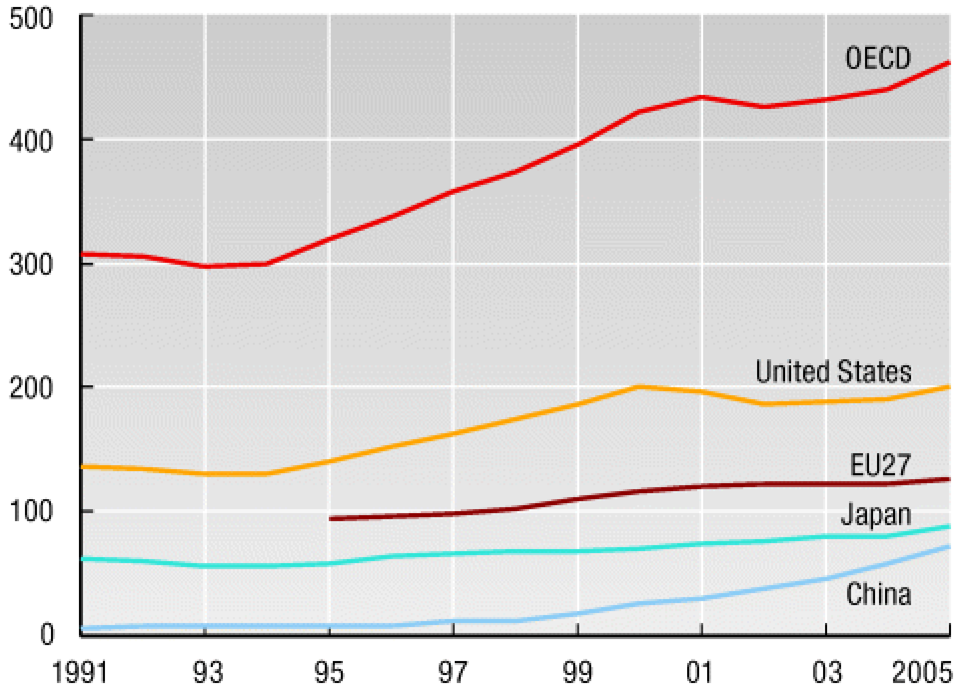


1. Gross domestic expenditure on R&D as a percentage of GDP.
2. Data are adjusted up to 1995.
3. USD of 2000 in purchasing power parity (PPP).

Source : OECD Science, Technology and Industry Scoreboard 2007
http://oberon.sourceoecd.org/vl=4414362/cl=13/nw=1/rpsv/sti2007/ga2-3.htm

Business enterprise R&D (BERD) reflects firms' desire and effort to produce new products and service. BERD retained an upward tendency in China from 1991 to 2005 but was lower than Japan, EU (27), USA and OECD total (see Figure 1.11). In 2005, BERD reached US$78.7 billion (in current PPP), or roughly the combined value for Germany, France and Italy (OECD, 2007). The growth of BERD is most probably linked to certain public policies which encourage R&D investment, such as preferential tax polices, favorable bank loans as well as the right to depreciation fixed assets like facilities (Jakobson, 2007)[43]. Moreover, the participation of firms in national S&T programs (e.g. Key Technology R&D Program, "863" Program and National New Product Program) and outsourcing technology from technology market facilitates the growth of BERD.

Figure 1.11: Evolution of business enterprise R&D in selected areas, 1991-2005.



Source: OECD Science, Technology and Industry Scoreboard 2007
http://titania.sourceoecd.org/vl=3103434/cl=12/nw=1/rpsv/sti2007/ga5-4.htm

[43] These advantages were all mentioned in the draft of revised S&T Progress Law under consideration in early 2007. Ministry of Science and Technology, "法制办就科技技术进步法（修订草案）征求意见" [Legal Office seeks opinions on the revised draft of the S&T Progress Law], 22 March 2007, http://www.most.gov.cn/yw/200703/t20070326_42340.htm.

Large medium-sized enterprises are the main spenders of R&D expenditure in China, sharing 66% of total BERD in 2000 and increased to 75% in 2005. However, only 24.1% of total LMEs conducted in-house innovation activities. The increased R&D expenditure may have been used to outsource foreign or domestic technology or both. Compared with medium-scale industrial firms, Chinese large firms show more innovation motivation. 55.7% of large firms conducted innovation whereas merely 21% of medium firms did so[44]. This is in part due to the concentration of R&D personnel and financial resource in large firms.

In general, Chinese firms are improving but insufficient in-house innovation activities have not filled up the gap of GERD and BERD compared with world leading innovation countries yet. China needs more incentive policies to motivate firms to increase R&D investments.

2) Education intensity

Expenditure on education is an investment that can help to train human innovators, enhance productivity, and contribute to economic growth. In contrast with OECD countries, education intensity in China is also backward. OECD countries invest a substantial proportion of national resources in primary, secondary and tertiary education. For instance, as a whole, these countries spent 6.1%[45] of their collective GDP in education institutions in 2002 (OECD, 2006).

China's education intensity in 2002 was less than 3% of its GDP and the target to attain 4% in 2005 was not realized. The lower education investment may decrease the quantity and quality of human innovator training and education. In fact, the expensive university tuition has brought heavy economic burden to poor Chinese families. The government provides financial support to poor students but the support is limited in certain specialties and universities. These specialties and universities may be not responsive to students' interest. Given that these students do not enjoy university courses after enrollment,

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44 See http://www.stats.gov.cn/tjsj/qtsj/dzxgyqyzzcxtjzl/2005/t20060330_402376465.htm; http://www.stats.gov.cn/tjsj/qtsj/dzxgyqyzzcxtjzl/2006/t20061026_402360121.htm.

45 In 2000, the public education expenditure in OECD countries approached 5% of their collective GDP (Cf. Lerais *et al*., 2006, pp.94).

it not only damages students' study enthusiasm but also wastes educational resource. Under this situation, training human innovators seems far away a target.

After analyzing R&D and education intensity, we can say that the absorptive capability of Chinese firms is improving but is still backward as compared to developed countries. Next we turn to analyze the indicators (R&D personnel and new products) to measure the innovative capabilities of Chinese firms. The following section 1.3.1.2 discusses this in detail.

1.3.1.3 Innovative capabilities of firms

1) R&D personnel

R&D personnel include researchers, technicians and support staff. They are employed directly in R&D activities. Researchers are viewed as the central element of R&D system. They are professionals engaged in the conception and creation of new knowledge, products, processes, methods and systems and are directly involved in the management of projects (OECD STIS, 2007). R&D personnel, especially researchers working in business sector, are the fundamental determinant of firms' innovation capabilities.

The number of R&D personnel and business researchers in China increased very fast as compared to many OECD countries, with an average growth rate of close to 9% and 15% respectively over the past five years (see Figure 1.12 and Figure 1.13). This may be partly due to the increased number of postgraduate students who perform R&D activities and the merger of research institutes into enterprises. The rising number of R&D human resources provides a sound base for Chinese firms to improve innovative capabilities.

Figure 1.12: Growth of R&D personnel, 1995-2005

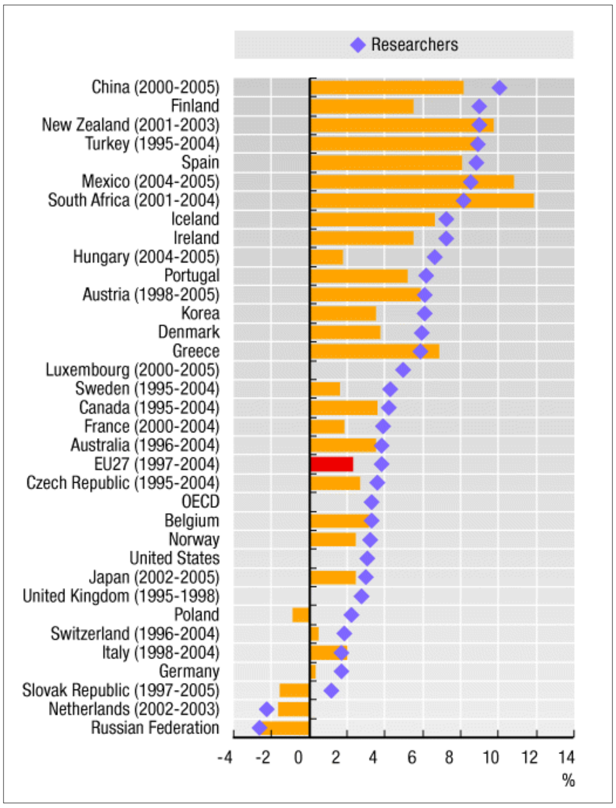
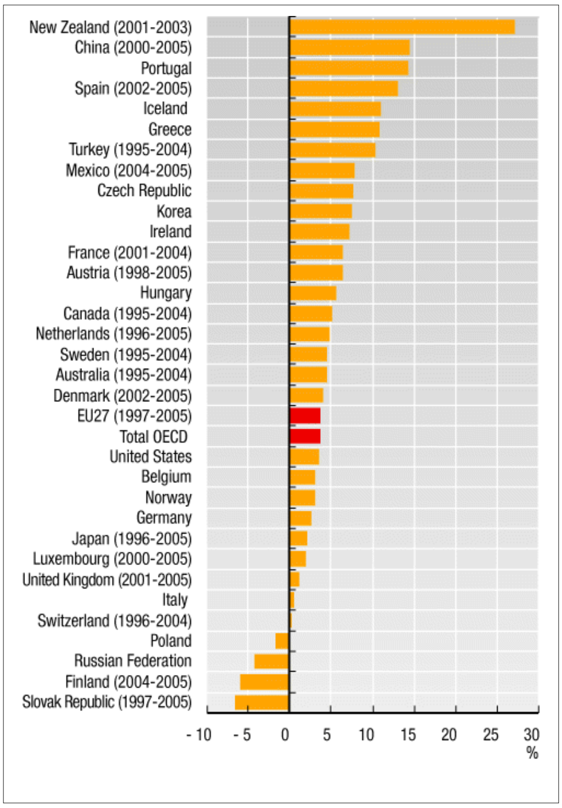


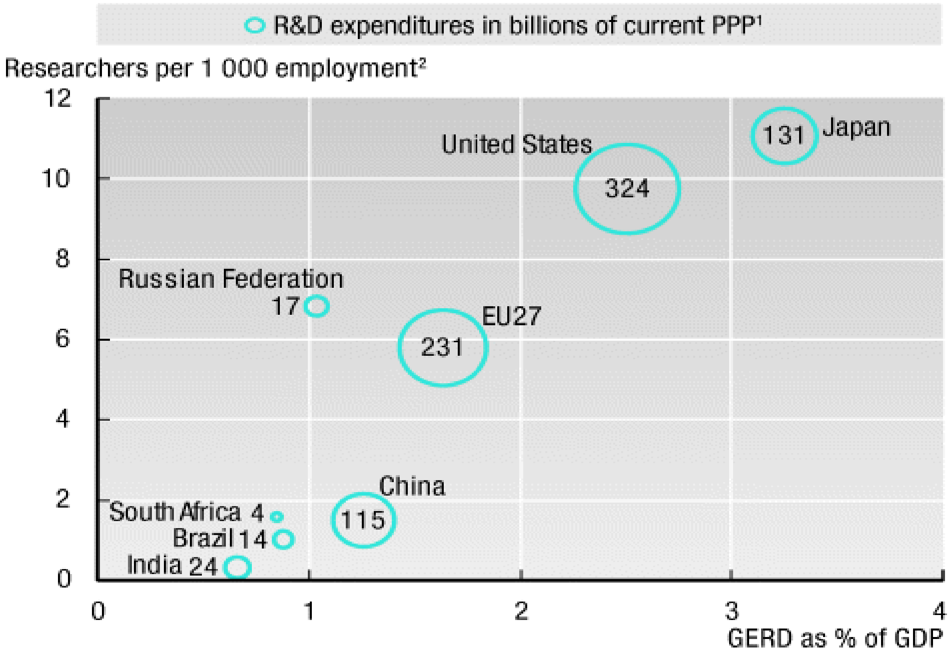
Figure 1.13: Growth of business researchers, 1995-2005



Source: OECD Science, Technology and Industry Scoreboard 2007
http://fiordiliji.sourceoecd.org/vl=1099946/cl=42/nw=1/rpsv/sti2007/gb7-2.htm
http://caliban.sourceoecd.org/vl=15200610/cl=21/nw=1/rpsv/sti2007/gb8-2.htm

However, if we take a closer look at the number of R&D personnel per 1000 employees, China lags behind Japan, the USA, the EU (27) and Russian Federation (see Figure 1.14).

Figure 1.14: R&D in the OECD and non-OECD area, 2005



1. The size of the bubble represents R&D expenditure in billions of current USD in PPP; data for Brazil, India and South Africa are for 2004.
2. For researchers per 1 000 persons employed: India 2000 and EU27 2004.
3. Based on data in constant 2000 prices. Different reference years: Argentina 1996-2000; Brazil and India 2000-04; China 1995-99; Croatia and Chile 2002-04; Cyprus, Estonia and Hong Kong (China) 1998-2000; Malta 2002-05; and South Africa 1997-2001 and 2001-04.

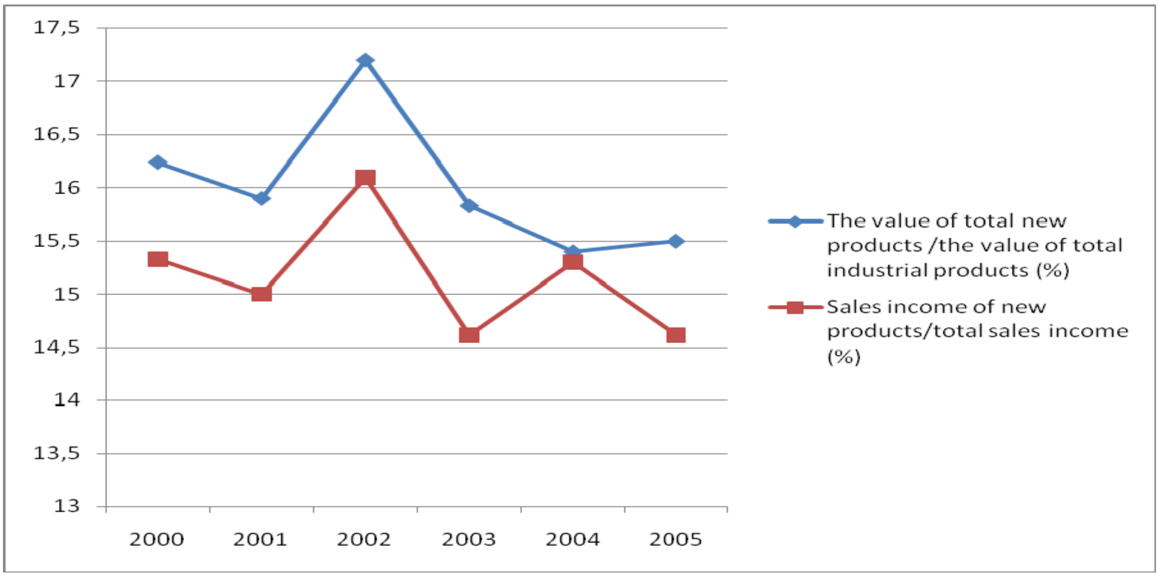
Source: OECD Science, Technology and Industry Scoreboard 2007http://puck.sourceoecd.org/vl=18494021/cl=15/nw=1/rpsv/sti2007/ga4-1.htm

The Figure 1.14 displays that there is not a very big difference of R&D expenditure in current PPP between Japan and China. But the number of researchers per 1 000 employments in Japan is much higher as compared to the Chinese counterpart, almost 6 times more. Continuously heavy investment in education and R&D activities helps Japan retain its leading place in innovation. If we compare the EU (27) with China, we can see China's R&D intensity approaches the EU (27) level, but China merely holds about one third of the number of researchers in the EU (27). Thus, China should continue increasing not only R&D investment but also researchers to upgrade the innovative capabilities of firms.

2) New products

New products reflect firms' overall capabilities in transforming new knowledge into visible new goods. In contrast with firms' rising patentability[46], the growth of new products does not give very conclusive evidence (see Figure 1.15). The value of total new products as compared to the value of total industrial products attained the peak of 17.5% in 2002 but soon dropped to 15.5% in 2005. The ratio of new products' sales to total sales was even lower, standing only at 14.61% in 2005. One reason may be a result of LMEs' insufficient capability to transform their rising patents into commodities, while the other reason may be linked to LMEs' less knowledge-intensive patents which add little value to new products.

Figure 1.15: The evolution of large medium-sized firms' new products in terms of value and sales income



Source: China Science & Technology Statistics.
http://www.sts.org.cn/KJNEW/maintitle/MainMod.asp?Mainq=8&Subq=1;
http://www.sts.org.cn/KJNEW/maintitle/MainMod.asp?Mainq=8&Subq=2

To sum up, Chinese firms has upgraded their absorptive and innovative capabilities in spite of a big gap with foreign counterparts. A strong growth in terms of business enterprise R&D, R&D personnel and patents does not generate significant new products. From this viewpoint, Chinese firms still have no enough absorptive and innovative capabilities. How to overcome such weakness of Chinese firms so as to improve the whole nation's competitiveness? Observing strong innovators, like Finland, Japan and USA, we find that

[46] Details about firms' patentability can be found in section 1.2.2.3.

they are world leading countries not only in R&D expenditure but also in researchers per 1 000 employees. Chinese firms can determine the increase of R&D expenditure themselves, but training researchers mainly depend on universities. Thus, universities are an important support for Chinese firms.

1.3.2 The contribution of university to industry

In this section, we employ Cohen *et al.*'s research findings (2002) to analyze three possible channels for university to help build firms' competitiveness: training and education (open science), R&D collaboration (semi-open science) and creation of spin-offs (market-based science).

1.3.2.1 Training and education

"*A well-educated and well-trained population is important for the social and economic well-being of countries and individuals. Education plays a key role in providing individuals with the knowledge, skills and competencies to participate effectively in society and the economy. Education also contributes to an expansion of scientific and cultural knowledge.*"

--OECD, 2006.

As compared to primary and secondary education, university training and education is more knowledge-intensive, professional and career-oriented. Postgraduates and Ph. D students are a potential driving force of innovation. The competitiveness building of firms relies on these students' innovation competences. This section discusses the linkage between training and education and firms' competitiveness, and then analyzes how universities help firms improve competitiveness through training and education.

1.3.2.1.1 Training and education and firms' competitiveness

Many developed countries emphasize university's third role in transferring technology to industry since the 1990s so as to retain national competitiveness. China follows the tendency but also stress on university's traditional mission in education. This is determined by China's specific context.

Western product users are usually critical consumers and they are the second most important innovation sources for innovative firms, following suppliers (Eurostat, 2007). In China, the influence of users on producers is not as strong as western countries. For example, the service after sales concentrates in large medium-sized firms and is not popular in small firms. Over 50% of population is peasants who have no strong consciousness about the novelty of commodities. Firms seldom receive critical feedbacks from rural consumers. Urban consumers are aware of the novelty of commodities but they are often tolerant clients rather than critical people. Thus, the enlargement of education enrollment and training talents with critical minds can push firms to innovate in products and service.

In addition, the progress of Chinese national innovation system is linked to FDI and endogenous innovation. Much prior research has demonstrated that the scope of international technology spillovers from FDI may depend on the absolute technological level or "absorptive capacity" of local firms (Borensztein *et al*., 1998; Glass and Saggi, 2002; Durham, 2004). Recent study on Chinese high-tech industries (Liu and Buck, 2007) argues that learning by exporting and technological import by licensing have a direct, positive link with domestic innovation performance but whether local firms benefit the externalities generated by MNCs' R&D is influenced by firms' absorptive capability and deliberate learning effect. Concerning China's endogenous innovation, universities and public research institutes have created a large bulk of new knowledge. However, the shortage of R&D personnel hampers Chinese firms to commercially exploit scientific research outputs. Our study in section 1.3.1 indicates that Chinese firms have improved absorptive and innovative capabilities but not enough to support China's further economic development.

To upgrade the current absorptive and innovative capabilities of Chinese firms, it requires universities to provide firms with high-skilled engineers and scientists. Japan and Korea have caught up with developed countries during the 1960s and 1980s due to the provision of well-trained engineers and scientists by universities (Kim, 2000; Eun *et al.*, 2006). Thus, the growth of human capital investment in innovation is a key element for China to catch up, especially in today's knowledge-based economy.

The following Table 1.6 displays from a quantity point of view that university training and education is directly connected with the competitiveness firms. The number of scientists and engineers in Chinese large medium-sized enterprises has a significant correlation with the number of applied patents and also has a positive correlation with the value of new products and sales incomes of new products.

Table 1.6: Correlation coefficients

	1	2	3	4	5
1. R&D expenditure (billion€) of LMEs	1				
2. Number of Scientists & Engineers	0,91385021	1			
3. Number of patents applied	0,998367795	0,902969453	1		
4.Value of new products (billion€)	0,997010507	0,887171761	0,997251981	1	
5.Sales income of new products (billion€)	0,993137208	0,864414034	0,994731858	0,998854484	1

Note: 2. Number of Scientists & Engineers means the number of scientists and engineers (10000 persons) engaged in technical development in large medium-sized enterprises (LMEs).
3. Number of patents applied refers to the number of on-duty patents applied by LMEs in SIPO.

Since well-educated scientists and engineers have proved to be helpful to strengthen firms' competitiveness, we analyze the contribution of university to industry through training and education in section 1.3.2.1.2.

1.3.2.1.2 Training and educational reform

To compensate for the shortage of human innovators for Chinese firms, universities try to increase the quantity and the quality of education to cultivate human resources with critical minds and good learning skills.

1) Expansion of Chinese higher education

Regular higher education institutions[47] have expanded student enrollment and teaching staff employment in recent years. The enrollment of students at undergraduate level

[47] Regular higher education institutions include public universities and colleges. Adult and private higher education institutions are excluded in the Table 1.7.

and at college level[48] dominants the expansion of higher education, followed by teaching staff, students at Master and Doctor level[49] (see Table 1.7).

Table 1.7: Expansion of Chinese higher education institutions between1998-2006

Item	1998	1999	2000	2001	2002	2003	2004	2005	2006
Number of regular higher institutions (unit)	1022	1071	1041	1225	1396	1552	1731	1792	1867
Student enrollment (undergraduate level and college level, 10 000 persons)	108.36	159.68	220.61	268.28	320.50	382.17	447.34	504.46	546.05
Student enrollment									
-doctor level (10 000 persons)	1.50	1.99	2.51	3.21	3.83	4.87	5.33	5.48	5.60
-master level (10 000 persons)	5.75	7.23	10.34	13.31	16.43	22.02	27.30	31	34.2
Employment of full-time teaching staff (10 000 persons)	40.72	42.57	46.28	53.19	61.84	72.47	85.84	96.58	107.6

Source: National Education Development Report 1998-2006, Ministry of Education.

Student enrollment at various level focuses on science and engineering disciplines. In 2005, 48% of total enrolled students at master and doctor level were registered in science and engineering fields, and 41.2% of registered students at undergraduate and college level in the same fields. These graduates are the most probably destined to occupy jobs in R&D activities and the large source of excellent science and engineering graduates can lay a solid foundation for ameliorating Chinese firms' absorptive and innovative capabilities. Science and engineering disciplines are traditionally privileged by excellent students because the labor market provides more employment opportunities to graduates with such two disciplinary backgrounds.

According to the statistics of Chinese labor market, the manufacturing sector created 24.9% of total employments and there was a strong demand for higher skilled engineers in 2006. The upgrading of traditional industrial sectors, the concentration of FDI in manufacturing and the increasing tendency of R&D centers created by multinational companies (MNCs) in China, all these factors require the Chinese labor market to provide more qualified graduates with science and engineering education background. For example, a

[48] Students at undergraduate level mean those students have a four-year full time study in universities, whereas students at college level mean those students have a three-year full time study in colleges.
[49] The training of graduates of master and doctoral level is devoted to regular higher education institutions and some public research institutions, like Chinese Academy of Sciences.

UNESCO report (UNECSO, 2005) underlines that in future years, multinational companies in China will create about 75 000 jobs of senior managers in the field of engineering and in the future 5 years, those MNCs would need to employ 750000 Chinese university graduates accounting for 60% of all graduates in corresponding period, which would leave about 40% of all graduates for equivalent jobs in domestic or smaller foreign companies. MNCs usually afford an attractive package of welfare to hunt for excellent graduates. Students who want a job with good payment often choose science and engineering discipline as a major then management science as an option.

2) Quality improvement of university training and education

The growth of student enrollment improves the higher education attainment. The key issue for regular higher education institutions is to train innovative labor force meeting the industrial need. Under the centrally planned economy, teaching and research activities in universities were divorced from industry. The government was responsible for working out teaching programs, drawing up plans for student enrollment and job assignment on their graduation, designating enterprises to provide students with internship sites and learning situation (UNESCO, 2005). Universities trained students under the planned teaching program without considering the need of labor market. When the command economy is transforming to a market-oriented economy and enterprises are reformed to self-management entities, universities are required to provide qualified professionals for China's industry sectors, to transfer technology achieved in basic researches and key researchers tackling technological difficulties into productivity, to develop a complete system for knowledge innovation and industrial upgrade (UNESCO, 2005). Moreover, universities are exposed to the challenges of the constrained budget, competition from private higher education institutions and the pressure of labor market. Universities have reformed training and education program to face these challenges, paying more attention to the needs of industry. Industry has become the second important source of university R&D funding, after the government. And the weak competitiveness of industry seeks for human capital and technical support from universities. Teaching programs, qualification of teaching staff, pre-job training and scientific research are put at the core of university training and education reform.

Teaching programs

Universities have gained more autonomy in curriculum design. The central issue of teaching programs is how to identify appropriate courses to explore students' knowledge background and train them as initiative takers, creators and problem solvers. Certain leading universities (e.g. Tsinghua University and Beijing University) take a global vision to trace the development of science and labor markets, targeting to train not only 'China-needed' talents but also 'world-needed'. The contents and methods of teaching courses are adjusted to adapt to the requirements.

First, universities provide students more optional courses which are helpful to develop student competence. These optional courses are not limited by campus teaching resources but are open to competitive professors from other universities, business professionals and foreign teachers. Teaching staff are responsible for the contents of option courses. The open academic atmosphere pushes professors to make their courses more attractive. Bilingual courses or courses in a full foreign language are widely encouraged in campus.

Second, some pioneer universities shorten the timetable of obligatory courses and set up short term summer schools for students. The summer training lasts between 6 and 9 weeks, providing student interest-based option courses. These courses are important to develop the innovation capability of students.

Third, universities in the east regions invite enterprises to work together on decision about course setting, contents and methods of teaching, student internship and assignments, mobility of researchers, etc. The interaction with industry in education helps university identify the needs of the industrial world and promote the quality of talent training. Students benefit from university-industry linkage in terms of learning some practical experience from entrepreneurs and also possibly acquiring future internships and jobs from industry.

In total, universities have opened many new optional courses to explore students' theoretical and practical knowledge and to narrow the gap between skills of graduates and business sector needs. These courses are composed of foreign teacher-given courses, courses introducing new emerging technology, courses on intellectual property rights, practical courses, self-cultivation courses and so on. For instance, Shanghai Jiaotong University changed its curriculum in automotive engineering, opening new specialties (such as automobiles and energy resources or White Body Manufacturing Process for Automotives) according to new development of automotive design. Suzhou Industrial Park Institute of Vocational Technology (SIPIVT) has pushed the idea even further by introducing "order driven" training model, selecting students together with enterprises, but also cooperating with them in designing labs, setting specialties and courses and creating teaching programs; in addition, MNCs established around the universities (such as Nokia, Siemens or Samsung) frequently provide equipments on which students can experiment and apply modern research techniques and methods. Different processes of the SIPIVT have already been ISO 9001 qualified in 2004 (Cf. Bach *et al*., 2007). SIPIVT's average employment rate has been over 98% for 8 years in row and about 1/3 graduated have obtained employment in the world's top 500 enterprises (UNESCO, 2005).

The success of SIPIVT demonstrates that the university-industry cooperation in education facilitates the training of industrial needed talents. Training talents with international vision, strong innovative mind, scientific knowledge structure, comprehensive practical ability, communication ability and team-work spirit are the core of the reform of teaching program.

Qualification of teaching staff

Accompanying the continuously upward student enrollment, many universities have set up new beautiful teaching buildings, student dormitories, laboratories and other good facilities by using governments' allocation funds, tuition and bank loans. However, the quality of education is not ameliorated as fast as the construction of university hard infrastructure. First, the number of teaching staff has not increased to correspond with the big increase in student enrollment. Second, the merger of universities and colleges in 1990s has led to the decrease of teaching quality. Some college teachers with only bachelor degrees give course to undergraduate students. The mismatch between university physical facilities and education quality is unfavorable to achieve China's goal of becoming an innovative power. Universities have recognized the weakness and emphasize the construction of software. Three measures have been carried out: attracting foreign and overseas Chinese scholars; raising employment criteria (e.g. doctoral level); giving students the rights to assess teaching quality.

China has a very rich overseas "brain resources", distributed in USA, Europe and Japan[50]. To tap high-level intellectuals, especially overseas Chinese scholars, universities provide various preferential policies: attractive salary, flexible employment-term contract, start-up funds for research and other incentives. During the period of 2000-2005, the number of returnees has increased markedly, attaining 119,000 returnees. But as compare to the total overseas Chinese students 599,000, only 20% returned in 2000-2005[51]. The inward brain resources to universities bring some new ideas, new teaching models and their network with international scientific community, which promote the quality of education.

Before the 1990, it was possible for students with a bachelor degree to get a teaching position in universities. These graduates usually take enrollment in a master or doctor level training after employment. Nowadays, a doctor degree is a 'must have' to get a teaching position in research universities. Other criteria of selection, like scientific publications and research activities, heavily influence university's recruitment decision making. The raised selection criteria push new university entrants to become competitive. At the same time, stimulated by the attractive rewards given to new entrants, some incumbent teaching staff tries to upgrade their study background. For example, many young university professors prepare for a national examination and winners are supported by National Natural Science Funds for a short-term overseas study (6 months or one year).

Besides, students are given autonomy to assess the quality of teaching. At the end of each term, professors receive anonymous feedbacks and comments from students given through internet. Professors, especially young professors, are forced to ameliorate teaching quality. One reason is for gaining academic reputation, the other is because the assessment result influences professor incomes. A good professor can attract more students to attend his/her class which increases his or her teaching load. The volume of teaching load is directly bound to professor wages.

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[50] According to the report of OST (2006), 68796 Chinese students were enrolled in European Union universities at master and doctoral level, accounting for 9.7% of total registered foreign students in 2003. And 92774 registered in USA, sharing 15.9%; 51656 in Japan with 59.7%.

[51] The statistics is collected from China S&T Statistic Data Book 2006.
http://www.sts.org.cn/sjkl/kjtjdt/data2006/2006-3.htm

Although the qualification of teaching staff is uneven in Chinese universities, the traditional teaching model (e.g. one textbook serving for several years, force-feed duck education model, etc.) is no longer adaptable to the goal of cultivating creative talents. As more and more competitive talents join university teaching forces, the quality of education would be improved.

Pre-job training-internship

Internship is obligatory for Chinese students before receiving bachelor degree. When universities were subordinated to industrial departments under the government, students were sent to these departments-affiliated enterprises for six-month internships before graduation. After the reform of higher education system, internships as well as job assignment have been decentrally organized. Students either seek for an internship by themselves or universities recommend them to firms which have signed an agreement on cooperative training with universities. University-affiliated firms and start-ups created by professors usually provide internship opportunities for students. Take Tsinghua University for example, some tens of enterprises controlled by Tsinghua Holding Co, Ltd, which sign contracts worth nearly €10 million with Tsinghua professors annually, receive students at different levels for internships. Beijing Jiaotong University and Suzhou have also established regular industry-university cooperation with many enterprises. These enterprises offer internship positions and allocate financial rewards to students as well as to teachers. In fact, some students have got part-time jobs during their academic term to practice their learning as well as to compensate their daily expenses and tuition.

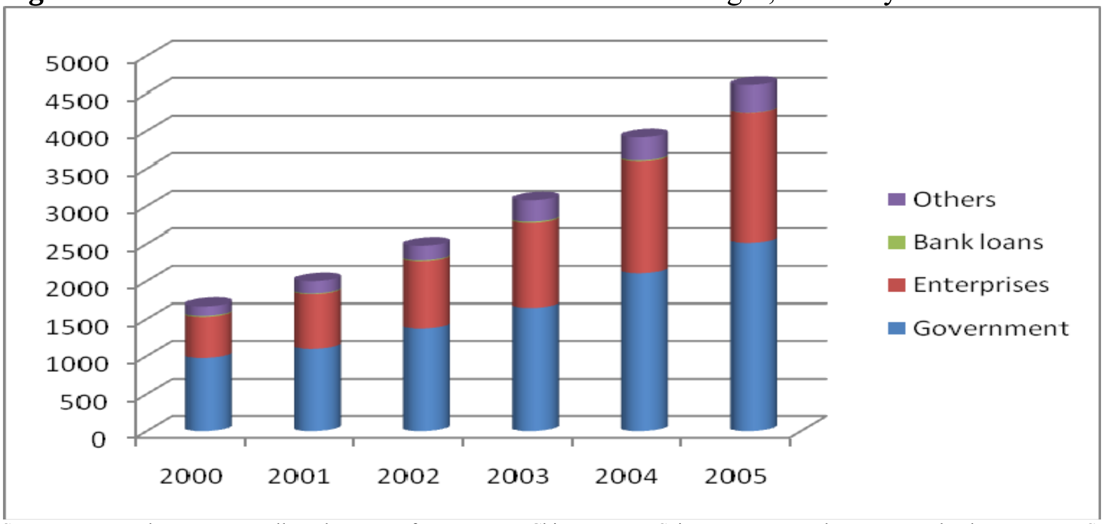
Through internship, students gain practical experience and identify their job orientation on one side, and on the other side, enterprises shorten the cost of talent-hunting and pre-job training. Students act as intermediaries between universities and enterprises. The feedback from students helps universities identify which specific training is needed by the industrial world. The information exchange between students and enterprises can help firms discover and exploit advanced research output arising from universities.

1.3.2.2 R&D collaboration

R&D collaboration is one of the key types of university-industry interactions (EC, 2001). Industry can benefit from university technical support and the provision of human capitals. We analyze the collaboration from the point of view of university's R&D funding structure and of firms' outsourcing.

Since 1990s, the R&D funding structure of university has changed. The government decreased its funding share from 66.6% in 1990 to 54.9% in 2005 whereas industry witnessed an increase from 20.8% to 36.7%[52]. Concerning the source of university S&T funding[53], industry accounted for a slightly higher share. During the period of 2000-2005, the government source dropped from 58.5% to 54.6% whereas funds from industry increased from 33.3% to 37.5% (see Figure 1.16). In key universities, expenditure on scientific research accounts for 50% of the total educational expenditure, and 50% of that comes from enterprises (UNESCO, 2005).

Figure 1.16: Source of S&T funds to universities and colleges, monetary unit: €million



Source: data collected from China Science and Technology Statistics http://www.sts.org.cn/KJNEW/maintitle/StruMod.asp?UnitCode=070105000000&Title=%27 科技经费筹集额%27&

The industrial sector plays a decisive role in supporting university scientific research. The closer university-industry relationship links industry with the technology frontier and

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[52] Data collected from «2006 中国科技统计年度报告», http://www.sts.org.cn/zlhb/2007/3.1.htm

[53] The boundary of S&T funding is larger than R&D funding. It supports not only R&D activities but also the commercialization activities of R&D output and services related to R&D activities.

also links scientific research with markets. Enterprises have, to some degree, improved the capability of problem-solving and promoted innovation.

Although industry has become the secondary R&D expenditure supporters for universities, the share of R&D expenditure outsourced by enterprises to universities is low, namely 7.6% in 2005. Firms with a long-term perspective on R&D are expected to collaborate with universities in R&D activities target (Motohashi and Yun, 2007). Data on R&D projects for the years 2000 and 2003 conducted by large and medium-sized enterprises (LMEs) also displayed that the percentage of cooperation with higher education institutes was not high, about 8%. Most of the R&D projects were implemented in an independent way by LMEs, and the proportion of these projects even slightly rose from around 70.8% up to 73.5% (see Table 1.8).

Table 1.8: R&D projects of large and medium-sized enterprises

	2000		2003	
Number of R&D projects	23576		24665	
% of projects chosen by enterprises	69.8%		75.5%	
	Number of projects	%	Num. of projects	%
With overseas institutes	471	2%	686	2.8%
With higher education institutions	1883	8%	2091	8.5%
With governmental research institutes	1787	7.6%	1791	7.3%
With foreign-owned enterprises	190	0.8%	162	0.7%
With other enterprises	2067	8.8%	1393	5.6%
Independent implementation	16701	70.8%	18132	73.5%
Others	477	2%	410	1.7%

Source: The Ministry of Science and Technology (2006).

The low percentage of joint R&D projects with universities most probably results from the promotion of LME's innovation capability. R&D personnel in LMEs remains upward, increasing from 329 000 in 2000 to 606 000 in 2005[54]. The remarkable growth is in part attributed to a flow from university graduates to industry. Another part can be deduced from public research institutes. Because during the period of research institution reform (1999-2005), 1104 out of 1239 research institutes have been transformed or incorporated in

[54] Source from http://www.stats.gov.cn/tjsj/ndsj/2006/indexch.htm

companies, which bring 114000 S&T personnel to these companies[55]. The massive increase in R&D personnel is an actual or potential driving force for firms' endogenous innovation.

1.3.2.3 University spin-offs

In contrast with training, education and R&D collaboration with industry, university spin-offs is a more direct way for university to improve industry's competitiveness. Section 1.3.2.3.1 discusses the relationship between university spin-offs and firms' competitiveness and section 1.3.2.3.2 analyzes two types of university spin-offs.

1.3.2.3.1 University spin-offs and firms' competitiveness

There were 29774[56] Chinese LMEs in 2005 but only 24.1% of them conducted self-innovation activities. LMEs hold advantages in size and R&D expenditure in comparison with small firms. Small Chinese firms account for 90% of all firms, spending 14% of total R&D expenditure. Most small Chinese firms do not engage in S&T but those who do, tend to be more S&T intensive than LMEs with S&T (Lundin *et al*., 2006). To survive in the market, small firms either imitate the same products as LMEs but with lower cost or produce new products. Since LMEs have become aware of intellectual property rights protection in recent years and consumers with good education background and high purchasing power would not tolerate fake products, imitations have become costly and risky. As a result, small firms tend to present self-innovative products to the market. Among these small firms, university technology-based spin-offs are a strong force to push LMEs to conduct innovation. They tap university technology frontier and make competitive products. To compete with these rivals, the strategy of LMEs is to either acquire them or produce more attractive new products. Under the market competition, the innovation capabilities of firms would be improved as a whole.

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[55]See research report «2005 年改制科研机构科技实力与产业发展概况»
http://www.most.gov.cn/kjtj/tjbg/200612/t20061229_55425.htm

[56] The number of large medium- sized enterprises in 2005 is collected from China Statistics Year Book2006. The percentage of self-innovation LMEs is collected from:
http://www.stats.gov.cn/tjsj/qtsj/dzxgyqyzzcxtjzl/2006/t20061026_402360121.htm

1.3.2.3.2 Creation of university spin-offs

Chinese universities are one of the key institutions to carry out national research projects. The fruitful research output arising from publicly financed research projects and a growing political pressure to change university traditional role of education and research, promote university entrepreneurship. University has actively taken part in commercializing academic findings since 1980s. University-run enterprises (UREs) are a very typical way for universities to market their research output and link with industry. Later, the ambiguous ownership of UREs causes a lot of management problems. Universities turn to create intellectual property (IP)-based spin-offs to transfer technology. These university spin-offs are an important institutional innovation to promote Chinese national innovation system. We analyze these two types of university spin-offs: university-run enterprises in section 1.3.2.3.2.1 and intellectual property-based spin-offs in section 1.3.2.3.2.2.

1.3.2.3.2.1 University-run enterprises (UREs)

University-run enterprises are viewed as traditional university spin-offs in China. It emerged in the 1950s and was used to provide students short-term internship or apprenticeship in a real production environment. During the period of 1980s and 1990s, university-run enterprises enjoyed a booming development due to the reform of S&T management system (Liu and Jiang, 2001). Engineering schools and other schools strong in applied disciplines are pioneer creators of UREs. UREs are characterized as firms which are typically established, staffed, funded, and managerially controlled by the mother institutions (i.e. universities). They are usually endowed with the de facto right to exclusively take advantage of the mother institutions' various assets including research outcomes or resources, such as financial resources, physical spaces, manpower, social links, and even the title of the university as a commercial brand (Eun *et al*., 2006). We analyze the performance of UREs at a general level, and then discuss the distribution of UREs in this section.

1) The performance of UREs at a general level

The evolution of UREs' performance has progressed from technology related service provision to commercial technology exploitation. Between 1980s and 1990, university-run enterprises were run under three models. The first one was university-run factories or print shops. The second model was to bring university technologies to create joint commercial entities with enterprises outside universities. The third model was technology development companies created by universities and departments (Xue, 2004). UREs act as experimental entities for universities to commercialize academic achievements, train innovative talents and contribute to the development of regional innovation capabilities. Although the number of UREs shows a decreasing tendency, the share of technology-based UREs has been increasing in recent years (see Table 1.9).

Table 1.9: The development of science & technology university-run enterprises, monetary unit: million €

Year	Number of UREs	Number of S&T UREs	Share of S&T UREs	Sales of S&T UREs	Net profit of S&T UREs	Tax paid by S&T UREs	Income of S&T UREs to university
1997	6634	2564	38.6%	1848.7	158.3	68.7	68.4
1998	5928	2355	39.7%	2149.7 (16.3)	158.4 (0.06)	83.1 (21)	65.8 (-4)
1999	5444	2137	39.2%	2673.1 (24.3)	180.4 (13.9)	109.6 (31.9)	139.2 (11.6)
2000	5451	2097	38.4%	3681.2 (37.7)	280.3 (55.4)	187.9 (71.4)	84.6 (-39.2)
2001	5039	1993	39.6%	4477.5 (21.6)	239.8 (-14.4)	200.9 (6.9)	77.8 (-8)
2002	5047	2216	43.9%	5390.8 (20.4)	186.3 (-22.3)	259.2 (29)	76.1 (-2.2)
2003	4839	2447	50.6%	6680.7 (23.9)	147.3 (-21)	294.0 (13.4)	77.4 (1.7)
2004	4563	2355	51.6%	8067.8 (20.8)	238.6 (62)	384.8 (30.8)	82.5 (6.6)

Source: S&T development Centre, Ministry of Education 1999, 2005, figures in ( ) indicate growth rates.

Table 1.9 shows that S&T affiliates accounted for 38.6% of total UREs in 1997 and rose to 51.6% in 2004. It indicates that universities focus on the development of technology-based spin-offs. The growth of sales income and tax paid from UREs signals that universities do contribute to the build-up of national and regional competitiveness.

University-run enterprises not only generate economic revenue but also create jobs, train innovative talents and conduct R&D activities. In 2004, 4563 UREs employed 294 600 personnel and 31.67% of them were S&T staff. The number of total staff in S&T affiliates on average was higher than in university-run enterprises, namely 78 against 65[57]. It displays that UREs are small but tend to technology-based firms. UREs also received 759 300 internship students and trained 7077 students at Master and Doctor level (see Table 1.10). On the one hand, students test their academic knowledge and receive pre-job training; on the other hand, enterprises get access to new university knowledge and good skilled manpower. The linkage between university and real world can be enhanced through the mobility of students.

Table 1.10: General statistics of Chinese university-run enterprises in 2004

Characteristics of university-run enterprises	Number of enterprises
Total	4563 (including 2355 S&T UREs)
Number of employees (10 000 personnel)	29.46
- S&T staff (10 000 personnel)	9.33
Receive internship students (10 000 personnel)	75.93
- Train Ph.D students	1488
- Train students at Master level	5589
Number of patents granted (unit)	2949
Specialized techniques owned by UREs (unit)	2838

Source: S&T development Centre, Ministry of Education 2005.

Concerning R&D activities, UREs comprised of 5.6%[58] of total patents granted to Chinese firms in 2004. The R&D activities of UREs can lead to more value-added production. The growth of their sales income may support this viewpoint. The sales income remained upward although the number of S&T affiliates fluctuated between 1997 and 2004.

Another characteristic of university-run enterprises is displayed in Table 1.11 which shows that these firms have become more production-oriented and the linkage between universities and domestic partners (most probably firms) has been enhanced when we compare UREs in 2000 with those in 2004. For instance, in terms of business orientation, 41.5% of university-run enterprises were engaged in industrial production in 2004 against

[57] Figures collected from S&T development Centre, Ministry of Education 2005.
[58] In 2004, Chinese firms got 6128 domestic service invention patents, 22299 utility model patents and 23830 design patents (China Statistics Year Book, 2005)

36.6% in 2000. In terms of ownership structure, the percentage of university wholly-owned enterprises dropped from 87.9% in 2000 to 66.7% in 2004. On the contrary, the percentage of joint ventures with domestic partners was almost tripled but it decreased for joint ventures with foreign partners. This phenomenon indicates that universities and domestic enterprises are the main force to commercialize endogenous technology arising from university research. In addition, universities mostly centralize the management of their affiliated enterprises. 2004 witnessed that 88.3% of UREs were managed at university level which came down to 77.4% in 2000. This is because, UREs managed by universities are said to perform better than those managed at faculty or department level (Xue, 2004).

Table 1.11: Compare the characteristics of university-run enterprises in 2000 and 2004.

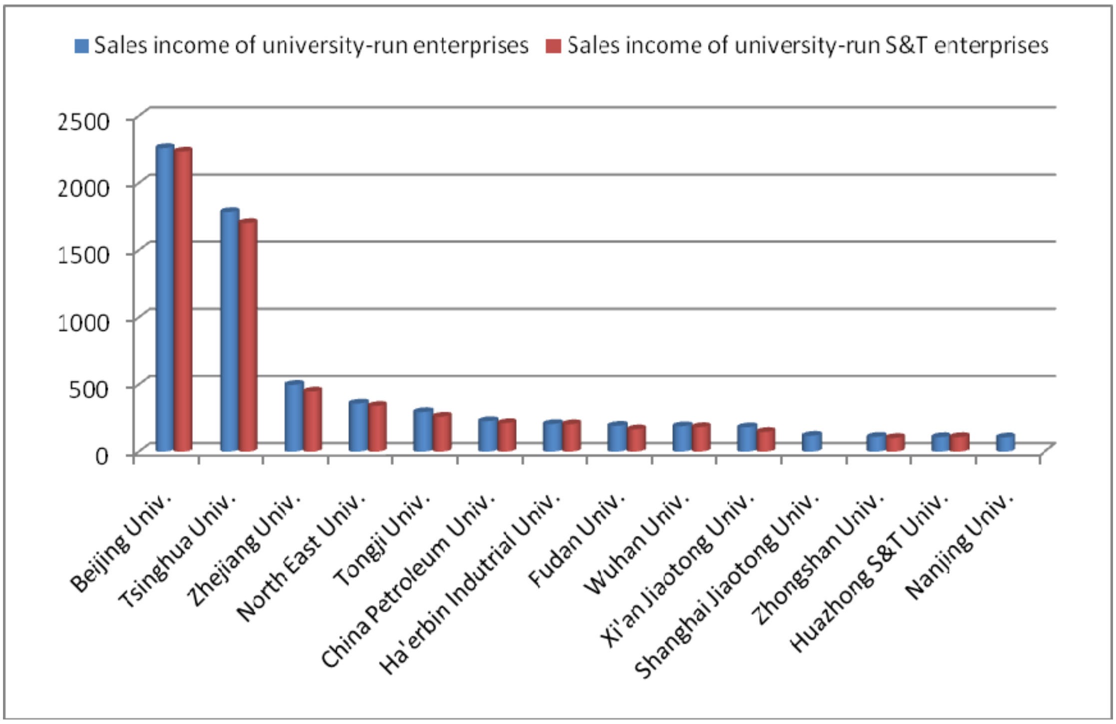
Characteristics of university-run enterprises		Number of enterprises	
		2000	2004
Total		5451	4563
Business orientation	Industrial production	1995 (36.6)	1893 (41.5)
	Trade & related service	849 (15.6)	425 (9.3)
	Others	2607 (47.8)	2245 (49.2)
Ownership property	Wholly-owned by universities	4793 (87.9)	3044 (66.7)
	Joint ventures with domestic partners	556 (10.2)	1478 (32.4)
	Joint ventures with foreign partners	102 (1.9)	41 (0.9)
Level of management control	Universities	4217 (77.4)	4031 (88.3)
	Faculty, department	1234 (22.6)	532 (11.7)

Source: S&T development Centre, Ministry of Education 2005. Figures in ( ) indicate the ratio to the total number of university-run enterprises.

2) The distribution of UREs

Do all university-run enterprises generate a large bulk of economic return? According to Xue (2004), while there are many university-run enterprises (UREs) in China, only a very small proportion of the enterprises are successful, like *Beida Fangzheng, Tsinghua Tongfang* and *Dongda Aerpai*. The same is true from the point of view of universities. Many Chinese universities have university-run enterprises, but only a small number of them have successful ones, like Beijing University and Tsinghua University. Successful and influential UREs are concentrated in a small number of prestigious universities. Indeed, top 14 universities affiliated enterprises created 6634.9 million € of sales income in 2004, accounting for 68.5% of entire sales income generated by UREs. Similarly, the sales income of top 12 universities affiliated S&T UREs attained 6110.1 million €, sharing 75.7% of total. Except Shanghai Jiaotong University and Nanjing University, the top 12 universities in terms of URE sales income were also the top 12 in terms of sales income created by S&T UREs. In these elite universities, S&T UREs generated almost over 90% of sales income created by all UREs (see Figure 1.17).

Figure 1.17: Sales income of university-run enterprises (UREs) and those of university-run science & technology enterprises (S&T UREs) generated by top 14 and 12 universities respectively, monetary unit: million €



Source : Science &Technology Development Centre, Ministry of Education 2005.

Why do sales incomes highly concentrate in a small number of universities? If we take a close look at these 14 universities, we can discover the rationality of the result. For instance, these 14 universities belong to “211 project”[59] and research universities (except China Petroleum University: research-teaching-orientation). Tsinghua University, North East University, Tongji University, China Petroleum University, Ha’erbin Industrial University and Huazhong Science &Technology University are classified as “engineering type” universities (Xue, 2006). Strong engineering research and talented faculty and students provide consolidate technology backbone for university-run enterprises. The rest 8 universities are comprehensive prestigious universities in China, engaging in both basic and applied research. Their academic strength and reputation contributes to the strong growth of university-run enterprises. In 2004, 33 university-run enterprises went to the stock market, engaging in information technology industry, medicine, agricultural products, retailing, generic S&T activities.

In terms of the location of UREs, 24.57% of UREs (1121 UREs) entered university science parks in 2004. These firms accounted for 67.29% of net profits generated by all UREs, employing 114 600 personnel. And 35.6% of them were scientific staff. 106 400 students did internship in these firms and these firms also took part in training 4155 Ph. D students and graduates[60]. This somewhat indicates that those located in university science parks perform much better than off-park UREs. On one hand, enterprises entering science parks are healthy and technology-based firms; on the other hand, incubation services and other facilities provided by university science parks promote the growth of on-park UREs.

The “umbilical cord” connection between universities and UREs facilitates academic technology transfer and contributes to regional economic development. However, some short-term profit oriented and poorly managed university-run enterprises bring troubles to their mother universities. 90% university-run enterprises are legal institutions with unlimited

[59] 211 project: it was launched by the Chinese central government in 1993 and implemented in 1995. The purpose of the project is to breed 100 key universities and build up key disciplinary areas. The project is composed of the improvement of overall institutional capacity, the development of key disciplinary areas and the development of the public service system of higher education.
[60] Figures in this paragraph collected from Science &Technology Development Centre, Ministry of Education 2005.

liability and their mother universities have to undertake civil responsibility once management risks emerge (Lü, 2007). For example, some universities guarantee for UREs to get bank loans. Given that university-run enterprises fail to survive, universities would be obliged to take debt burden which affects normal teaching performance. The same management risk arises from those firms traded in the stock markets. Most universities hold the majority of equity stakes of university-run enterprises. Rigid and non-professional management of universities hinders UREs to operate like real commercial enterprises. Some enterprises use universities' brand and take engaged in activities which damage university's public image. Universities are exposed to actual, potential economic and legal risks.

To get universities out of such troubles, the Ministry of Education in 2005 required universities to "de-link" university-run enterprises and set up a corporate which represents universities to manage UREs. All operational university assets[61] should be transferred to the corporate and universities can not run firms directly any longer. They should complete this transformation at the end of 2006. And university-run enterprises are also required to introduce the corporate-management system. University leaders are allowed to take part-time job in the corporate but without material compensation. However, universities leaders are prohibited from taking any positions in university-run enterprises. Additionally, they cannot hold equity stakes of UREs except when they are inventors. All these measures are used to cut the "umbilical cord" connection between universities and UREs, avoid the direct involvement of universities and make university-run enterprises become independent corporate. The linkage between universities and UREs now begins to be reconfigured from direct funding and management to intellectual property-based technology transfer.

[61] Operational university assets refer to investments pouring into university-run enterprises by universities, relative profits arising from these investments and other profits legally devoted to universities (Xi'an Jiaotong University, 2004).

1.3.2.3.2.2 Intellectual property-based spin-offs

Bekkers *et al*. (2006) define an intellectual property (IP)-based spin-off as follow a new firm which includes a novel technological knowledge that has recently developed at a public research institutes (including universities), and where this knowledge is protected by an intellectual property right that is either licensed or transferred to the firm. University researchers/staff may or may not get involved in the management of the spin-off firm.

We make use of this definition to analyze Chinese IP-based spin-offs. IP-based spin-offs are not a new phenomenon to many western universities but they are rather new for Chinese counterparts. For a very long time, universities had got used to directly financing and managing university-run enterprises (UREs). And the traditional philosophy of universities views academic findings as public assets and the identification of knowledge ownership is against open science. In the 1990s, the poor performance of some UREs had caused serious disruption to universities that spawn them. Universities were exposed to economic and legal risks. The arising problems force universities to rethink the linkage with their affiliate enterprises. The implementation of Chinese version of "Bayh-Dole Act" in 2002[62] and the attitude of Ministry of Education toward the reform of UREs in 2005 provide university incentives to create IP-based spin-offs.

Universities prioritize technology transfer through licensing. However, Chinese firms going to universities are usually small medium-sized firms for quick problem solving. University research rarely produces "prototypes" of inventions for development and commercialization by industry (Mowery and Sampat, 2005). Embryonic invention is often bound to sponsored research and includes payment schemes like up-front fees and royalties (Thursby *et al*., 2001). Many small and medium-sized firms are not interested in contractual

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[62] "Bayh-Dole Act" was originally created in USA in 1980. It is an act which gives universities greater incentives to commercialize technology. The act allows universities to patent the results of federally-funded research and license the resulting technology to business and other entities (Joint Economic Committee US Congress, 1999, p.31). The Chinese version of "Bayh-Dole Act" is initially called "regulations on the management of IP arising from national financed S&T programs". It was implemented in 2002 which specified the executors of these programs (i.e. universities, public research institutes, firms, etc.) as the owners of IP resulting from the government financed research. As the Chinese regulation is similar to the US Act, we call it the Chinese version of "Bayh-Dole Act". In fact, Chinese Patent Law executed in 1984 has already authorized universities to own intellectual property rights arising from their on-duty research findings but they have to ask for permission from the superior authorities for transferring patents.

licensing agreements. Thus, universities usually cooperate with inventors and other partners to create IP-based spin-offs. University technology transfer offices (UTTOs or equivalent) play an important role in evaluating the value of technology and seeking for investors outside campus. This phenomenon is confirmed by our interview with a technology transfer officer in Chongqing University. They are in favor of contractual licensing agreements but it is difficult to find the right buyer because of the difficulty in assessing the value of the technology and highly uncertainty of downstream product market and firms' weak absorptive capability. Consequently, universities themselves get involved in capitalizing the technology with potential market value. The involvement of universities functions as a leverage to attract other investors in the new firms.

Since spin-offs typically face financial bottleneck, which restricts their possibility to cover patent costs, up-front license fees, costs of research facilities and marketing activities, Chinese universities usually invest the patented technology or transfer the technology to the new firms in return for a certain amount of equity stakes in the firms. The equity investments of universities in their own spin-offs are more important in early stages of a spin-off creation than the availability of formal venture capital (Di Gregorio and Shane, 2003). In addition to universities, inventors, faculty department or business outside campus, all can be stakeholders of IP-based spin-offs. Indeed, Chinese universities encourage inventors to participate in commercializing the research findings. For example, inventors can be allocated 20%-50% of total equity stakes of the new firm according to their contribution. Inventors are often appointed as director or consultant of technology in the new firm. The direct involvement of inventors in spin-offs promotes the transfer of both codified and tacit knowledge (Jenson and Thursby, 2001; Siegel *et al*., 2003a; Link and Siegel, 2005), and reduces asymmetrical information, the moral hazard and opportunistic behaviors. This is because, inventors are the owners of the new firms and their revenues are tightly bounded with the performance of the spin-offs. The internal constraint pushes them to make efforts in marketing the research outputs.

The diversity of investors explores the funding source of IP-based spin-offs and decreases the financial dependency of spin-offs on universities. Each investor undertakes responsibilities and enjoys rights in response to the share of their equity stakes. Universities are not necessarily the main shareholders of the spin-offs. They can not manage the spin-offs in a rigid administration way any longer. The introduction of corporate-based management in IP-based spin-offs makes the new firms perform more like the business world. As the liabilities and rights are identified at the creation stage between universities and IP-based start-ups, universities get out of endless liabilities in case of bad performance of spin-offs.

However, the reconfiguration of university-spin-offs linkage does not hamper university's support to the new firms. In comparison with traditional UREs, IP-based spin-offs are typically innovative firms and they exploit university inventions into new products and service. Their emergence directly compensates the insufficiency of innovative Chinese firms. Due to their technology-based background, these spin-offs are often hosted in spawning university incubators. University incubators often work with TTOs to identify intellectual property rights linked to academic start-ups. They provide a favorable environment to accompany the development of new firms. The services of university incubators range from physical facilities to value-added business support. Details about university incubators are analyzed in chapter 3.

As university incubators are often built around or in campus, IP-based spin-offs benefit from geographical proximity to their mother universities. They can remain informal contacts with university researchers, get easy access to laboratory equipments and gain options to attract new talent. The mobility of researchers and new idea exchanges between spin-offs and universities contribute to the tacit technology transfer.

Although university-run enterprises are the main mechanism for technology transfer because of historic legacy, in a long term, IP-based spin-offs will replace the dominant position of university-run enterprises and play a pivotal role in transferring technology developed in Chinese universities. In fact, university-run enterprises have been exposed to government pressure to transform into IP-based spin-offs nowadays. Furthermore, the connections between UTTOs and other knowledge commercialization and diffusion institutions (i.e. technology market, productivity promotion centers, technology business incubators) should be enhanced to facilitate the creation of IP-based spin-offs.

1.3.3 Conclusion

This section has analyzed how universities fulfill their role in upgrading domestic firms' absorptive and innovative capabilities under the Chinese national innovation system. We find that universities promote firms' such capabilities through the provision of human innovators, R&D collaboration and the creation of spin-offs.

Chinese universities build up the competence of labor force to be used in innovation and R&D activities in two sides. On one side, universities have enlarged student enrollment; on the other side, they reform teaching program, recruit elite professors and provide student internships. The expansion of university training and education as well as the improvement of education quality has provided numerous scientists and engineers for the industrial world. This improvement in human capitals is one of the key elements which influence firms' competitiveness.

R&D collaboration strengthens the linkage between university and industry. Following the government, industry has become the second largest R&D funding supporter for universities. However, the R&D cooperation between large medium-sized enterprises and university is found to be weak. This phenomenon results most probably from the increase of firms' in-house innovation. The merger of research institutes into companies, the high growth of R&D personnel and R&D expenditure promote the absorptive and innovative capabilities of domestic firms.

Although domestic firms have upgraded such capabilities, most of them are not endogenous innovators. Firms complain that they lack qualified R&D personnel. This is related to the examination-oriented education model and the employment criteria of university which emphasize the academic background of candidates but little in industrial background. Universities should further reform educational model and train creative minded, multi-disciplinary background and problem solving talents for industries. The creation of spin-offs, especially technology-based spin-offs, is an efficient way to compensate the insufficiency of innovative Chinese firms. Traditional university-run enterprises (UREs) have contributed to job creation, nurturing entrepreneurship and regional economic growth. But poorly managed UREs bring economic and legal issues to the spawning universities. Intellectual property-based spin-offs are an institutional innovation which makes the “umbilical cord” connection between university and UREs healthy. They institutionally shape the relationship between the mother university and the new firm on the basis of equity identification. Moreover, IP-based spin-offs tap university cutting-edge technology and they are a driving innovation force in the Chinese national innovation system.

Section 1.4 General conclusion

China officially adopted the concept of national innovation system (NIS) about ten years ago. The government has taken many measures to shape its NIS for catching up. In this chapter, we center our analysis of China's NIS on its institutional and organizational innovation. And we discuss the importance of universities in the Chinese national innovation system.

The evolution of China's NIS is found to follow two dimensions. One dimension focuses on technology imports mostly embedded in foreign direct investment (FDI). Policy makers have implemented open policy, laws, restructured financial system and R&D infrastructure to attract FDI. The other dimension of China's NIS emphasizes endogenous innovation. The government has constructed supporting infrastructure of knowledge generation, commercialization and diffusion to promote endogenous innovation. The two dimensions are complements rather than substitutes. These active national actions have positively impacted on the improvement of China's competitiveness. The institutional reforms for technology imports and the construction of knowledge generation infrastructure are proved to be efficient. The inflows of FDI open a technological learning for domestic firms and promote the development of high-tech industry. The supporting infrastructure in terms of knowledge generation leads to the remarkable growth of scientific publications and patents. However, China's high-tech industry heavily depends on FDI. Large medium-sized enterprises (LMEs) in this sector spend much more funds in outsourcing technology than assimilating it. The exponential increase of publication and patentability has not brought an evident growth of new products. These weaknesses, to some degree, reflect that domestic firms have weak absorptive and innovative capabilities.

Chinese universities are found to play an important role in building up domestic firm competitiveness in innovation. The growth of university student enrollment and the promotion of education quality provide more human innovators to industry. But the improvement of overall Chinese education level is a long process, like what Confucius said: "If you think in the terms of a year, plant a seed; in terms of 10 years, plant trees; if in terms of 100 years, teach the people". Universities should continue to reform teaching program and recruit qualified professors but need to carefully deal with the imbalance reward allocations between elite professors and ordinary teaching staff. Policy makers should continue to increase investment in R&D activities and education.

R&D collaboration with industry and the creation of spin-offs are other two ways for university to upgrade firms' competitiveness. Although LMEs have little R&D cooperation with universities, they can tap university technology frontier and get human capital support. In contrast with R&D collaboration, universities get more involved in the creation of spin-offs. University run-enterprises (UREs) are a very typical type of spin-offs in China. But universities have suffered economic and legal problems caused by poorly performed UREs. UREs should accelerate the introduction of corporate-based management system and identify clearly responsibilities and rights between UREs and spawning universities. University technology transfer offices (or equivalent) and other components under knowledge commercialization and diffusion infrastructure (i.e. technology market, productivity promotion centers, technology business incubators, etc.) should enhance interconnections and promote the transformation of traditional UREs into IP-based spin-offs. IP-based spin-offs are typical technology-based new firms and they compensate the shortage of innovative firms. They facilitate technology transfer to industry, act as the cradles for training academic entrepreneurs and generate economic returns for university. In long term, IP-based spin-offs would become the main stream of UREs.

As Chinese firms still have not enough absorptive and innovative capabilities, universities will continue to play an important role in building-up and strengthening firms' competitiveness.

Chapter 2

University technology transfer offices (UTTOs) and the Chinese ‘Bayh-Dole Act’

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Universities are centers of knowledge generation. Their research outputs are displayed in different forms, varying over time and across industries: scientific and technological information, equipment and instrumentation, skills or human capital, networks of scientific and technological capabilities and prototypes for new products and processes (Sampat, 2006). Disseminating such outputs has been viewed as the engine driver of society's development. As captured by David (1997:4)[63], "the university are not just a creator of knowledge, a trainer of young minds and a transmitter of culture, but also a major agent for economic growth: the knowledge factory, as it were at the center of knowledge economy". Therefore, the commercialization of university research results requires university to transfer efficiently more market-based knowledge and technology to industry.

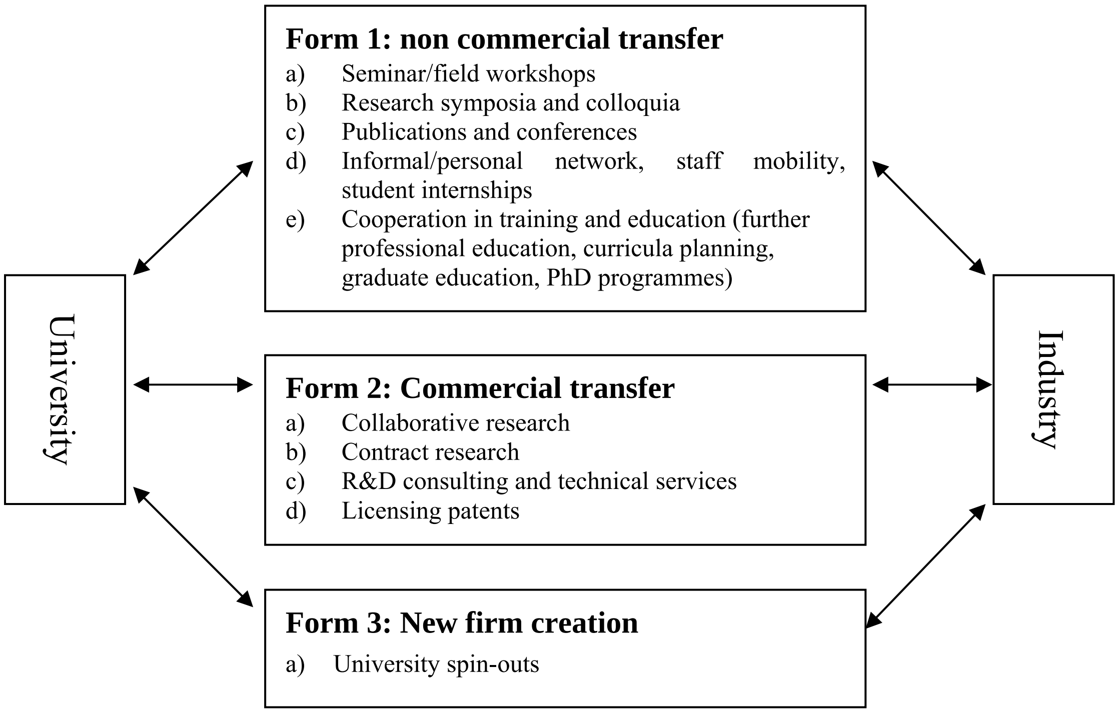
Actually, more recent developments such as an increasing number of strategic partnerships/relationships with industry (Siegel *et al.*, 2003b), significant increase in technology licensing agreements (Mowery *et al.,* 1998; 2001; 2002; Thursby and Thursby 2002; Mowery and Sampat, 2005), a marked rise in the number of university spin-outs[64] (Gregorio and Shane, 2003; Lerner, 2005), the emergence of technology parks or science parks around universities and the emergence of highly successful economic zones, such as Silicon Valley and Route 128 around elite universities (Bercovitz and Feldman, 2006) have firmly positioned the universities at the center of commercial technology development (Sharma *et al.,* 2006).

[63] Cited from Sharma *et al*., 2006: p.110.

[64] Spin-outs: they are defined as new companies formed around a core technology discovered in a lab. The parent organization sells licenses or somehow transfers the technology to the spin-out, which is often founded by researchers from the parent company or campus (3i/EIU, 2002, p.4). They are different from university-founded companies and university start-ups. University-founded companies arise from commercial opportunities that have been identified by university personnel and need not necessarily be an outgrowth of the university's research base. University personnel are seldom involved directly in the management of the venture, even though such personnel may serve on the advisory board or in a consultancy capacity. Instead, a surrogate entrepreneur or external independent entrepreneur is appointed to develop the venture (Franklin *et al*., 2001). University start-ups are defined as companies set up by current or former students and members of staff, drawing on knowledge and expertise (usually not research) in all areas and on innate or acquired entrepreneurial skills…founders of start-ups establish their companies to exploit expertise and knowledge gained during their careers and not, in contrast to spinoffs, from specific research projects (Hague and Oakley, 2000, p.5).

There are various channels for university-industry technology transfer (UITT), such as the publication of research results in scientific journals, academic meetings, personal mobility, training, industry-sponsored research, licensing patented technology and new company creation. Upstill & Symington (2002) have outlined three principal forms of UITT, namely, non commercial transfer (form 1), commercial transfer (form 2) and new company generation (form 3). The same model, integrated OECD (2002) and EC's (2001) research results, to fully cover the different channels of UITT, can be demonstrated as follows (Figure 2.1):

Figure 2.1: Different forms of university industry technology transfer



Source: Sharma *et al*., 2006. OECD, 2002 and European Commission, 2001.

Universities usually mix these three forms to transfer technology to industry. Form 1, non commercial transfer, illustrates university's initial role as teaching and not-for-profit research. Publications and the number of graduated students are usually two critical factors to assess university's output. Form 2 and Form 3 show the strategies of universities to commercialize their intellectual property, which are responsive to their economic contribution.

As we have discussed about Form 1 in Chapter 1, hereafter we emphasize Form 2 and Form 3. This is because our research focus is positioned to examine whether the Chinese national technology transfer centers (NTTCs, equivalent to UTTOs) and the Chinese 'Bayh-Dole Act' influence the commercialization of R&D results in science. Section 2.1 introduces the background of UTTOs at a rather general level, and then it analyzes the rationale behind the creation of UTTOs.

Section 2.2 assesses whether the Chinese 'Bayh-Dole Act' has a similar impact on university patenting and licensing as the US Act. It describes the background of the Chinese 'Bayh-Dole Act'. Then it analyzes university patenting and licensing activities before and after the promulgation of the Act. Adopting Yin's (1994) theory on case study research, we sample Tsinghua University and Chongqing University to examine the effect of the Act on the patenting activities of both universities.

Section 2.3 discusses whether the establishment of NTTCs is an efficient policy tool to promote university technology commercialization. It introduces the context of emergence of NTTCs in China, distinguishes NTTCs, STACOs and TTOs and assesses the effect of NTTCs on marketing university research achievements. 6 universities with NTTCs and one university without NTTCs are sampled in our case studies.

Section 2.1 Background of university technology transfer offices

This section aims to picture the background of university technology transfer offices (UTTOs) at a rather general level. Section 2.1.1 introduces the context of emergence of UTTOs and their roles. Section 2.1.2 analyzes rationale behind the creation of UTTOs. Section 2.1.3 discusses the linkage between UTTOs and the Bayh-Dole Act.

2.1.1 Introduction

The emergence of UTTOs and their roles are associated with the government legislation on university technology transfer and university's third mission of economic development in addition to research and teaching.

The United States is a pioneer in the establishment of UTTOs. The success stories of American UTTOs in closing the gap between science and industry encourage other universities in Europe and Asia to set up UTTOs. Nowadays, UTTOs have functioned as "technology intermediaries" that transmit technological innovations from university to industry in many countries.

2.1.1.1 The emergence of UTTOs

Throughout much of the 20th century, universities were reluctant to become directly involved in patenting and licensing activities as they wanted to avoid possible criticism on damaging open science. Consequently, before 1980 most major US universities used to trust a third party[65] to manage patent operations or to set up affiliated but legally separate research

[65] A third party: before 1980, many US universities contracted with Research Corporation to manage their patent operations. The Research Corporation was founded by Berkeley chemist, Frederick Gardner Cottrell in 1912, as a non-profit third party technology transfer agent. The initiation of the company is to administer Cottrell's patents on the electrostatic precipitator, a pollution control device.

foundations[66] to administer their patents (Mowery and Sampat, 2001; Sampat, 2006). Since the implementation of the Bayh-Dole Act in 1980 authorized universities and small businesses to obtain the rights to any patents resulting from grants or contracts funded by any federal agency, a rising number of US universities became directly involved in patenting and licensing, setting up internal technology transfer offices (TTOs) to manage the disclosure and license the inventions of their commercial potential (Sampat, 2006; Jensen *et al.,* 2003). The number of TTOs has grown sharply from 25 to well over 200. And the patenting and licensing activities of US universities increased at an amazing speed during the late 1970s and 1990s. The number of patents issued to US universities kept on doubling during the periods 1979-1984, 1984-1989 and over the 1990s. At the same time, university licensing revenues increased greatly, from $221 million in 1991, to $698 million in 1997 alone (Nelson, 2001).

Stimulated by the achievements obtained by the USA, China, France, Germany, Japan, the U.K. and others changed their intellectual property policies along the lines of the American "Bayh-Dole Act" and also carried out a number of related initiatives on organizational innovation to build UTTOs or organizations equivalent to UTTOs, which may or may not be affiliated with a given university (Mowery and Sampat, 2005).

2.1.1.2 The role of UTTOs

The initial role of UTTOs is to build the bridge between university research achievements and the market, by encouraging faculty members to disclose inventions, simultaneously evaluating the commercial potential of the technology and determining whether to patent the invention, then marketing the technology (Nelson, 2001; Jenson and Thursby, 2001; Jensen *et al*., 2003; Sharma *et al*., 2006; Siegel *et al*., 2003). UTTOs represent

[66] Research foundations: the first and most prominent of these foundations was the Wisconsin Alumni Research Foundation (WARF) founded by members of the University of Wisconsin in 1924. It is a university-affiliated but legally separate foundation that would accept assignment of patents from university faculty, would license these patents and would return part of the proceeds to the inventor and the university.

the university in the management of intellectual property arising from publicly financed research outputs.

UTTOs act as double intermediaries between university and faculty/inventors on one hand, between university and market on the other hand. They collect invention reports from faculty inventors and once an invention is disclosed the technology is assessed. If the evaluation is favorable, attempts are made to identify potential licensees (Sharma *et al*., 2006). US UTTOs file for patents only if a potential licensee is confirmed (Jensen and Thursby, 2001; Thursby and Thursby, 2002). The unified management of inventions under UTTOs shortens the cost of transaction, because the labor division between inventors and UTTOs helps to save inventors' time and effort which can be concentrated on their R&D activities. UTTOs have advantages in terms of experiences, information collection and coordination with other relevant players in the licensing process which is helpful to improve the probability of success in the commercialization of R&D results, even though the competences of UTTO officers to fulfill their mission are questioned (Owen-Smith and Powell, 2001; Siegel *et al*., 2003; Chapple *et al.,* 2005).

Moreover, shared organizational culture and physical proximity promote the dealings of UTTOs with inventors/faculties, but generally not with firms (Markman *et al*., 2005). University institutions are helpful to overcome the market failure in terms of asymmetrical information, moral hazard and opportunistic behaviors in the internal exchange market (UTTO interactions with inventors/faculties). Concerning the external exchange market, UTTOs represent university to contract with licensees so that UTTOs tend to recommend the appropriate technology to licensees because they want to sustain the university's public image and to target a long-term cooperation with firms. Licensees can call on UTTOs for help if conflicts arise between licensees and inventors. UTTOs actually play a role of a guarantor of invention quality.

In additional to being intermediaries, UTTOs act as executors of university-owned IP in order to retain and increase the value of IP as well as to protect university IPR. This role of UTTOs solves the ambiguous executor problem of IP arising from publicly financed research which existed before the Act. Since the university's potential income is bound to the operation of UTTOs, more universities are interested in setting up UTTOs.

2.1.2 Rationale behind the creation of UTTOs

The rationale behind the creation of UTTOs is found to be linked to the changing environment for universities, namely the political requirements for strengthening university-industry technology transfer and university's motivation to pursue economic income. On one side, the policy makers concern about the absence of specified executors of IP arising from publicly funded research, which causes undersupply of university-industry technology transfer. They require that universities fulfill the third mission of economic contribution to society in addition to research and education. On the other side, universities seek economic income because of the need to compensate for decreasing public funds and the attractivity of potential pecuniary interest arising from the exploitation of research findings. The modeling of the university licensing process below demonstrates that the creation of UTTOs is helpful for universities to realize their economic utility.

2.1.2.1 Rationale linked to the changing environment for universities

Before the enactment of the Act, governments used to hold the ownership of publicly financed research results. But the question of who represented governments to exploit these research findings was ambiguous. Governments are macro-policy makers and are not as sensitive as industry and other players to the market. Governments are usually interested in commercializing those R&D research findings which are relevant to national security and public interest. For example, during the first and second world wars, the US government facilitated the exploitation by industry of many public research findings (EC, 2001). Since governments were identified as the holders of inventions arising from publicly funded research, universities had few incentives to encourage researchers to disclose on-duty inventions, and even more - needless to say- to commercialize the findings. Some on-duty inventions may have been privatized by researchers which caused the loss of university intellectual assets.

Furthermore, fuelled by the notion that smooth interactions between science and industry are important but not obvious for the success of innovation activities and ultimately for economic growth, industry-science links have become a central concern of government policy across the globe (Sharma *et al*., 2006; Stadler *et al*., 2007). Many studies in the USA and the EU identify the importance of an appropriate governance and incentive structure to encourage science institutions to market academic research and development (Branscomb *et al*., 1999; Siegel *et al*., 2003a). The creation of university technology transfer offices is often regarded as instrumental to secure a sufficient level of autonomy for developing relations with industry (Sharma *et al*., 2006). And, the ownership of inventions was usually distributed to various governmental agencies. Exploiting inventions implied dealing with different bureaucracies which increased the transaction cost. The emergence of UTTOs helps reduce administrative procedures. The underlying motive behind the US Bayh-Dole Act was to simplify IPR management, unifying 26 separate statutes that governed the ownership of patents arising out of government sponsored research (Sharma *et al*., 2006).

Additionally, facing tight budgets and the increasingly accepted concept that the successful commercialization of university originated technology can result in pecuniary gains, universities attempted to formalize university-industry technology transfer by establishing UTTOs (Siegel *et al*., 2003a). The sharing of royalty revenues is common across countries and institutions, and is increasingly seen as a way to provide incentives not just to individual researchers but to research teams (OECD, 2002). Although the majority of universities receive no gross income from their intellectual property rights (IPR) and in most cases, the income cannot cover the expenditure of UTTOs (Mowery *et al*, 1998; Mowery *et al*., 2002; Mowery and Sampat, 2005; Bercovitz and Feldman, 2006; Geuna and Nesta, 2006), UTTOs are viewed by some economists as a policy instrument which facilitates technology transfer from the academic world to private sectors (Siegel *et al*., 2003; Markman *et al*., 2005) and licensing has traditionally been the most frequent mode of university technology transfer (Chapple *et al.*, 2005). Actually, effective technology transfer almost always requires university patenting and licensing (Nelson, 2001), which reduces the potential prosecutions on intellectual property resulting from transferred technology.

2.1.2.2 Rationale underlying the university licensing process

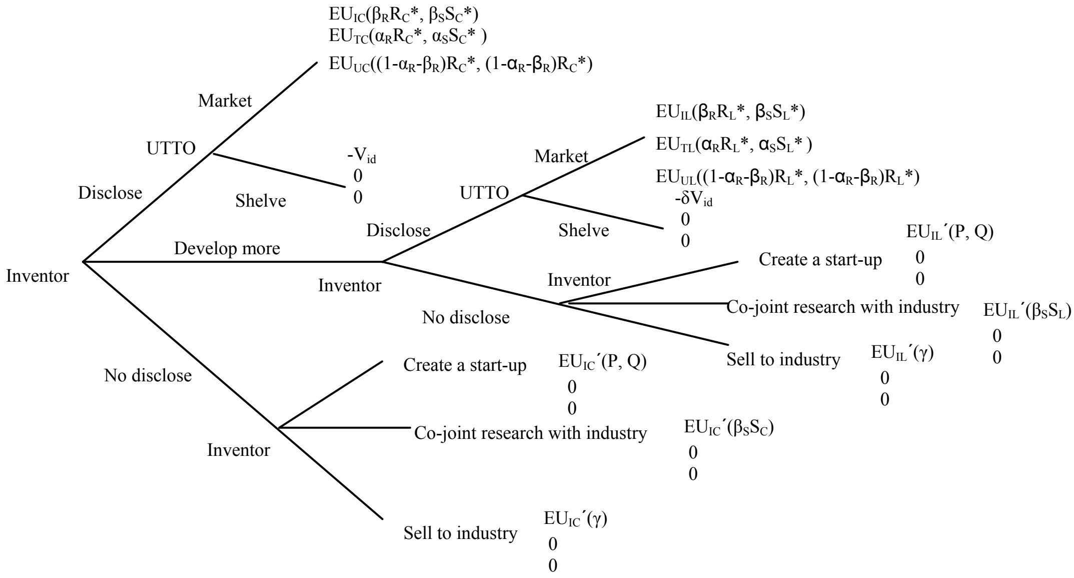
To understand well the rationale behind the creation of UTTOs, we will explore a model proposed by Jensen *et al.* in 2003. They apply a game theory to model the university licensing process. There are three players in the game, namely inventor (I), UTTO (T) and university (U). Supposing an inventor generates a potential invention at the 'proof of concept' stage[67] of development, he has three choices:

- To disclose this potential invention to the UTTO
- To continue research to develop the potential invention to the 'lab-scale prototype' stage[68]
- Not to disclose (this choice is explored by the author)

[67] Proof of concept stage: an idea or new technology has been developed to the point that it shows signs of having the proposed effect. Similarly, a few target compounds in a crude extract may have been identified, but the mechanism by which they act may not have been discovered yet (Markman *et al*., 2005).
[68] Lab-scale prototyping stage: the new technology can now be constructed at a laboratory scale as a reliable method of producing a given result and/or if it can be predictably manipulated to produce desired results (Markman *et al*., 2005).

The above choices of the inventor can be described as the following model (see Figure 2.2):

Figure 2.2: Modeling the university licensing process



Source: Jensen *et al*., pp.1275, 2003, non-disclosure part is explored by the author.

Figure 2.2 shows that the performance and profit of UTTO depends on the invention disclosure of faculty members. If an inventor chooses not to disclose his/her findings to UTTO, UTTO conducts no licensing activities. Hence university, UTTO and faculty would not share the proceeds arising from potential licensing agreements with the inventor. By contrast, after the disclosure of inventions, the importance shifts from inventor to UTTO. The latter dominates the consequent licensing process. If UTTO succeeds in marketing the inventions, the inventor, faculty/university and UTTO would benefit from the success. If UTTO determines to shelve the inventions, nobody would obtain income. For the inventor, before making a decision whether to disclose the inventions or not, he/she balances the opportunity cost between continuous development, disclosure and no-disclosure. If his/her expected gain of no-disclosure is higher than that of disclosure and development, he/she tends to take a no-disclosure strategy. In the case of no-disclosures, university and UTTO get no return from on-duty inventions. But the inventor takes the risk of being accused of violating university IPRs.

After capturing the content of Figure 2.2, we would like to introduce our explored part (not-to disclose) on the basis of Jensen *et al.*'s model[69]. The third choice for the inventor is called "switch" in the original model. If the inventor does not disclose the invention to UTTO, he has three choices: to create a start up; to continue a research project together with industry; or to sell to industry. We start by calculating each player's expected utility both at the proof of concept stage and at the lab-scale prototype stage.

At the proof of concept stage, if the inventor chooses ***not to disclose the invention***, both the expected utilities of UTTO and university are ***zero***. But, his/her expected utility depends on his/her choices:

To create a start up: $EU_{IC}'(P, Q) = \rho' PQ - S - K$ under the condition $EU_{IC}'(P, Q) \geq \max〔EU_{IC}(\beta_R R_C^*, \beta_S S_C^*), EU_{IC}'(\beta_S S_C), EU_{IC}'(\gamma)〕$. Here we suppose that the inventor bears the cost S for developing the technology which is equal to the sponsored research funds given by a firm and the same cost K for marketing the technology as the firm bears. ρ' denotes the probability of success at the time the inventor finds a customer to buy his products.

To develop research together with industry: $EU_{IC}'(\beta_S S_C) = \beta_S S_C - S'$ under the conditions $EU_{IC}'(\beta_S S_C) \geq \max〔EU_{IC}(\beta_R R_C^*, \beta_S S_C^*), EU_{IC}'(P, Q), EU_{IC}'(\gamma)〕$. Here $\beta_S S_C$ represents the sponsored research funds paid by the firm to the inventor. S' is the fund invested by the inventor.

[69] See appendix 2.1, p.312 about Jensen *et al.*'s model (2003).

To sell to industry: $EU_{IC}'(\gamma) = \rho''\gamma - S$ under the conditions $EU_{IC}'(\gamma) \geq \max〔EU_{IC}(\beta_R R_C^*, \beta_S S_C^*), EU_{IC}'(P, Q), EU_{IC}'(\beta_S S_C)〕$. γ is the revenue of technology transfer from the inventor to industry and ρ'' is the probability of success when the inventor finds a customer to buy his technology.

At the lab-scale prototype stage, if the inventor chooses ***not to disclose the invention***, the expected utilities of UTTO and university are ***zero***. But, his expected utility depends on his choices:

To create a start up: $EU_{IL}'(P, Q) = \delta〔\rho' PQ - S - K〕$ under the condition $EU_{IL}'(P, Q) \geq \max〔EU_{IL}(\beta_R R_C^*, \beta_S S_C^*), EU_{IL}'(\beta_S S_C), EU_{IL}'(\gamma)〕$.

To develop research together with industry: $EU_{IL}'(\beta_S S_C) = \delta〔\beta_S S_C - S'〕$ under the condition $EU_{IL}'(\beta_S S_C) \geq \max〔EU_{IL}(\beta_R R_C^*, \beta_S S_C^*), EU_{IL}'(P, Q), EU_{IL}'(\gamma)〕$.

To sell to industry: $EU_{IL}'(\gamma) = \delta〔\rho''\gamma - S〕$ under the condition $EU_{IL}'(\gamma) \geq \max〔EU_{IL}(\beta_R R_C^*, \beta_S S_C^*), EU_{IL}'(\beta_S S_C), EU_{IL}'(\gamma)〕$.

The above model illustrates that UTTO and university may realize their expected economic utilities if the inventor discloses the invention to UTTO and UTTO can find a licensee. If the inventor decides not to disclose his invention, UTTO and university will gain ***zero economic*** utility either at the proof of concept stage or at the lab-scale stage. In this case, it demonstrates that the inventor is willing to take the risk of legal consequences and hopes to benefit from the personally privatized on-duty invention. Then, the university intellectual asset is shifted to the individual pocket and the university interest is damaged. The expected utility of the inventor under the non-disclosure case is determined by the alternative choices, e.g. start-up creation, co-joint research with industry and selling to industry. The inventor will compare the potential utility arising from the three choices respectively including the expected utility gained from the disclosure. Then he makes the final decision. The inventor chooses to disclose the invention at the proof of concept stage only if the inventor's expected utility is not lower than that gained at the prototype stage and the utility received forms his next best alternative research project. At the lab-scale prototype stage, the inventor discloses the invention only if his expected utility is not less than the utility obtained from his next chosen research project. Under the disclosure case, the realization of the expected utility of the inventor depends on whether UTTOs think the invention is worth marketing and then can find a licensee. Otherwise, the invention will be shelved and the inventor's utility is negative because of the existence of disclosure cost.

Therefore, in order to avoid zero economic utility for UTTO and university, the most important job for UTTO at the proof stage is to encourage inventors to disclose their inventions (Thursby and Kemp, 2002; G. Thursby and C. Thursby, 2002; Siegel *et al*., 2003b). Although all on-duty inventions are obliged to be disclosed to UTTOs in some countries, such as Germany, the USA, and China (Huelsbeck and Lehmann, 2007; Mowery *et al*., 1998; Siegel *et al*., 2003a), the US UTTO officers indicated that less than half of the faculty inventions with commercial potential were disclosed to their offices, though several noted an increasing willingness to disclose (Thursby *et al*., 2001; Thursby and Kemp, 2002).

2.1.3 The linkage between UTTOs and the Bayh-Dole Act

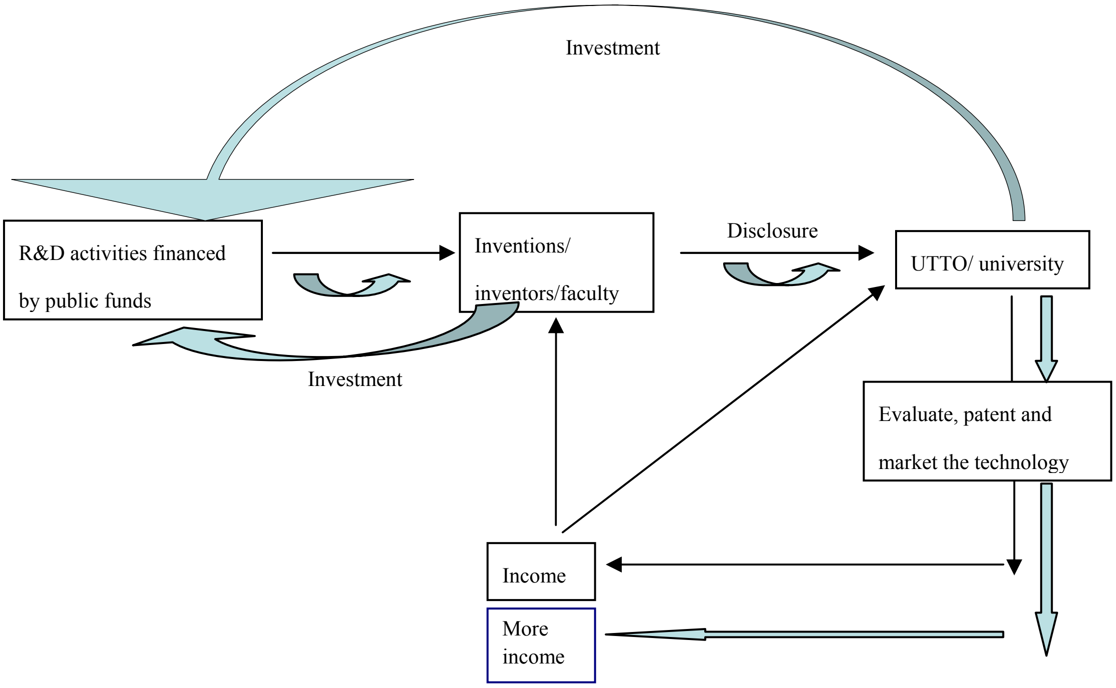
Few universities had UTTOs before the Bayh-Dole Act of 1980 and little legislative framework triggered universities to manage on-duty inventions. But after the implementation of the Bayh-Dole Act, many US universities set up UTTOs to manage IP arising from publicly supported research findings. And the widespread creation of UTTOs in many other countries arose from international emulation of the American Bayh-Dole Act in 1980. Hence, from this point of view, UTTOs are the direct consequence of the Bayh-Dole Act or one of the effects of similar Acts on the organizational level of university-industry technology transfer (Huelsbeck and Lehmann, 2007). The Bayh-Dole Act provides a legislative base for universities to establish UTTOs. And the performance of UTTOs represents the effectiveness of the Act. The Act and UTTOs both contribute to the rising university patenting and licensing. In Section 2 we will assess whether the Chinese Bayh-Dole Act has a similar impact on university patenting and licensing as the US Act. And Section 3 will examine whether national technology transfer centers in 6 Chinese universities function as an effective policy tool for promoting the commercialization of university research findings.

2.1.4 Conclusion

The emergence of UTTOs is associated with the implementation of the Bayh-Dole Act, the requirement of policy makers for strengthening university-industry technology transfer and the motive of university for pursuing economic income. UTTOs represent university in the management of IP activities. They encourage inventors to disclose on-duty inventions and license the inventions with commercial potential. The institutional management of inventions under UTTOs is helpful to decrease the transaction cost and improve the probability of success in the commercialization of R&D results.

The income of licensing patented technology is usually shared between university, faculty/department/UTTO and inventors (Jensen and Thursby, 2001). Similarly, a part of the license revenues may be used to support other R&D activities of universities. This can form a rolling snowball mechanism (see Figure 2.3). The more license incomes are obtained, the more universities will be willing to invest in promising research portfolios. The more promising research projects are conducted, the more opportunities researchers have to broaden and enrich innovative research fields (Sharma *et al.*, 2006). The more innovative research fruits are achieved, the more possibilities universities hold to receive a bulk of license revenues. From this point of view, UTTOs can not only probably create gains for universities but also increase university's interest in research.

Figure 2.3: The process of university-industry technology transfer



Source: author herself

Note: → represents the initial cycle of university licensing process

⇨ represents the recycle of university licensing process

Section 2.2 The effect of the Chinese 'Bayh-Dole Act' on university patenting and licensing

This section will assess whether the Chinese 'Bayh-Dole Act' can have the similar effect on university patenting and licensing as the US Bayh-Dole Act. Section 2.2.1 gives a brief introduction of the Chinese Act. Section 2.2.2 presents the research literature and our study methodology. Section 2.2.3 assesses the growth of university patenting and licensing activities before and after the promulgation of the Act in 2002.

2.2.1 Introduction

The US Bayh-Dole Act is widely credited with the significant increase in the university patenting and licensing activities during the last two decades as it essentially clarified the nature of processes that need to be in place to bring university technology onto the marketplace (Sandelin, 1994). However, some research findings converge to show that the Bayh-Dole Act encourages universities to market and manage academic inventions, but that it is only one of several factors behind increased patenting and licensing (Mowery *et al*., 1998; Mowery *et al*., 2001; Mowery *et al*., 2002; Mowery and Sampat, 2005).

Although the "catalytic" effects of Bayh-Dole Act on university-industry technology transfer still lack abundant evidence (Nelson, 2001; Sampat, 2006), many OECD and non-OECD governments believe that the Act is one of the most successful pieces of economic growth and job creation legislation and they have adopted or are considering policies emulating the Act's provisions. Denmark and Germany altered the "professor's privilege", which used to grant academic researchers patent rights on inventions funded by the governments, and since 1999 and 2002 respectively they have authorized universities to be holders of patents and take responsibility for licensing patents. In France, the Ministry of Research urged universities to assert their rights to employee inventions in 2001. There is no similar Act in France because institutions always have the right to take intellectual property on publicly financed research (Dosi *et al.,* 2006b). And Austria, Ireland and Spain have emphasized the change of employment laws so that university can legally own the intellectual property rights generated by employees (OECD, 2003). Similarly, the ownership of inventions resulting from publicly funded research was shifted from individual inventors to universities in Canada and Japan, starting from 1999 (Mowery and Sampat, 2005).

China follows the global trend to emulate the US Act. China established a Patent Office in 1980 and executed the Patent Law[70] in 1984. The aim of the patent law was part of the broad efforts in trying to promote innovative activities, and to facilitate more effective technology transfer from public R&D laboratories to industries (Sun, 2003) as well as to improve firm's competitiveness. The law was amended twice. First, in 1993, public universities were allowed to own the IP arising from their on-duty research findings but they had to gain permission from the superior authorities for transferring patents. The second amendment in 2000 released universities from asking for permission from the upper supervisors. Universities can transfer patents freely on the domestic technical market under the condition that they keep the authorities informed of the contractual deals. It also elaborates the concrete definitions of on-duty invention and off-duty inventions and introduces the system of "*contract priority*" which means the ownership of patent rights follows the contract signed by the parties concerned before the generation of inventions. This fresh concept broadens the scope to off-duty inventions (Zhang, 2005). All these amendments are designed to facilitate the commercialization of results of publicly funded research and, more generally, to better connect science to innovation (OECD, 2005).

But the law which comes closest to the US Act was "***Regulations on the Management of IP Arising from National Financed S&T Programs***" implemented in 2002. It officially specifies the executors of these programs as the owners of IP resulting from the

[70] See appendix 2.2, p.314: summary of the Chinese Patent Law

government financed research. We call it the Chinese ‘Bayh-Dole Act’. The Chinese universities were authorized to have the legal right to deal with the intellectual property (IP) and to enjoy the incomes resulting from the IP, e.g. to create spin-offs, to seek for a licensee, to transfer, to make an equity investment in a new firm and other models to commercialize their R&D results. To formalize the management of IP activities, UTTOs are being widely set up in those universities who had not set up UTTOs before 2002.

To sum up, the Chinese ‘Bayh-Dole Act’ and UTTOs (or equivalent) are institutional and organizational innovations. They are used as political tools to solve the externalities, uncertainty and limited rationality linked to university technology. The ultimate objective of these tools is expected to promote the national innovation system. We analyze their effect on the commercialization of university intellectual property in the following sections.

2.2.2 Relevant literature and research methodology

Numerous studies have been carried out on the effect of the US Bayh-Dole Act on academic patenting and licensing. A group of researchers confirmed the positive impact of the Act on university technology transfer (Mowery *et al*., 1998, 2001, 2002a, 2002b; Thursby and Thursby, 2002; Mowery and Sampat, 2005). Another group of scholars expressed their concern about possible negative effects arising from increased university commercial activities (Henderson *et al*., 1995, Nelson, 2001; Foray, 2002; Dosi *et al*., 2006; Tang, 2006a; Sampat 2006; Geuna and Nesta, 2006). And case studies are widely used as a study methodology in evaluating the effect of the Bayh-Dole Act on university patenting and licensing.

2.2.2.1 Research literature review

Mowery *et al*. (1998, 2001) sampled three academic institutions that were the leading recipients of licensing and royalty income for much of the 1990s to assess the effect of the Act: Columbia University, the University of California, and Stanford University. Two out of the three, Stanford University and the University of California had been active in technology licensing well before the passage of the Bayh-Dole Act, while Columbia University had not. Their findings indicate that the Bayh-Dole Act itself has had little impact on the shift of university research toward applied questions and away from basic research. The Act only partially contributes to the increasing university patenting and licensing activities because other factors, such as court rulings, growth in federal financial support for basic biomedical research in universities, broadened patentable field (engineered molecules), a series of federal laws strengthening IP protection, influence such university activities.

Thursby and Thursby's (2002) research, based on survey data from 64 universities, support Mowery *et al*.'s findings in terms of discipline shifts within universities. Their results suggest that increased licensing is due primarily to an increased willingness of faculty and administrators to license and increased business reliance on external R&D rather than a shift in faculty research.

Mowery *et al*. (2002) and Mowery and Ziedonis (2002) extended the previous analysis to an examination of the Act's effects on "incumbent" academic patenters (universities with at least six patents issued during 1975-1980, such as Stanford and California) and "entrants" (institutions that obtained less than six patents during the same period, like Colombia University). Their research results contradict the work of Henderson *et al*. (1995, 1998a), who suggest that the intensified post-Bayh-Dole effort to market faculty inventions were associated with the issue to US universities of patents that were less "important" and less "general", based on the patterns of citations to the patents. According to

Mowery *et al*., there is no decline in the importance and generality of the post-1980 patents assigned to universities with substantial pre-1980 patent portfolios. Because of a broader process of learning based on spillovers among universities, entrants learn the complexities of protecting and marketing intellectual property and become more selective in their patenting. The learning by doing mechanism accounts for the convergence in importance between the patents of incumbent and entrant universities.

Even though there is little convincing evidence that rising university patenting and licensing have facilitated increased technology transfer or any meaningful growth in economic contributions of universities (Sampat 2006; Geuna and Nesta, 2006; Larsen *et al.*, 2007), the Bayh-Dole Act is viewed as "***possibly the most inspired piece of legislations to be enacted in America over the past half-century***", as characterized by a recent article in the Economist (2002). Believing that the Act enhanced technology transfer and universities' contributions to innovation in the United States, many OECD countries have been or are considering adopting a similar Act (OECD, 2002). Mowery and Sampat (2005) doubted that the Act could successfully immigrate elsewhere in the OECD without greater attention being paid to the underlying structural differences among the higher education systems of these nations. In the USA, there is a long-standing and relatively close relationship between university and industrial innovation (Sampat, 2006). The US institutional context differs significantly from another nation being emulated the Act. Mowery and Sampat (2005) suggest that reforms to enhance inter-institutional competition and autonomy within national university systems, as well as support to external institutional contributors to new-firm formation and technology commercialization, appear to be more important.

Besides Mowery and Sampat's doubt, many arguments have been expressed on the negative effect of the Act considered as representing a socially inefficient 'privatization' of academic research and a threat to the ethos of science itself (Sampat, 2006). Henderson *et al.* (1995) criticize university involvement in business-side activities as it may cause universities to shift research disciplines from basic to more applied work. Nelson (2001) focuses his attention on the problematic nature of US universities' patenting and licensing. He considers that if universities are in the business of research to make money this may cause a significant change in public attitudes and university-industry interest conflict in terms of IP. He thinks the appropriate way to "market" open science is to advertise it through non-commercial transfer models, e.g. talks, publications, conferences and to place science in the public domain. Universities should remember that their comparative, or absolute, advantage in national innovation systems, lies in the arena of open public science and training.

Foray (2002) demonstrates that substantial IP-related transaction cost may increase to block knowledge exploitation and accumulation. University professors may refuse to share their academic outputs with colleagues and students, because of their awareness of intellectual property rights protection. In this case, it prevents students and colleagues from acquiring new knowledge and decreases the possibilities to make knowledge innovation. The total quality of S&T human capital will be damaged (Tang, 2005). The users who can afford technology transfer do not guarantee they can succeed in exploiting a good entirely, because an excess of privatization is related to excessive fragmentation of the knowledge base, linked to intellectual property rights on parcels and fragments of knowledge that do not correspond to an industrial application (Foray, 2002). Even though licensees do exploit a new product with patented technology, nobody is sure that the product is the best one. We cannot exclude that a better one would come from others who do not have sufficient financial resources to get involved in technology transfer.

Furthermore, before being granted patents or licenses, researchers may delay their publications on purpose. Then the public gets the knowledge with a time lag. Innovative activities based on these publications will be delayed as well as further research. Too much emphasis put on appropriability and IPR is likely to exert a pernicious influence on both the rates and directions of research. It might also represent a significant hindrance to business-led innovation (Dosi *et al*., 2006b).

Geuna and Nesta (2006) explored previous studies and identified five main possible negative impacts of increased university patenting and licensing:

- ***Publishing versus patenting***: active patenting activities for young researchers from the start of their careers may prove to be less productive in the long-term;
- ***Teaching quality***: if patent output is to be used in the academic evaluation process, teaching will be the activity most likely to suffer the highest time reduction;
- ***Open science***: negative impact on the culture of open science, in the form of increased secrecy, delays in publication, increased costs of accessing research material or tools;
- ***Fundamental long-term research***: diverting research resources (researchers' time and equipment) from the exploration of fundamental long-term research that tend not to be suited to the development of IPRs;
- ***Further academic investigation***: theoretically, university researchers are allowed to use patented inventions for their further research without being obliged to pay license fees. However, this exception is not sustainable if the firm holding the exclusive right to exploit a patent decides that the research exception is not applicable to university projects financed by industry.

Nevertheless, there is no systematic evidence in European countries and the US that the growth of university patenting and licensing affects negatively the conduct of or return from open science (Neslon, 2001; Geuna and Nesta, 2006; Sampat 2006). Since conclusive evidence has been found neither on the positive effects nor on the negative effects of the Act implemented in many OECD countries, more studies need to be explored, especially in some developing countries like China who emulates the Bayh-Dole Act, too. In Section 2.2.3, we would like to assess whether the Chinese Act has a similar impact on university patenting and licensing as the US one. Following Geuna and Nesta's (2006) research, we will also discuss the negative impacts proposed by of increased university patenting and licensing in China.

2.2.2.2 Methodology and data

Mowery *et al.* (1998, 2001, 2002a and 2002b) and Sampat (2006) are among the main contributors in assessing the effect of the US Bayh-Dole Act on university patenting and licensing. Their research focuses on the comparison of university patenting activities before and after the Act in 1980 on the basis of three elite US universities. Following their research methodology, we first analyze university patenting and licensing before and after the promulgation of the Chinese Act in 2002, and then examine two academic institutions that are research universities: Tsinghua University and Chongqing University. Slightly different from Mowery *et al.*'s and Sampat's case study, our sampled universities are not at the same level in terms of comprehensive competitiveness and patenting activities. According to Chinese university rankings 2007, Tsinghua University is recognized as the No.1 among all Chinese universities while Chongqing University is ranked 45th. With respect to the number of applied and granted patents between 2001 and 2004, Tsinghua University took the first place and Chongqing the 32nd place among all the Chinese universities. Our purpose is to test whether the Chinese Bayh-Dole Act influences the IP activities of universities at different level. Tsinghua University represents the group of national leading universities and Chongqing University represents the group of provincial leading universities.

For ensuring the validity and reliability of the results of our analysis, we paid much attention to the quality control during the data collection process (Yin, 1994). We collected the information from multiple sources of evidence which converged on the number of applied and issued patents: documentation and archival records. The patenting and licensing data used in this section were published by governmental authorities: National Bureau of Statistics of

China, State Intellectual Property Office and Science & Technology Development Center of Ministry of Education. Only the data 1999-2000 of issued university patents were collected from internal reports of our sampled universities. We compared the data on university patenting before (1999-2001) and after (2003-2005) along with the data on university license contracts number/incomes before (2000-2001) and after (2003-2004) the Bayh-Dole Act to discuss the effect of the Act on university's innovation outputs.

To examine whether the Bayh-Dole Act is the unique factor which influences rising university patenting activities, we conducted an open-ended interview with an IP director of Chongqing University and he helped us fill in a structured survey on university IP management. Information about IP management in Tsinghua University was collected from the university's internal records, publicly available documentations and some discussions with Tsinghua professors.

2.2.3 The effect of the Chinese Bayh-Dole Act on university patenting and licensing

In this section, we would like to examine the impact of the Chinese 'Bayh-Dole Act' on university patenting and licensing at a general level then move on to a case study.

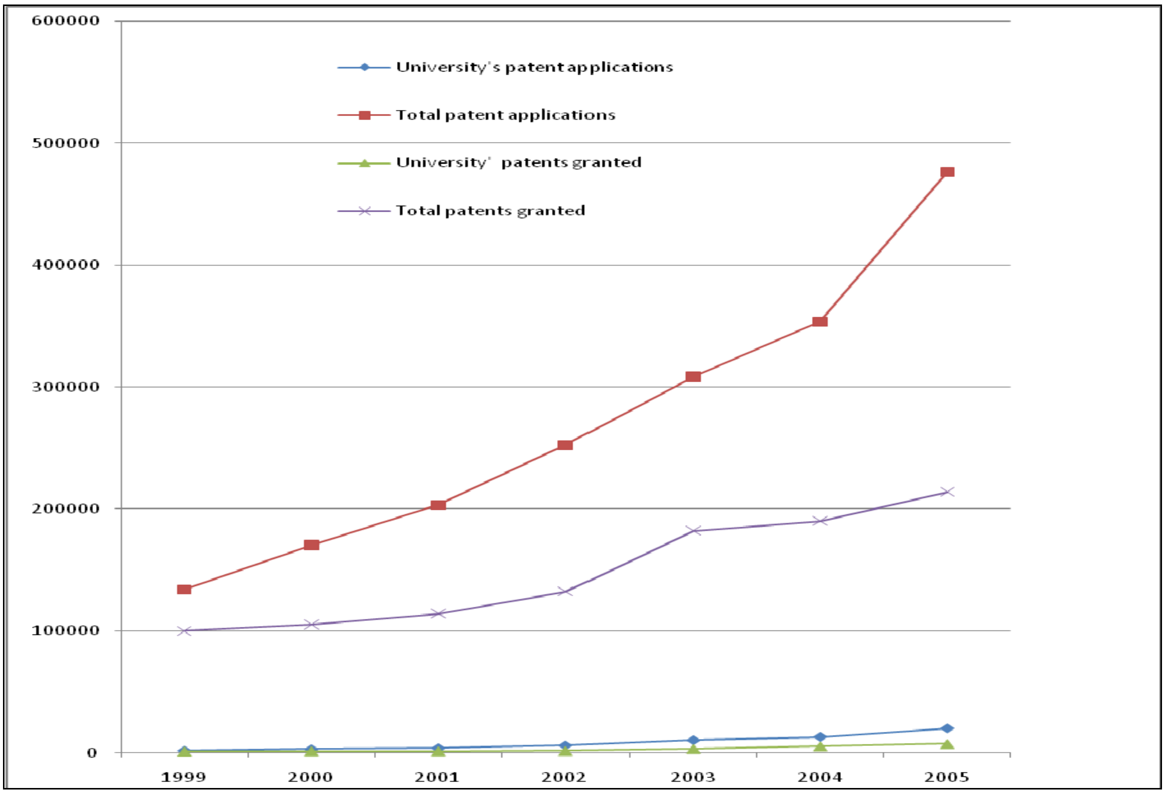
2.2.3.1 University patenting activities before and after the Chinese 'Bayh-Dole Act'

To examine whether the university patentability is influenced by the Act, we compare the total patenting activities with university patenting activities first (see Figure 2.4) then we focus on university patentability. Figure 2.4 shows that the total patentability[71] and university patenting kept increasing from 1999 to 2005. But the growth rate of total patenting before and after the Act was not as significant as university patenting. For example, the total patent

[71] Total patentability: it includes patenting activities in terms of applied and issued patents which are conducted by firms, universities, research institutes and individuals and other organizations.

applications increased by 52% in the pre- Act period (1999-2001) and 54% in the post- Act period (2003-3005). The total issued patents grew slightly from 14% pre-Act to 17% post-Act. As for university patenting, the growth rate of patent applications amounted to 115% before the Act (1999-2001) to 94% after the Act (2003-2005). And the number of issued university patents increased significantly, from 18% in 1999-2001 to 117% in 2003-2005. It demonstrates that the Chinese Bayh-Dole Act retains the expansion of university patentability.

Figure 2.4: Patenting activities before (1999-2001) and after (2003-2005) the Act in SIPO[72] (unit: piece)



Source: data collected from China S&T Statistics Data Book 1999, 2001, 2002, 2003, 2005 and 2006.
Note: university patenting* here includes three types of on-duty patents in China: invention, utility model and design[73].

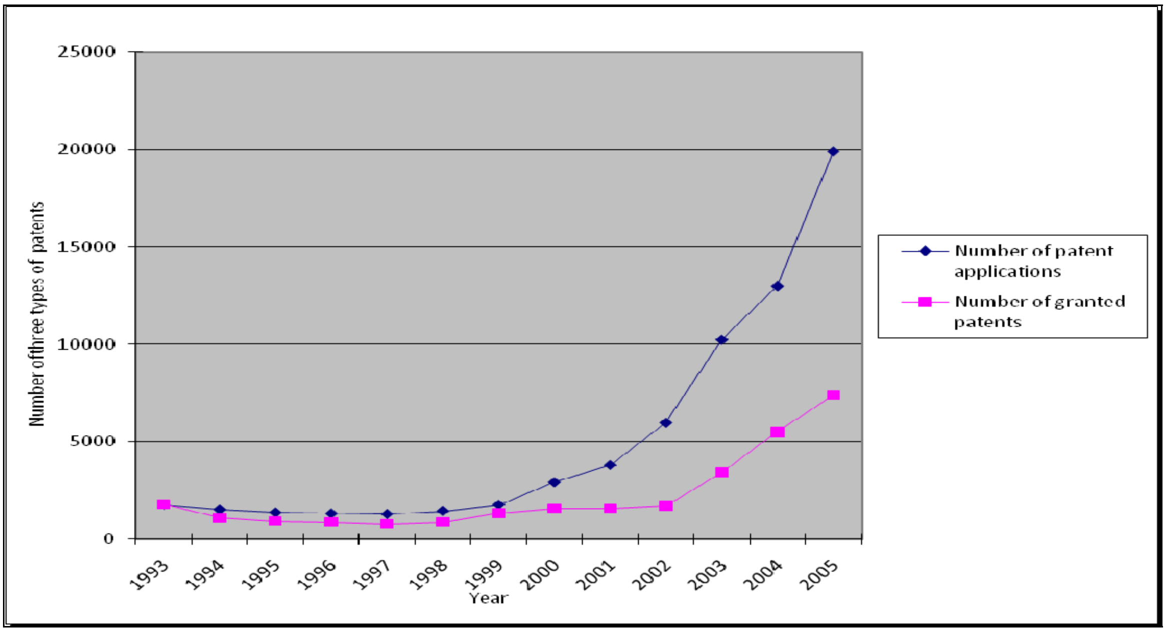
[72] SIPO: its entire name is called State Intellectual Property Office of the People's Republic of China. The former body of the State Intellectual Property Office (SIPO) was the Chinese Patent Office, founded in 1980. In 1998, during a reform of governmental bodies, the name of the Chinese Patent Office changed to the State Intellectual Property Office, which is directly subordinated to the State Council. Now, the Patent Office is affiliated to the State Intellectual Property Office.
(Source: http://www.sipo.gov.cn/sipo_English/about/basicfacts/overview/200707/t20070723_182116.htm).

[73] "Invention" means any new technical solution relating to a product, a process or improvement thereof.
"Utility model" means any new technical solution relating to the shape, the structure, or their combination, of a product, which is fit for practical use.
"Design" means any new design of the shape, the pattern or their combination, or the combination of the

After comparing the development tendency of total patenting activities with university patentability, we now focus on university patenting activities pre-and post-Act. Similar to US universities, university patenting activities experienced a significant growth after the enactment of the Chinese Bayh-Dole Act (see Figure 2.5). Between 1993 and 1996, the number of patent applications and patents issued to universities decreased dramatically from 1765 to 1320 and from 1774 to 854 respectively. However, the number of patents began to increase from 1998 onwards. The remarkable growth in university patenting appeared after 2002 in terms of both applied and issued numbers. The applied patents by universities increased again by 94% during the 2003-2005 period, whereas the issued patents climbed by over 117%. This confirms that the Act has promoted university patenting expansion and it has had a stronger impact on the growth of university's granted patents than on patent applications. Although the patents issued to universities were much more important between 2003 and 2005 than between 1999 and 2001, it was surprising to discover that the growth rate with respect to patent applications was higher between 1999 and 2001 than between 2003 and 2005. It seems that some other factors may have provided incentives to universities for patenting before the enactment of the Chinese Bayh-Dole Act. We will discuss the question later.

colors with shape or pattern, of a product, which creates an aesthetic feeling and is fit for industrial application. – Source: Intellectual Property Rights in China, 2006.

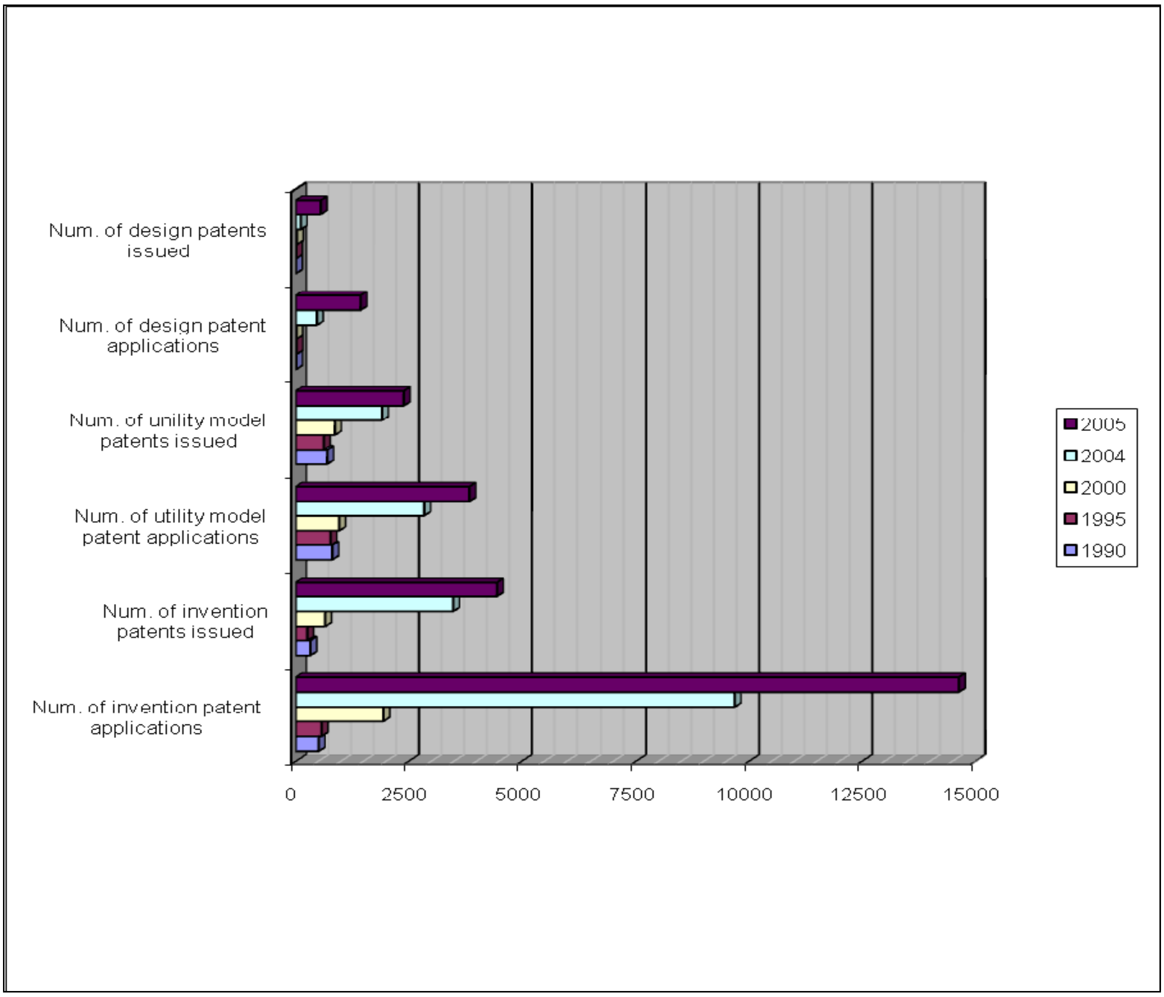
Figure 2.5: University patenting* in SIPO from 1993 to 2005 (unit: piece)



Source: data collected by the author from www.stats.org.cn

Among the three types of on-duty patent applications (invention, utility model and design), the majority of university patent expansion focuses on invention patents (see Figure 2.6). This shows that universities concentrate on knowledge-intensive innovations.

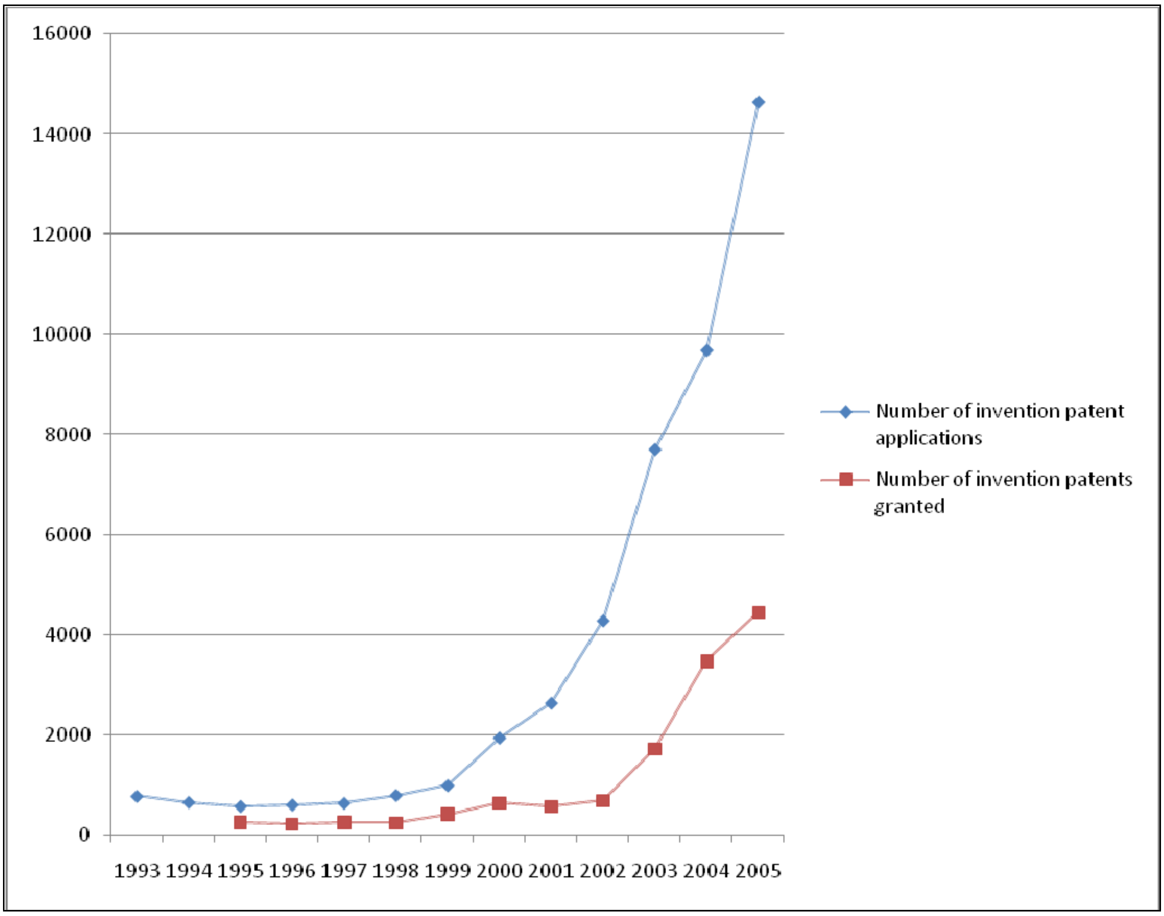
Figure 2.6: Three types of on-duty patenting activities of universities in SIPO



Source: data collected from the China Statistics Year Book 2006.

The on-duty invention patent applications of universities (see Figure 2.7) were consistent with the upward tendency of three types of patent applications showed in Figure 2.5 before and after the Act. In terms of granted patents, except the period of 1996-1998, the invention patents granted followed the tendency of total issued patents. But the universities kept a much higher growth rate in filing invention patent applications before (1999-2001) the Act than after (2003-2005) the Act, namely 167% against 90%. In comparison with the growth rate of granted invention patents, universities had a rather higher rate (157%) after the Act than before the Act (36%). The result provides evidence that the Chinese Bayh-Dole Act contributes to the rising university patenting and plays a more important role in issued invention patents than in invention patent applications. Concerning the marked rise in patent applications before the Act, we will explain the reasons after discussing university's licensing incomes.

Figure 2.7: On-duty invention patents applied by and granted to universities in SIPO from 1993 to 2005 (unit: piece)



Source: data collected from China S&T Statistics Data Book 2002, 2006.

Simultaneously with increased patenting, Chinese universities expanded their efforts to market their inventions.

2.2.3.2 University licensing activities before and after the Chinese 'Bayh-Dole Act'

The yield of university's marketing efforts can be measured by the number and the value of licensing transaction contracts. Licensing contracts are one of the four categories of technology transfer contracts[74], accounting for less than 10% of the total contracts (except 2002) and less than 20% of the total value. Licensing contracts prove not to be the most frequent technology transfer mechanism for Chinese universities. Compared with the upward tendency of university patenting, licensing activities seem more fluctuating (see Table 2.1).

Table 2.1: Universities licensing activities from 1993 to 2004

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Number of technology transfer contracts signed with firms*	4709	4065	4179	4065	3790	3727	3336	4223	4807	4816	6323	8096
Received income from firms based on the technology transfer contracts (million €)	21.7	20.5	23.4	30.8	35.8	46.7	59.3	100.4	97	81.7	118.2	121.2
Number of license contracts	390	326	364	367	362	371	298	299	410	532	611	731
Received license incomes (million €)	2.35	1.17	2.2	3.96	3.65	5.54	7.01	12.54	18.6	15.01	23.36	15.2

Source: www.sts.org.cn
Note: university licensing agreements* here relate to engineering, medicine and agriculture fields in universities. Some elite universities with strong engineering disciplines are the major players in licensing activities (Xue, 2006).
Exchange rate: 100RMB = 10 EURO

Before 1998, the number of licensing contracts was around 360, with royalty incomes fluctuating from 5.69% to 12.85% of total incomes of technology transfer contracts. During

[74] Technology transfer contracts are composed of four categories of technology transfer: transfer the right of filing for patent applications, the patent, licensing the patented technology and technical secret.

the period of 1998 and 2001 the license incomes kept a sharp increase from 5.54 million € to 18.6 million €, but the income dropped dramatically to 15.01 million € in 2002 and rebounded to its peak 23.36 million € in 2003. Unfortunately the tendency to grow did not remain for a long period, and in 2004 the license income rapidly went back to approaching the level of 2001. These statistics underline the fact that universities were active in licensing before the Chinese 'Bayh-Dole Act'. On the contrary, after the Act, 2004 saw the sharp drop of licensing revenues gained by universities, in spite of increased licensing contracts. It is also strange to observe that the decreasing number of licensing contracts in 1999 and 2000 led to a major growth of licensing revenues. And the sharp increasing number of licensing contracts in 2004 caused the licensing income to decrease. It seems that licensing incomes do not depend necessarily on the number of licensing contracts but on the quality of a very small group of patented inventions, which may account for the majority of gross licensing (Mowery *et al*., 1998, 2001).

To sum up, the number of university licensing agreements remained the upward tendency pre- (2000-2001) and post- Act (2003-2004) but the incomes received did not follow the growth. The licensing incomes decreased by 35% after the Act whereas before the Act the incomes had increased by 149%. The enactment of the Act facilitates slightly the growth of university licensing agreements but seems not to be in favor of increasing licensing incomes.

To show the effect of the Chinese 'Bayh-Dole Act' on university patenting and licensing in a clearer way, we would like to synthesize the above data in Table 2.2.

Table 2.2: University patenting and licensing before and after the Act in SIPO

Indicators		Before the Act (1999-2001)	After the Act (2003-2005)
Three types of	Applied	115%*	94%

patents	Granted	18%	117%
Invention patents	Applied	167%	90%
	Granted	36%	157%
Licensing contracts*	Number	37%	20%
	Value	48%	-35%

Source: calculated by the author herself.
Note: all percentage rates mean growth rates. When we compare licensing contracts in terms of number and value before and after the Act, the comparative periods refer to 2000-2001 and 2003-2004.

Table 2.2 demonstrates that the Chinese Bayh-Dole Act plays a similar role in facilitating the growth of university patenting and licensing agreements as the American Act but it is not as convincing as the US one in increasing the licensing revenues. Moreover, the rising rhythm of university granted patents is much more significant after the Act than it was before the Act. It may induce that the Act improves the quality of applied patents. Concerning the applied patents and licensing contracts the number increased faster before the Act than those after the Act; we consider that besides the Act, other factors may have contributed to the rising university patenting and licensing activities. The next part will discuss these factors and also address the question why universities do not generate as much license revenues as expected.

Based on published literature, university internal records, survey and our interviews with university IP managers, we find that other Chinese legislations, university internal organization and policies have a positive influence on the increasing patenting and licensing activities.

Actually, before the enactment of the Chinese Bayh-Dole Act, the Chinese Patent Law authorized universities to hold invention IPR arising from publicly funded research and to share the technology transfer incomes. A series of other established governmental laws before 2002 improved university's interest in intellectual property rights (IPRs) protection and facilitated the commercialization of innovation outputs (see Appendix 2.3, p.315). These laws along with China's economy turning into market-orientation promoted the change of the university's philosophy from pure knowledge generation and diffusion to somewhat the pursuit of economic return arising from intellectual outputs. Before the implementation of IP policies, the intellectual property rights resulting from research achievements belonged to the

"Nation" or the "Chinese people as a whole" (Zhang, 2005). Traditional Chinese philosophy emphasizes the interest of the state and society as a whole, as opposed to the individual (Bosworth and Yang, 2000). The not-for profit personal contribution to society is widely recognized as a merit. And Chinese thinkers preferred to see the universe as an organic whole, recoiling from the analysis of the inner mechanism of its parts, and steadily refusing to draw a clear distinction between the spiritual and the material (Huang and Needhan, 2004). The spiritual satisfaction offset Chinese people's desire for material pursuit. The university's mission followed traditional Chinese philosophy and conducted not-for-profit knowledge creation and diffusion activities. Professor's responsibilities are oriented to transfer the 'order of Nature' **(*Chuan Dao*),** professional knowledge/technique **(*Shou Ye*)** to students and help students address questions **(*Jie Huo*)**[75]**.** The involvement of universities in any commercial activities would be criticized as being against their mission and shameful. Later, material incentive systems and a systematic protection of IPRs were viewed as tools to promote progress in science and technology, to move from invention to innovation and to develop the economy. The university's participation in commercialization of research findings is gradually accepted by society although the debates on university's mission have never ended.

Furthermore, Chinese universities themselves have suffered from many IP infringements in recent years: on-duty inventions privatized into off-duty inventions, loss of laboratory inventions with the mobility of S&T researchers, university name and mark improperly used for commercial purpose by private firms, faculty inventions transferred personally to industry without university's permission, etc (Lin, 2005; Zhang *et al*., 2005; Chen and Guo, 2006; Tong and Qian, 2006; Yuan *et al*., 2006). Viewing the IP infringements as an economic loss, universities have or start to get engaged in patenting and licensing activities to protect intellectual achievements. And the creation of IP courts in 1993 provides universities with the last resort for protecting their IP rights.

Last but not least, to attract brilliant researchers and students, to gain more public research funding as well as to pursue economic revenues, universities, especially research-oriented universities, have conducted institutional innovations. On one hand, universities restructure the reward system for inventors. Given an inventor takes part in the process of

[75] The orientation of professor's responsibilities (Chuan dao, Shou ye, Jie huo) is cited from Yu HAN's famous article "On the Teacher". Yu HAN (768-824) was a great literator and philosopher in the Ancient China.

marketing inventions, he could share at least 20% of the net technology transfer income (Tang, 2006a). Universities also create patent funds to support the patentability of researchers. And some universities have started to use patenting in the academic evaluation process. On the other hand, universities set up technology transfer offices (or similar) and IPR offices to commercially exploit research outputs and manage IP issues. For example, in Zhejiang province, 54.3% of the universities have set up IPR offices and patent funds (Yuan *et al.*, 2006). These institutional innovations in universities arouse academic entrepreneurial spirit, guiding R&D activities to meet market demand.

All the above factors are considered to encourage faculty researchers to be active in patenting activities. Inventors directly benefit from such activities in terms of material compensation and academic reputation. Recent studies on Chinese university IPRs have demonstrated that the series of laws for promoting technology transfer, the creation of UTTOs (or similar) and IPR offices, patent funds and the assessment of professor workloads related to patenting, have contributed to rising university IP activities (Chen and Guo, 2006; Mei et *al., 2005*; Tang, 2006b). Thus, the Chinese 'Bayh-Dole Act' is only one of the factors which lead to increasing university patenting and licensing.

Concerning the effect of the Act on licensing revenues, it is not as convincing as that of the US Act. The reasons are found to be the following:

The interactions between university and industry on technology markets are represented by technology development contracts. Under this form of contracts, enterprises entrust universities with technology tasks or do joint research with universities for a specific issue or even set up an institute with universities for long-term research in a special field. Pure licensing agreements account for a very small part of all technology contracts transacted by universities, although licensing activities have been rising in recent years (Xue, 2006).

From the university side, it is very hard to find a firm that has an interest and the capability to commercially exploit university inventions (Thursby and Kemp, 2002; Eun *et al.*, 2006). University inventions are usually embryonic and need further research investment. From the industry side, weak absorption capability prevents firms from exploiting university-licensed innovation outputs. And according to the statistics of the State Intellectual Property Office, over 90% of Chinese firms have no patenting activities. The shortage of intellectual property (IP) experience also hinders firms from identifying and evaluating the value of university research findings correctly. But business firms in advanced countries are routinely active to engage in patenting activities and get licensed technology from universities. That is the reason why licensing agreements are used as a very traditional and effective technology transfer tool between science and industry in western countries.

Moreover, problems of asymmetrical information and moral hazard discourage licensing transactions. For example, inventors may not disclose full technology information to licensees or licensees may refuse to pay the agreed amount of royalties[76] entirely once they have learned the know-how. The potential risks provide university incentives to create IP-based spin-offs or make equity investments in start-ups instead of patent and license costs.

2.2.3.3 Case studies: Tsinghua University and Chongqing University

After assessing university expansion in patenting and licensing activities before and after the effective date of the Chinese Bayh-Dole Act at a general level, now we would like to focus on Tsinghua University's and Chongqing University's patentability before and after the Act. Licensing activities are not included in our analytical framework because licensing transactions are not an important technology transfer mechanism for both universities. The two sampled universities belong to experienced 'incumbent' academic patenters (universities are ranked among the first 74 Chinese ones in terms of cumulative patent applications during the period of 1985-2000).

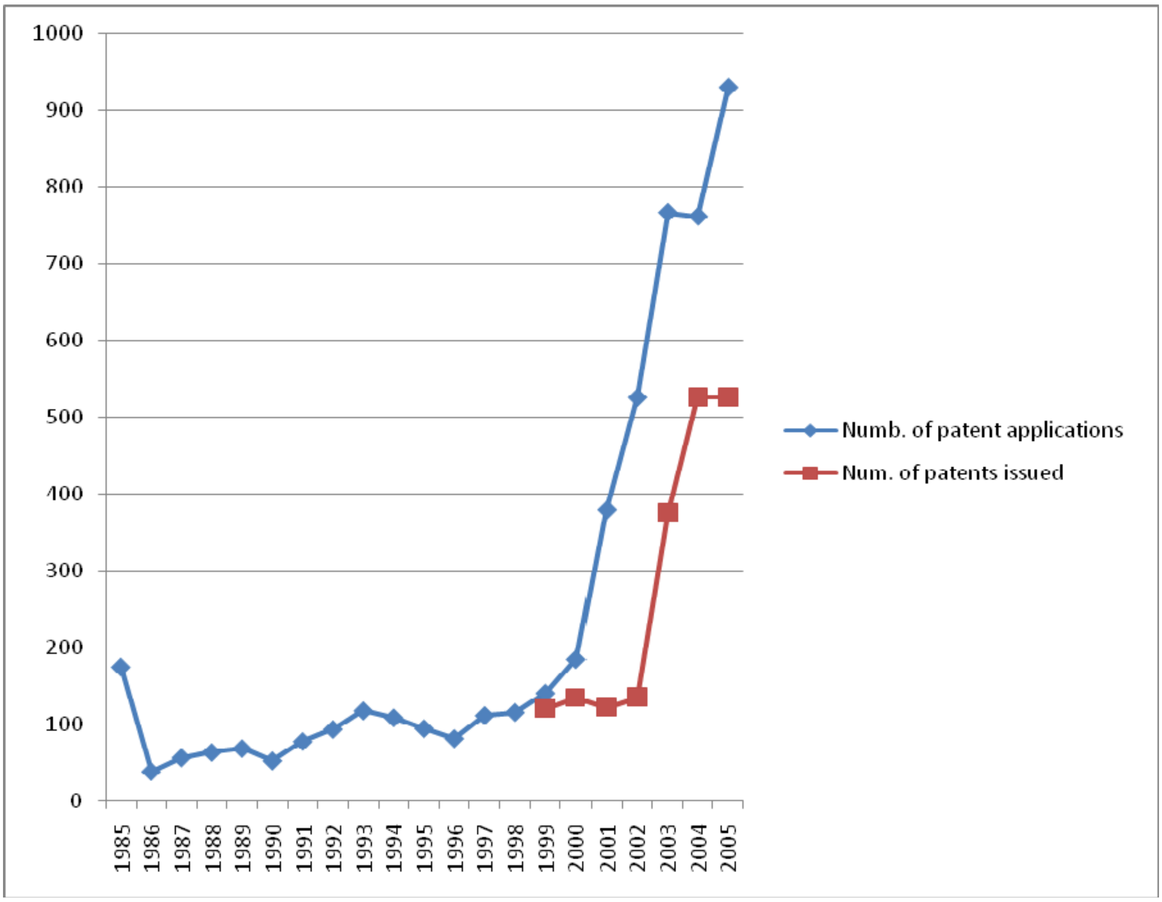
2.2.3.3.1 Tsinghua University

Tsinghua University started to file for patent applications from the effective date of the Chinese Patent Law in 1985. Except for a very few periods of decrease, the amount of patent applications has been increasing up till now (see Figure 2.8). The patenting in Tsinghua experienced a stable growth before 1998. During the period 1986-1992, the number of patent applications was lower than 100. From 1993, the number rose above 100 and kept growing

[76] The payment of royalties takes the form of up-front fees at the time of closing the deal, and annual, ongoing royalty payments that are contingent upon the commercial success of the technology in a down-stream market (Bercovitz and Feldman, 2006).

except in 1995 and 1996. After 1997, the activities in patent applications increased sharply, from 141 in 1999 to 930 in 2005. Concerning the number of patents issued, the dramatic growth appeared in 2003 and 2004 and remained unchanged in 2005. Before the Act, there was a slight increase in 2000 followed by an immediate decrease in 2001.

Figure 2.8: Patenting activities of Tsinghua University in SIPO (1985-2005)



Source: S&T Development Center, Ministry of Education, SIPO and Tsinghua University.
Note: data of issued patents in 1999 and 2000 collected from Tsinghua University and data of patent applications and issued patents in 2005 collected from SIPO. The rest is collected from S&T Development Center, Ministry of Education.

If we compare the patenting of Tsinghua during the periods of before and after the Chinese Bayh-Dole Act, it is in line with the tendency of Chinese universities at the general level in terms of patenting growth (see Table 2.3). That means that the expansion rate of Tsinghua's patent applications was faster before the Act than after the Act but the growth rate of granted patents after the Act was higher than before the Act. It shows that the Act influences more on the increase of granted patents than on patent applications. And the growth rate of patenting activities before the Act demonstrates that some other factors may have had an impact on Tsinghua University's enthusiasm towards patenting.

Table 2.3: Assessment of the effect of the Chinese Bayh-Dole Act on the patenting activities of Tsinghua University in SIPO

Indicators		Before the Chinese Bayh-Dole Act (1999-2001)	After the Chinese Bayh-Dole Act (2003-2005)
Three types of patents*	Num. of patent applications	170%	21%
	Num. of patents issued	1.65%	40%

Source: original data collected from S&T Development Center, Ministry of Education, SIPO and Tsinghua University.
Note: Three types of patents include invention, design model and utility. All percentage rates mean the growth rates and are calculated by the author herself.

Tsinghua's organizational innovation and internal incentive policies are found to influence the expansion of patenting activities of Tsinghua University. We will explain the two factors in the below.

In terms of organizational innovation, an office similar to a technology transfer office was set up by Tsinghua University (Tang, 2006b) in 1983 and a national technology transfer center was officially created in 2001. The creation of these two offices proves that Tsinghua has been engaged in marketing university research outputs over the last two decades and has accumulated some experiences in exploiting the commercial value of research findings before the Act. Tsinghua was also the pioneer university for the implementation of the regulations on IPR management in 1997. Along with the regulations, the IPR office was established with the specific task to manage university IP activities. There were initially two persons working for the office. One was a full-time staff appointed directly by Tsinghua University, the other was a part-time administrator. Now the office has expanded in terms of personnel and services. Tsinghua's experiences were recognized and disseminated by the State through the enactment of regulations on university IP management in 1999.

Apart from organizational innovation for marketing inventions and IPR protection, Tsinghua University provides incentive mechanisms before the Act to professors for the inventions disclosure and their participation in putting R&D findings onto the marketplace (Mei *et al.*, 2005): material and moral rewards to inventors, appointment and tenure related to patenting activities, the creation of patent funds to support patenting… The Act of 2002 seemed to maintain the growing trend of patenting, except for the year 2004.

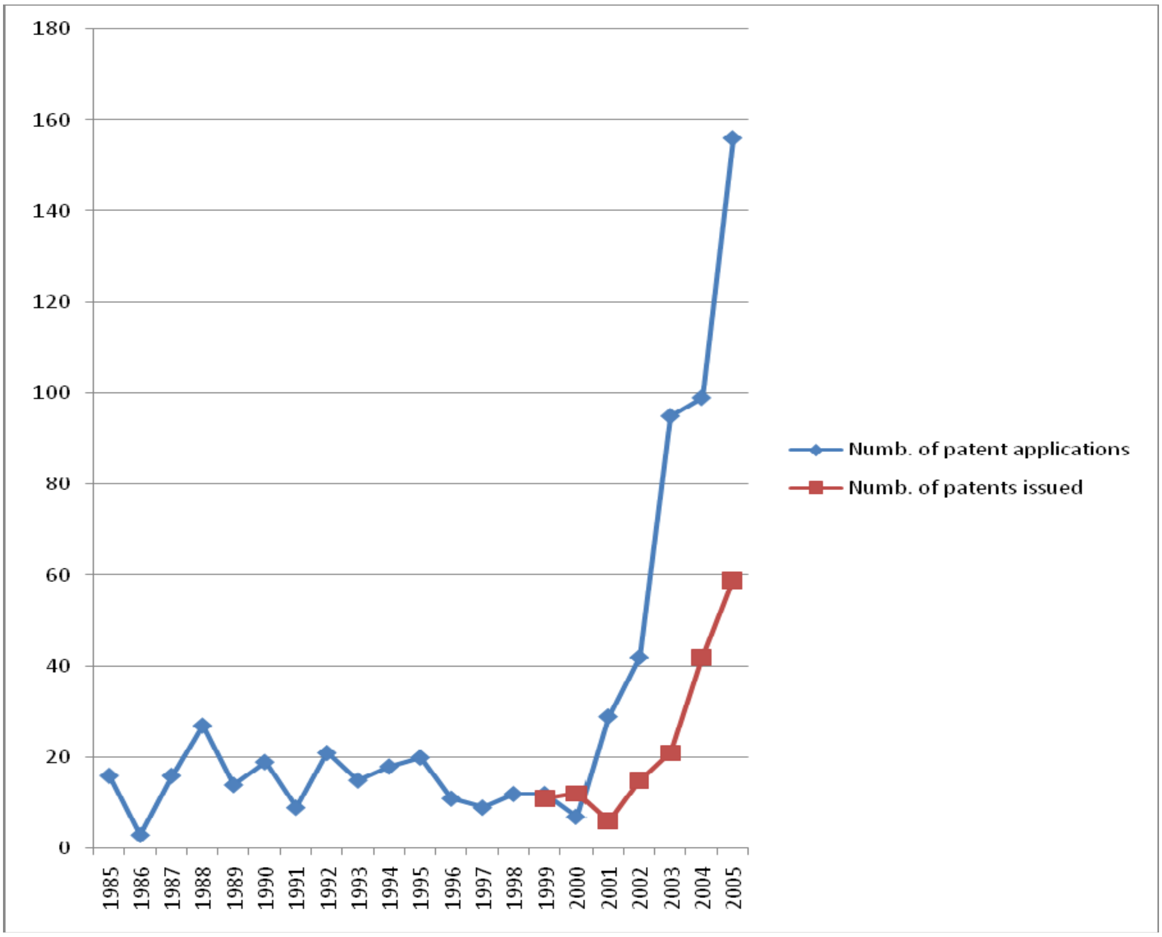
The renewed expansion of patent applications in 2005 was probably linked to the research advancement of biotechnology and co-patent applications with industry. According to the statistics of the State Intellectual Property Office (2007), the share of university patenting in the biotechnology field jumped from 20% in 2001 to 40% in 2005 of the total patenting. In 2006, 8 out of the top 10 patenters in biotechnology were universities and Tsinghua occupied the first rank with 102 pieces. It appears that the increasing university patenting benefits partially from the growth in biotechnology patenting. The phenomenon supports some western research results that the increase in university patenting has been due more to opportunities in the bio-medical field than to any new policy action in the US and European cases (Nelson, 2001; Bercovitz and Feldman, 2006; Geuna and Nesta, 2006). And in 2005, co-patenting with industry accounted for about 30% of all patent applications (Tsinghua University's S&T report, 2005). Thus, the Chinese Bayh-Dole Act is merely one of the factors which contribute to the growth of university patenting.

In terms of licensing in Tsinghua, we only know that in recent years, pure licensing agreements account for less than 5% of all technology contracts transacted by Tsinghua. Approximate 75% of the contracts are technology development contracts, about 20% are technology transfer and service contracts (Mei *et al*., 2005). Similar to US cases, licensing agreements often bind technology development contracts (Jensen and Thursby, 2001). On one side, the licensed technology is embryonic and remains at the proof of concept but not at the prototype stage which needs continuous research from the contract parties concerned. On the other side, the industry's weak absorption capability requires to co-operate with university to exploit the licensed technology.

2.2.3.3.2 Chongqing University

Chongqing University is a leading provincial university and it ranked 20th among all Chinese universities in terms of patent applications between 1985 and 2000. Although its patent applications are much lower than Tsinghua University, the growth tendency of patentability presents similar characteristics (see Figure 2.9). Before 2001, the number of patent applications in Chongqing University experienced a series of ups and downs. Starting from 2001, the activities of patent applications kept growing very fast. And the patents issued remained an upward tendency from 2002. The expansion of patentability before 2002 induces that some other factors may have already efficiently promoted Chongqing University's activities in patenting.

Figure 2.9: Patenting activities of Chongqing University in SIPO (1985-2005)



Source: S&T Development Center, Ministry of Education, SIPO and Chongqing University.
Note: data of issued patents in 1999 and 2000 collected from Chongqing University and data of patent applications and issued patents in 2005 collected from SIPO. The rest is collected from S&T Development Center, Ministry of Education.

To assess the effect of the Chinese Act precisely on Chongqing University patenting activities, we now focus on the patentability at the period of before (1999-2001) and after (2003-2005) the Act (see Table 2.4).

Table 2.4: Assessment of the effect of pre- and post-the Chinese Bayh-Dole Act on patenting activities of Chongqing University in SIPO

Indicators	Before the Chinese Bayh-Dole Act (1999-2001)	After the Chinese Bayh-Dole Act (2003-2005)

Three types of patents*	Num. of patent applications	142%	64%
	Num. of patents issued	-45%	181%

Source: original data collected from S&T Development Center, Ministry of Education, SIPO and Chongqing University.
Note: Three types of patents include invention, design model and utility. All percentage rates mean the growth rates and are calculated by the author herself.

Table 2.4 confirms again that the enactment of the Act is helpful to keep the development tendency of university patenting upward. But the growth rate of patent applications was lower after the Act than it was before the Act. The issued patents exhibited a more significant expansion after the Act than before the Act. This result is consistent with our findings about the effect of the Act on university patenting at a general level. Concerning the reason about the sharp growth of patent applications appeared before the Act (1999-2001), our finding is somewhat similar to that of Tsinghua University.

On the basis of a review of some literature and of contacts with Chongqing University, we found that its patentability expansion was related to several factors. At the organizational level, an IPR office and an office similar to TTO were created before 2002, which were in charge of university IPR and technology transfer issues. The IPR office organizes IPR courses and seminars to diffuse IPR knowledge among researchers and assists inventors in filing patent applications. TTO takes various measures to introduce university research outputs onto the marketplace: publishing a yearly catalogue about patented and non-patented technology; participating in university hi-tech exhibitions; diffusing technology information through websites… A university innovation fund has been created to finance the patented technology with market potential. And attractive incentive rewards system is provided to inventors whose enthusiasm is stimulated for producing more patentable inventions. As is the case at Tsinghua University, patents are used as an indicator to assess researcher workloads in Chongqing University which promotes the expansion of faculty patenting activities. The organizational and incentive institutional system helps create a favorable environment for patenting. Furthermore, in 2000, Chongqing University merged with two architecture universities. The merger led to a sharp increase of R&D expenditure from 130 million RMB (about 13 million €) in 2001 to 251 million RMB (about 25.1 million €) in 2004, which probably facilitated the remarkable increase of patenting.

To test the relationship between R&D expenditure and patenting, we sampled 38 research-oriented universities in the period of 2001-2004 by a linear regression model. The data used here is provided by the S&T Development Center of the Ministry of Education. Our result supports the assumption that R&D expenditure has a positively significant effect on university patenting activities (see Table 2.5, 2.6). And R&D investment influences the number of patents applications more than it does patents issued.

Table 2.5: Linear regression result

Regression statistics

Adjusted R square	0.7324 (patent applications)
Observations	38

	Coefficients	Probability
R&D expenditure (million RMB)	0.6332	4.5990E-12*

Significance: *$\rho<0.01$

Table 2.6: Linear regression result

Regression statistics

Adjusted R square	0.7967 (patents issued)
Observations	38

	Coefficients	Probability
R&D expenditure (million RMB)	0.2678*[2]	3.1558E-14*

Significance: *[1]$\rho<0.01$

Concerning the impact of the Act on licensing, Chongqing University is engaged in even less licensing activities than Tsinghua University. According to interviews with an IPR officer in Chongqing University, the university prefers to license patented technology. But it is hard to find a firm that has an interest and the capability to commercially exploit university inventions (Eun *et al*., 2006). The university then tends to exploit the invention with commercial potential by creating a spin-off in a university incubator. Recent studies show much interest in university IP-based spin-offs (Bekkers *et al.,* 2006; Bercovitz and Feldman, 2006; Feldman *et al.,* 2002; Markman *et al.,* 2005).

2.2.3.4 The negative impacts of increased university patenting and licensing

As we mentioned in the literature review, many debates centred on the "unintended" effect of the Act on open science (Henderson *et al*., 1995; Nelson, 2001; Foray, 2002; Dosi *et al.,* 2005; Geuna and Nesta, 2006; Sampat, 2006; Tang, 2006a). We would like to follow Geuna and Nesta's (2006) arguments to examine whether five possible negative impacts of university patenting and licensing have appeared in China.

- ***Publishing versus patenting***: the Chinese patent law allows a grace period of six months and considers that presentations first made at academic or technical conferences do not disqualify the novelty of an invention (Sun, 2003). Researchers who are afraid of delaying publication can choose presentations in identified conferences. Previous western research demonstrates that the effect of an additional publication on patents is positive and significant (Owen-Smith and Powell, 2001; Jensen and Thursby, 2004; Stephan *et al*., 2007).

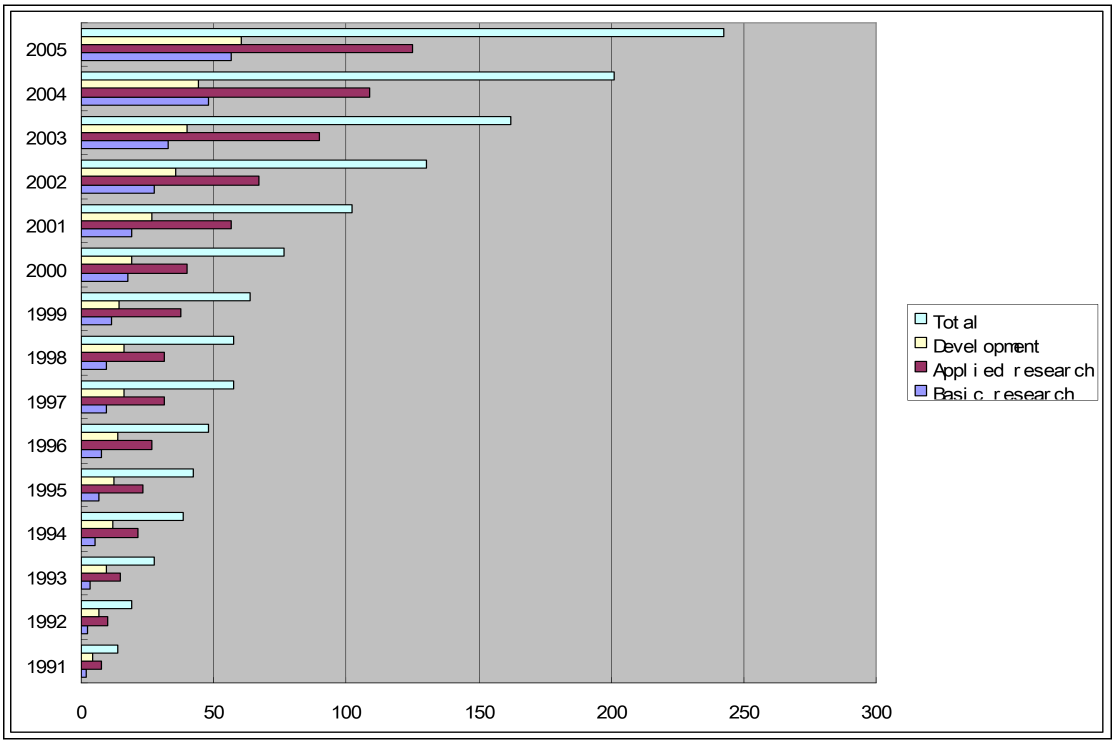
- ***Teaching quality***: a few Chinese universities start to use patent output as an indicator to evaluate professor workloads. In the short-term, this measure seems to have promoted professors' enthusiasm in patenting but in the longer-term, it will lead to the reduction of teaching quality because of professors' active involvement in a commercial world. Actually, some professors who have a close linkage with the business world appear often late at student classes and their lectures are not seriously prepared, as they merely fulfill their teaching duties.

- ***Open science***: Some university professors have gradually increased secrecy about teaching notes and research information. But other damages to open science, such as increased costs of accessing research material or tools and patenting more leading to less production in the long-term for young researchers, remain an open question for further exploration in the future.

- ***Fundamental long-term research***: on the basis of statistics on R&D expenditure in Chinese universities, it seems that Chinese universities have not suffered a research shift (see Figure 2.10). Figure 2.10 shows that applied research dominated R&D spending by Chinese universities, accounting for over 50% from 1991 to 2005. There was no great fluctuation on applied research spending. On the contrary, basis research almost kept increasing, jumping from 13.9% in 1991 to 23.4% of total R&D spending in 2005. And development expenditure was decreased over the past decade, dropping from 31.4% in 1991 to 25% in 2005. Therefore, the awareness of R&D resources shifting from basic research to applied research underlined by western scholars does not seem to apply to Chinese universities.

Further academic investigations: crossing-licensing is allowed in China and the access to patented technology for further research is exempted from infringing prosecution. Actually, the majority of university patents are managed by universities. Professors and students can get access to research findings. Co-patenting with industry accounts for 30% of all patenting in some leading universities, such as Tsinghua University.

Figure 2.10: R&D spending by Chinese universities (1991-2005), 10 million €



Source: data 1991-2003 from Xue, 2006 and data 2004-2005 compiled by the author from the website http://www.sts.cn.org.

Although China has not suffered from all the negative impacts of increasing university patenting and licensing for the moment, it needs to observe the influences for a longer time.

2.2.4 Conclusion

After comparing university patenting activities before and after the Chinese 'Bayh-Dole Act' at a general level and at a more specific level (in two sampled universities), our finding converges to the conclusion that the Act plays a similar role as the US Act in facilitating the expansion of university patenting (Mowery *et al.* 1998, 2001, 2002a, 2002b; Sampat 2006). And we broaden the US research outputs that the Act influences the growth of issued patents more significantly than patent applications. Furthermore, the effect of the Act on licensing agreements is not as efficient as licensing revenues although licensing activities have been rising in recent years. Actually, licensing agreements account for a very small part of university technology transfer mechanisms and universities do not get a big lump of revenues generated from licensing. The main reason first arises from the weak capacity of domestic firms to exploit the patented technology, especially when the technology is at the early stage of proof of concept but no prototype. Secondly, uncertainty of technology and potential risks in moral hazard discourage licensing transactions.

Additionally, our research result is in line with the US finding that the Chinese Act is merely one of the factors behind rising university patenting and licensing. Before the effective date of the Chinese Act in 2002, universities had begun to expand their commercial activities. The series of legislation before 2002, organization innovation (e.g. IPR office, an office similar to TTO) and internal incentive mechanisms (e.g., patent funds, workload assessment related to patents) in universities promote the increase of patenting. The intended positive effect of the Act not only impacts on leading national universities but also leading provincial universities, such as Tsinghua University and Chongqing University.

Concerning the possible negative effect of the Act, Chinese universities seem to have received a little unintended damage in terms of teaching quality and open science. But the other three negative effects have not been proved to appear in Chinese universities for the moment.

In short, the Bayh-Dole Act is an efficient instrument to solve the externalities of university technology. The identification of intellectual property has motivated universities to generate new knowledge but itself cannot solve the uncertainty of university technology. To accelerate the innovation process, it needs a creditable organization (i.e. technology transfer offices) to get involved in the technology trade deal. National technology transfer centers (NTTCs) were built to fulfill the function. We discuss them in the next section.

Section 2.3 National technology transfer centers (NTTCs)

As we discussed in section 2.2.3, increasing university patenting and licensing partly result from an organizational innovation. This section examines whether NTTCs function as an effective political tool in promoting the commercialization of university research findings. Section 2.3.1 analyzes the emergence context of NTTCs and makes a comparison between NTTCs, STACOs (Science & Technology Achievements Commercialization Offices) in the Chinese universities and UTTOs (University Technology Transfer Offices) in western universities. Section 2.3.2 presents the relevant literature and research methodology. Section 2.3.3 focuses on the role of NTTCs, the assessment on the effectiveness of NTTCs and the determinants of the effectiveness of NTTCs on the basis of 7 sampled universities.

2.3.1 Introduction

The US "Bayh-Dole Act" of 1980 led to an upsurge in the creation of UTTOs in many US universities (Jensen and Thursby, 2003). In China, many universities set up organizations (STACOs or similar, IPR offices and NTTCs) in charge of managing and marketing intellectual property outputs before the Chinese 'Bayh-Dole Act' of 2002.

2.3.1.1 The emergence of NTTCs

In accordance with governmental policies [77] toward accelerating the commercialization of university science & technology (S&T) findings in the 1990s, many Chinese universities began to establish STACOs or similar structures to manage academic technology transfer activities. Only very few such offices were set up in some leading research universities during the 1980s. In parallel with STACOs, an IPR office was set up to manage university IP issues. Considering that the separate division of labor between STACO and IPR office hampers the commercialization speed of university inventions (Zhao, 2005), in 2001 the Ministry of Education and the former State Economic and Trade Commission authorized 6 universities to establish national technology transfer centers (NTTCs) as an

[77] The government's policies refer to "S&T advancement law of the People's Republic of China" in 1993, "promoting S&T findings conversion law of the People's Republic of China" in 1996 and " the regulations on accelerating S&T findings conversion" in 1999.

experimental institutional innovation for coordinating university S&T resources and accelerating technology transfer. NTTCs integrate the services provided by STACO and IPR office. NTTCs are distributed in 6 elite universities: Tsinghua University, Shanghai Jiaotong University, China East Polytechnic University, Huazhong S&T University, Xi'an Jiaotong University and Sichuan University. The general map of 6 NTTCs is presented in section 2.3.2.2.

2.3.1.2 NTTCs, STACOs and UTTOs

To understand the function of NTTCs well, we would like to distinguish between NTTCs, STACOs in Chinese universities and UTTOs in western universities. Many Chinese universities have set up both IPR offices and STACOs or similar structures. IPR offices are in charge of assessing and registering the research findings, filing patent applications, applying for S&T awards at regional and national level, managing patent funds and other patenting activities. STACOs are designed to take responsibility for marketing, diffusing university inventions and managing technological contracts. STACO and IPR office are two separate offices, subordinated to the university's science and technology division (***Kejichu*** or equivalent). These two offices work together to perform the role of UTTOs in western universities. NTTCs were created in 2001 in 6 selected universities to integrate the function of STACOs with that of IPR offices. However, the existence of NTTCs does not lead to the disappearance of the former STACO and IPR offices in the 6 sponsored universities. Actually, NTTCs perform in parallel with STACO and IPR offices. These co-existing institutions sometimes share some staff with each other. UTTOs in western universities are responsible for the whole process from invention disclosure to invention exploitation. The similarities and differences between NTTCs, STACOs and UTTOs are presented in the Table 2.7 below.

Table 2.7: Comparison between national technology transfer centers (NTTCs), science & technology achievements commercialization offices (STACOs) in Chinese universities and technology transfer offices (UTTOs) in western universities

	NTTCs	STACOs	UTTOs
1 Similarities			
Objective	To promote the commercialization of university inventions		

Governance	To run by the university		
Structure	Not-for-profit organization		For-profit or not-for profit organization
Staff	The majority of staff are civil servants from the university		More professional staff
2 Differences			
Sources of funding	Initial funds coming from Ministry of Education and former State Economics & Trade Commission, subsequent funding supported by universities and local governments	University	University
Organization	At least two offices subordinated to NTTCs	One office, called STACO or S&T development office or S&T transfer office	-
Activities	Enact university IP and technology transfer policies; implement joint R&D projects on common technology with firms; create joint technology centers with firms; promote international technology cooperation between domestic firms and foreign firms; incubate innovative research projects	Focus on transferring university inventions to industry	disclose faculty inventions, evaluating commercial potential of inventions, file patent applications, find potential technological contractors, and execute and monitor technological contracts

Source: information about Chinese NTTCs and STACOs collected from questionnaires, published documents and university's website. Information about UTTCs collected from Stadler *et al.* (2007) and Jensen and Thursby (2001).

Table 2.7 shows that NTTCs, STACOs and UTTOs have similarities in terms of objective and governance but there are more differences existing between them in several respects: structure, staff, financial source, organization and activities. Compared with STACOs and UTTOs, NTTCs seem to engage in a wider range of technology transfer activities. STACOs fulfill partial functions of the UTTOs whereas NTTCs broaden the role of UTTOs in terms of university-industry linkage and international technology cooperation.

2.3.2 Relevant literature and research methodology

Literature on university technology transfer offices (UTTOs) developed mainly in the US towards the end of the 20th century. Previous research on UTTOs can be classified into three categories:

1) Role of UTTOs
2) Efficiency of UTTOs
3) Determinants of success of UTTOs

The three categories of research are mainly based on case studies. We will adopt these three categories and research methodology to analyze NTTCs in terms of role, effectiveness and success determinants.

2.3.2.1 Research literature review

1) Role of UTTOs

For the first category of research on the role of UTTOs, Jensen and Thursby (2001) stress that UTTOs aim at striking a balance between faculty and university administrator objective. They divide licensing objectives into five groups: license revenues, license agreements executed, inventions commercialized, sponsored research, and patents awarded. They find that maximization of license revenues is the ultimate objective of UTTOs and university administrator, while faculty pursues sponsored research. To coordinate these different purposes, they suggest that the inventor should share the royalties and equity so that he can be proactive to disclose invention and cooperate in future developments after the license agreement.

This research is explored by Jensen *et al.* (2003). They model the interplay between faculty, university and UTTO as a game in the commercialization of university research findings on the basis of a survey of 62 US universities. According to Jensen *et al.*, the role of UTTO is to be a dual agent for university and inventor. UTTO measures their own success based on their perceptions of both faculty and university administrator objectives.

Markman *et al.* (2005) absorb the previous research results but broaden the role of UTTOs to business incubation and new venture formation. Based on interviews with 128 US UTTO directors, they indicate that for-profit UTTO structures and licensing in exchange for equity are most positively related to new venture formation. Traditional and non-profit UTTO structures are unrelated to new ventures even if they are correlated with the presence of a university business incubator. Licensing in exchange for sponsored research is negatively related to new venture formation but licensing for cash is least related to new venture creation. However, compared with the traditional mission of UTTOs as licensing patented technology, they find that UTTOs underemphasize entrepreneurship.

Leitch and Harrison (2005) address a similar issue by using a case study of some of the spin-out activities of one of the longest established TTOs in the UK. They propose a wider role for UTTOs to take equity stakes in fresh spin-outs [78]created by established spin-outs although no university IP or staff is involved, especially in a peripheral non-technology-intensive regional economy.

Lowe (2006) examines the role and impact of US UTTOs on the determination of an inventor whether to start a firm to develop his/her idea or to license an invention to an

[78] Fresh spin-outs: also called second-order spin-outs. They are new companies formed by individuals who are former employees of the patent organization (original spin-out), or in a planned manner in that a new company is formed by individuals, formerly employed by the parent company around a core technology that originated in the parent organization. Second-order spin-outs provide a mechanism for the development of otherwise unexploited technological and market opportunities arising from R&D transferred or developed with the original spin-out (3i/EU, 2002).

established firm for it to be developed. UTTOs requiring a royalty rate distort the final output and result in a transfer from inventor to university with no apparent added productivity. However, UTTOs can improve the inventor's welfare by marketing and negotiating the licensing contract to secure a higher fixed fee payment.

Sharma *et al*. (2006) carry out a case study on the Carleton University Foundry Program[79] to show that UTTOs should play a more prominent role in molding themselves as innovation agents to help stimulate a culture of innovation on university campuses. They should practice what they preach about making innovation happen, besides addressing the university's needs of technology commercialization also treat nurturing of innovation and entrepreneurship as its core mission.

Stadler *et al*. (2007) develop a theoretical model, by using a simple reputation argument, to explain the specific role of UTTOs in the scientific knowledge market. UTTOs can reduce the asymmetric information problem firms encounter about the quality of the inventions. Their findings demonstrate that UTTOs are often able to benefit from their capacity to pool inventions across research units within universities and to build a reputation for honesty. When UTTOs have an incentive to 'shelve' some of the projects, it raises the buyer's beliefs on expected quality. This results in fewer but more valuable innovations being sold at higher prices.

This first category of studies is basically made around the principle role of UTTOs as "a license agent", although the trajectory to address the question is different. To sum up, the role of UTTOs is to coordinate the interactions between university, faculty/inventor and industry and to license university IP successfully.

[79] The Carleton University Foundry Program: it was launched in 2002 to assist Carleton University (located in Ottawa, Canada) researchers to commercialize technology. It is managed by the Technology and Research Development Office which takes care of the university-industry technology transfer aspects, such as IP management and industry liaison.

2) Efficiency of UTTOs

For the second research category on the assessment of the performance of UTTOs, Trune and Goslin (1998) examine the effectiveness of UTTOs from a financial profit/loss analysis perspective. Their results show that about half of these UTTOs are profitable and local communities benefit from their contribution to the economic development.

Thursby and Kemp (1998) use data envelopment analysis (DEA)[80] combined with regression analysis to examine the productivity of university commercial activities as well as changes in that productivity. They find that universities are today more commercially productive than they were in the recent past and private universities tend to be more efficient in commercialization than public ones, while universities with medical schools are less likely to be efficient. Thursby and Kemp's continuous research on the same issue in 2002 confirms their 1998 findings, but adds new results to the former research, namely that UTTO efficiency varies not only according to the capabilities of the faculty and staff, but also according to university preferences in the use of their resources. In their model, they use sponsored research agreements, license agreements, royalty payments, invention disclosures and patent applications as output and federal support, the number of professionals employed in UTTOs, the number of faculty in each university, the weighted average quality rating where the weights are faculty size, whether a university is private and has a medical school as input.

Siegel *et al.* (2003a) explore the quantitative research measure and use the stochastic frontier estimation (SFE)[81] tool to assess relative productivity in UTTOs together with 55 interviews of entrepreneurs, scientists and administrators. They conclude that the productivity of UTTOs depend on organizational practices, namely faculty reward system, TTO

[80] Data envelopment analysis (DEA): it is a linear programming approach to aggregating outputs and inputs and measuring productive efficiency (more details can be found in Thursby and Kemp, 2002).

[81] Stochastic frontier estimation (SFE): it generates a production or cost frontier with a stochastic error term that consists of two components: a conventional random error and a term that represents deviation from the frontier, or relative inefficiency (see more detail in Siegel *et al*., 2003a).

staffing/compensation practices, and cultural barriers between universities and firms. They specified that the outputs are the number of licensing agreements and licensing revenues and the inputs are invention disclosures, employees in the TTO, and legal expenditure.

Chapple *et al.* (2005) combine data envelopment analysis with stochastic frontier estimation to present evidence on the relative performance of U.K. UTTOs. Again, they find that having a medical school has a negative effect on efficiency and they suggest reconfiguring UTTOs and upgrading UTTO staff's competences to improve the efficiency of UTTOs.

Similarly, Anderson *et al.* (2007) used DEA approach to measure the performance of UTTOs. Their conclusion is not surprisingly the same as previous results in terms of a correlation between UTTO efficiency and the existence of a medical school, and university structure (private or public). The additional contribution of their research is that they propose to add other factors to analyze the productivity of UTTOs, like the number of people working in the UTTOs, the impact of different IP policies and faculty incentive systems.

The contribution of the second research category is that researchers use both quantitative and qualitative evidence to evaluate the performance of TTOs. The quantitative analysis is based on a production function framework which uses the outputs and inputs to measure the efficiency of UTTOs. And the qualitative study is based on university surveys. The above research results show that the university structure (e.g. public or private) and an affiliated medical school have an impact on the performance of UTTOs.

3) Determinants of success of UTTOs

For the third research category of determinants of success of UTTOs, most studies concentrate on the internal organizational structure of UTTOs. Siegel *et al.* (2003a) reveal the palpable differences in the motives, incentives, and organizational cultures of faculty/inventor-UTTO-industry. They believe that reward system for faculty involvement in university-industry technology transfer, compensation and staffing practices in UTTOs, and actions taken by administrators to extirpate information and cultural barriers between universities and firms determine the successful performance of UTTOs.

Friedman and Silberman (2003) support Siegel *et al.*'s results but broaden them to other factors, like the age of UTTOs, university location and mission to support technological transfer have significant positive effects on UTTO output (measured by licenses executed).

Link and Siegel (2005) devise a production model to evaluate the impact of organizational incentives on the effectiveness of UTTOs and show that universities having more attractive incentive structures for UTTOs, i.e. those that allocate a higher percentage of royalty payments to faculty members, tend to be more efficient in technology transfer activities. They propose that university administrators who wish to foster university-industry technology transfer should be mindful of the importance of financial incentives.

Chapple *et al.* (2005) sample 98 top U.K. universities and prove that the age and size of UTTOs influence their performances. Older UTTOs function less efficiently due to an absence of learning effects. Larger UTTOs suffer from the problem of being generalists rather than specialists. Decreasing return to scale to licensing activity requires the reconfiguration of large UTTOs. They stress the need to recruit and train technology licensing officers with the appropriate skills and capabilities.

Interestingly, Thursby *et al.* (2001) illustrate significant positive effects linking the size of TTOs (measured by the number of staff). Markman *et al.* (2005b) show that older and larger UTTOs are better and speed up licensing to new ventures, suggesting that they may have more developed organizational routines. Also, Chukumba and Jensen (2005) present the age of UTTO and the quality of engineering faculty as significantly positive influences on licensing activities.

This third category of studies highlights the importance of the organizational structure and attractive incentive system on the successful performance of UTTOs.

Thus, the above three categories of research analyze UTTOs in terms of their functions, performances and success determinants. We adopt the achieved research results (Thursby and Kemp, 2002; Jensen *et al*., 2003; Siegel *et al*., 2003a, Friedman and Silberman, 2003, Chapple *et al.,* 2005) to assess whether NTTCs function as an effective political tool in accelerating the commercialization of university research findings. The analytical perspectives focus on the role, the performance and the effectiveness determinants of NTTCs.

2.3.2.2 Methodology and cases

1) Research methodology

The methodology of used in this section is based on qualitative and quantitative analysis. Following up on previous research findings, we emphasize three dimensions to compare NTTCs in 6 Chinese universities, namely the role of NTTCs, the performance of NTTCs and the determinants of effectiveness of NTTCs. The qualitative research method is used to analyze the role of NTTCs and the determinants of effectiveness of NTTCs. The quantitative analysis centers on the performance of NTTCs.

To guarantee the quality of our qualitative analysis, our research design is built on construct validity, external validity and reliability (Yin, 1994). Multiple sources of evidence are used in our analysis: published documents, questionnaires (see Appendices 4 and 5), interviews, telephone contacts with people working in NTTCs and S&T divisions of universities.

In April 2006, 45 questionnaires were sent respectively to these 6 universities with NTTCs and to other 39 universities without NTTCs. We got two feedbacks from Sichuan University and Huazhong S&T University with NTTCs, 6 feedbacks from other universities without NTTCs. In order to collect information about the other 4 universities with NTTCs, we telephoned the directors of NTTCs in China East Polytechnic University, Xi'an Jiaotong University and Shanghai Jiaotong University. Concerning Tsinghua University, we had interviews with a director of NTTC in August 2006. Since we sampled Zhejiang University, which has no NTTC but gets great achievements in commercializing university inventions, to compare with universities with NTTCs, we contacted the director of the S&T division in Zhejiang University by telephone contacts and open-minded interviews.

Actually, telephone contact and interview methods are more efficient than the questionnaire. Although we attached our university's certificate, a business visit card and an envelope with a stamp, we got only little more than a return rate of one out of five questionnaires. Fortunately, we got the feedback from all sampled universities either by questionnaire or by telephone contacts and open-ended interviews. Two interviews with a Tsinghua NTTC director, 3 telephone contacts with NTTC director in China East Polytechnic University, 1 questionnaire feedback and 2 telephone contacts with NTTC director in Sichuan University, 1 questionnaire feedback and 2 telephone contacts with NTTC in Huazhong S&T University, 3 telephone contacts with NTTC staff in Shanghai Jiaotong University and 3 telephone contacts with NTTC director in Xi'an Jiaotong University. As we chose Zhejiang University as an example to compare with 6 universities with NTTCs, we telephoned with the director of its S&T division twice. On the basis of the collected feedback, we conducted a qualitative analysis of NTTCs in 6 Chinese universities.

Concerning the quantitative analysis, we adopted the basic principle of DEA and SFE, namely the input-output function to evaluate the productivity of NTTCs with a linear regression analysis. The input factors in our model are specified as the age of NTTCs and the number of NTTC staff. The outputs refer to published papers, patent applications and patents issued. We had planned to add licensing royalties and formation of startups as an assessment of outputs but we had difficulties to get such data. Instead, the income of university-affiliated technology firms is used as a complementary indicator to assess the output of NTTCs. We also use the correlation analysis to examine the relationship between the inputs and the outputs.

2) Cases

Our information access to all universities with NTTCs (Tsinghua University, Shanghai Jiaotong University, China East Polytechnic University, Huazhong S&T University, Xi'an Jiaotong University and Sichuan University) helped us build the complete units of analysis. The analysis of these 6 NTTCs provides a general picture of NTTCs in Chinese universities. To test whether NTTC is an efficient political tool in accelerating the commercialization of university inventions, we use Zhejiang University which has no NTTC to compare with the 6 sampled universities with NTTCs in terms of patenting and commercial activities. The rationale behind sampling Zhejiang University as a single case is because it represents the critical and revelatory case in testing the necessity to create NTTCs (Yin, 1994).

The characteristics of the 6 sampled NTTCs are mapped in Table 2.8.

Table 2.8: General picture of NTTCs in 6 Chinese universities

NTTC	Tsinghua Univ.	Shanghai Jiaotong Univ.	China East Polytechnic Univ.	Huazhong S&T Univ.	Xi'an Jiaotong Univ.	Sichuan Univ.
1. Similarities						
Objective	Commercialize university inventions; contribute to the social economic growth					
Structure	Non-for-profit organization					
Management	Co-managed by the Ministry of Education, National Development and Reform Commission and Universities; employ corporate management strategies					
Source of initial funding	Financed by the Ministry of Education and the former State Economics & Trade Commission					
Source of staff	Composed of university-background staff and outsourced personnel					
Relationship with university S&T division ***(Kejichu)***	Subordinated in terms of administrative linkage					
2. Differences						
Location	Beijing	Shanghai	Shanghai	Wuhan	Xi'an	Chengdu

Organization	R&D management department; University-industry cooperation committee; International technology center	Internal technology office; International technology office	Internal technology office; International cooperation office; IPR office; Engineering design research institute; Environment consulting office; medium-sized test base	Project consulting office; Project service office; Project incubation office	Project office; Common technology transfer office; Capital management office	University-industry committee; Comprehensive information office; Project development office; Technology transfer and IPR office; S&T achievements commercialization office
Priority activities	Introduce and diffuse foreign technology	Create joint R&D centers with firms and incubate innovative projects	Cooperate with large and medium-sized firms, focus on developing specified common technology and incubate lab inventions	Cooperate with key large and medium-sized firms; develop and diffuse regional common technology; incubate selected projects	Develop and diffuse common technology; foster hi-tech start ups	Create joint R&D centers with firms
Number of Staff	40	12	7	6	11	2

Source: published literature and our interviews.

Table 2.8 demonstrates that these 6 NTTCs hold similar characteristics in terms of objective, structure, management, sources of initial funding, staff and relationship with S&T division. Their differences are found in location, organization, priority activities and number of staff. Whether these differences influence the performance of NTTCs will be discussed in the following part.

2.3.3 Assessment of the effectiveness of NTTCs

This part focuses on the assessment on the effectiveness of NTTCs. First, we explore the role of NTTCs, which is associated with performance outcomes. Then, we employ Thursby and Kemp's (2002) input and output model as an analytical tool to evaluate the effectiveness of 6 NTTCs. In our model, the input factors refer to the age of NTTCs and number of NTTC staff. The outputs refer to the number of published papers, patent applications and patents issued. Our assessment framework is set up on the basis of four assertions. Finally, we discuss the determinants of effectiveness of NTTCs.

2.3.3.1 Role of NTTCs

Like UTTOs in western universities, NTTCs act as an intermediary between university and industry (Jensen and Thursby, 2001; Jensen *et al.,* 2003) to manage university intellectual property and technology transfer activities. However, NTTCs and UTTOs function in a different way to attain the target.

In UK and USA universities, UTTO personnel typically devote substantial effort to encouraging faculty members to disclose inventions (Siegel *et al*., 2003b; Thursby and Kemp, 2002, G. Thursby and Thursby 2002). In the Chinese universities, NTTC staff does not spend much time in persuading researchers to disclose inventions. On one side, the provision of university and local government's policies stimulates professor willingness to disclose inventions. On the other side, some universities think that the most important thing is that the technology can contribute to the economic development of society no matter who diffuses the technology. In fact, it is practically difficult to distinguish on-duty inventions from off-duty inventions. If inventors apply for patents and exploit the inventions out of the control of universities, universities seldom accuse the inventors of violating university IPR. Therefore, NTTCs do not put emphasis on encouraging invention disclosure but are active in helping inventors file for patent applications. When NTTCs receive the disclosure of inventions, they assess the inventions and determine whether they will support inventors to file for patent applications. If the invention is suitable for patenting, the NTTC will appoint an intermediary specialized in patent filing to conduct the patenting procedure with the cooperation of the inventors. The assistance of NTTC and IPR experts reduces invaluable patent applications by selection and facilitates the diffusion of IPR knowledge amongst researchers. The learning effect appears through the interactions between the inventor, the intermediary and the NTTC.

Additionally, UTTOs in western universities principally diffuse inventions through licensing (Jenson *et al.,* 2003; Siegel *et al*., 2003). The NTTCs in the Chinese universities mainly capitalize inventions through technology development contracts and the creation of university technology-based firms. The difference of technology transfer mode results from the stronger absorption capability of firms in the western countries than that of Chinese firms.

Last but not least, apart from the exploitation of university research findings, NTTCs undertake technology importation activities. Tsinghua NTTC is a very typical in that respect, engaged in importing technology from foreign small and medium-sized enterprises (SME) and localizing the imported technology. Due to limited financial resources and lack of capabilities to resist market risks, it is difficult for foreign SMEs to create foreign-wholly-owned firms or joint-ventures in China. But with the assistance of Tsinghua NTTC's broad network with domestic firms, foreign SMEs get easier access to the Chinese market. From this view of point, the NTTC in Tsinghua University acts as an intermediary between foreign firms and domestic firms. The 5 other NTTCs focus more on marketing university inventions, taking the forms of launching cooperative research projects on common technology and creating joint research centers with industry. Amongst them, the NTTCs in Huazhong S&T University and Xi'an Jiaotong University get more involved in incubating hi-technology start-ups. NTTCs pool internal and external resources to incubate selected university research projects. When these technology-based start-ups grow, the IPR-related investment of universities is compensated through selling stakes. In other words, NTTCs in these two universities perform like technology business incubators.

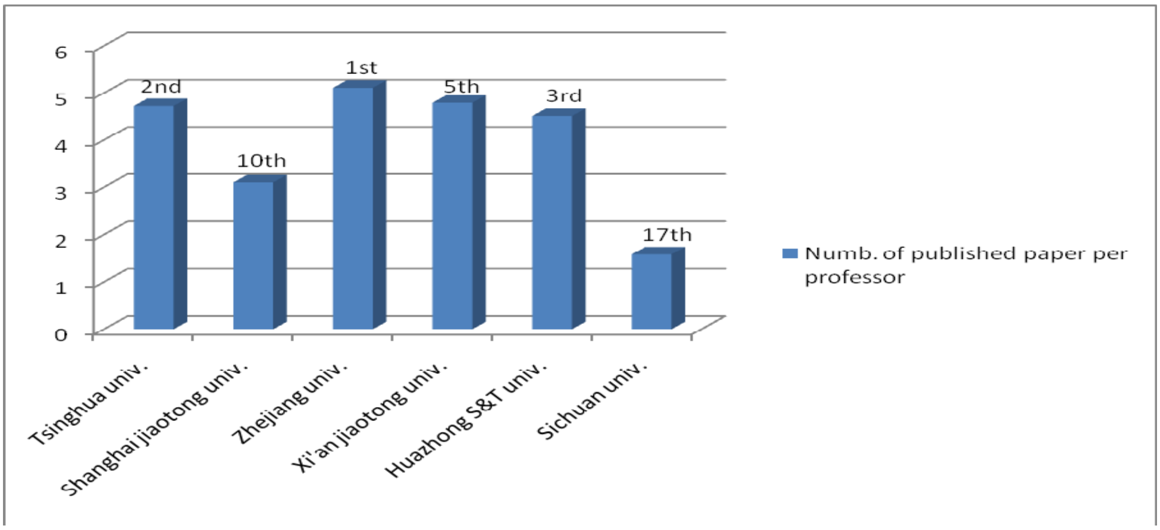
2.3.3.2 Examination of four assertions

The performance of NTTCs is linked to their role orientation. Since the role of NTTCs is to promote university commercial activities, we use published papers, patenting, licensing and university-run technology firms as indicators to assess the productivity of NTTCs. The following four assertions are used to conduct the assessment.

Assertion 1: All of these 6 universities were ranked in China's top six with regard to research outcomes and capability to market university inventions before having NTTCs.

We raise the assertion 1 because our interviews tell us that the imbalance of performance amongst NTTCs is related to the pre-existing disequilibrium in research outcomes and capability to market university inventions among these 6 sampled universities. Research outcomes are measured by published academic papers per professor (see Figure 2.11) and patent applications. The capability to market university inventions is evaluated by the actual technology transfer income, the income and net profit of university-run technology firms. We sample Zhejiang University in our analysis so as to test the effectiveness of NTTCs, by comparing 6 universities embodying NTTCs with other universities without NTTC, such as Zhejiang University.

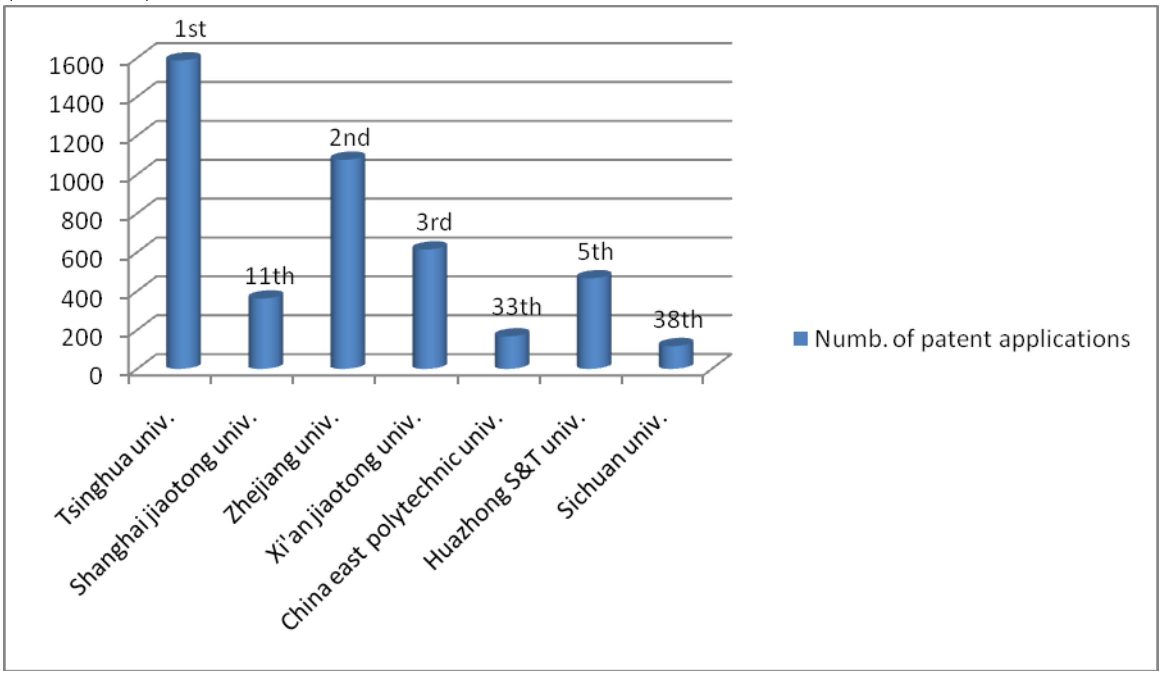
Figure 2.11: Number of academic papers published per professor at national and international level in selected Chinese universities (2000)



Source: data collected from S&T Development Center of the Ministry of Education.
Note: China East Polytechnic University is not presented in Figure 10, because the Ministry of Education reveals the rating of universities between 1 and 25 in terms of the number of paper publications. The number of professors is collected from each university's website in 2006.
The number on the top of each column represents the rating of university in terms of published papers.

Figure 2.11 demonstrates that Zhejiang University produces more academic papers per professor than other sampled universities. The number of its published academic papers was three times that of Sichuan University in 2000. In fact, according to the statistics given by the Ministry of Education, Zhejiang University ranked first, Tsinghua University 2nd, Huazhong S&T University 3rd, Shanghai Jiaotong University 10th, Sichuan University 17th and China East Polytechnic University even beyond 25th amongst all Chinese universities. Previous research shows that publications have a positive and significant effect on patents (Owen-Smith and Powell, 2001; Jensen and Thursby, 2001; Stephan *et al.*, 2007). However, the available data on published papers are constrained in one year (2000). It only partially reflects the research outcomes of sampled universities. Therefore, we use the aggregate number of patent applications during the period 1985-2000 as a complementary tool to measure university research outcomes (see Figure 2.12).

Figure 2.12: Aggregate number of patent applications in the sampled Chinese universities (1985-2000)



Source: data collected from S&T Development Center of Education Ministry.
Note: the number on the top of each column represents the ranking of each university in terms of patent applications during the period of 1985-2000.

Figure 2.12 illustrates that Tsinghua University held an absolutely leading place in terms of filing patent applications during the period of 1985-2000. In comparison with published paper ranking, Tsinghua University and Xi’an Jiaotong University got a higher ranking in terms of patent applications. It seems that these two universities not only generate a lot of knowledge but also have a strong awareness of IP protection. The patent rankings of other universities were a little behind their paper rankings. Following Tsinghua University, Zhejiang University was far ahead of the other 4 universities with respect to the number of patent applications. It had almost 10-times that of Sichuan University from 1985 to 2000. However, it has no NTTC. According to the statistics on patent applications during the period of 1985-2000, Tsinghua University takes the 1st place, followed by Zhejiang University, then Xi'an Jiaotong University 3rd place and Huazhong S&T University 5th place. Shanghai Jiaotong University, China East Polytechnic University and Sichuan University are ranked 11th, 33th and 38th respectively. The different ranking provides evidence that NTTCs are not necessarily distributed in the top 6 universities with high research outcomes. The already existing differences may influence the effectiveness of NTTCs.

To examine the marketing capability of universities, we use the actual technology transfer income, the income and net profit of university-run technology firms as indicators. Only Tsinghua University and Shanghai Jiaotong University were positioned in the first and third place respectively, the other four universities took the places beyond the 10 th. And Sichuan University even went beyond the 25th (see Table 2.9).

Table 2.9: Comparison of the marketing capability of the sampled universities in 2000

	Ranking[1]*	Actual technology transfer income* (million €)	Ranking[2]*	Income of university-run technology firms (million €)	Ranking[3]*	Net profit of university-run technology firms (million €)
Tsinghua univ.	1	23.532	2	582.708	1	51.973
Shanghai jiaotong univ.	3	11.088	4	157.007	6	13.262
Zhejiang univ.	9	2.515	10	89.987	12	6.083
Xi'an jiaotong univ.	13	0.9112	7	98.619	5	14.044

China east polytechnic univ.	18	0.6834	27	15.867	17	1.933
Huazhong S&T univ.	19	0.6608	15	35.616	9	6.923
Sichuan univ*.	Beyond 25th	--	26	15.929	19	1.658

Source: data collected from S&T Development Center of the Ministry of Education.
Note: ranking1* refers to the ranking of actual technology transfer income in 2000.
Actual technology transfer income* refers to the income actually got by universities arising from patents transfer, patent applications transfer, licensing agreements and technologic secrecy transfer.
Ranking2* refers to the ranking of income of university-run technology firms in 2000.
Ranking3* refers to the ranking of net profit of university-run technology firms in 2000.
Sichuan univ*.: The Ministry of Education discloses the ranking of universities from the 1st to the 25th in terms of actual technology transfer income and Sichuan University is not within the former 25 universities.

Table 2.9 reveals that universities obtain a very small income from actual technology transfer contracts in comparison with the income created by university-affiliated technology firms. Universities are more active in conducting technology transfer activities through creating enterprises than licensing agreements. The reason is associated with the demand of industry. Chinese SMEs go to universities usually for technological consulting and problem solving rather than licensing transactions. Large firms hold their own R&D centers and the cooperation between industry and universities focuses on joint R&D projects and co-establishment of research centers. The licensing transactions often bind the cooperative R&D projects (Mei *et al*., 2005), which decrease the actual technology transfer income received by universities.

Table 2.9 also demonstrates that universities without NTTCs do not necessarily have a lower capacity to commercialize S&T findings than those with NTTCs. Zhejiang University, which is ahead of China East Polytechnic University and Sichuan University, supports the point.

On the basis of the above figure 2.11, 2.12 and Table 2.9, it is proved that NTTCs have not been necessarily established in all the top six universities. Hence, assertion 1 is refused. Now we try and explain the reasons why NTTCs have been set up in the 6 Chinese universities.

Reasons for the locations of NTTCs in the above mentioned 6 universities

1) To overcome regional imbalance

If we pay attention to the locations of these 6 NTTCs, it is easy to find out that they are disseminated in the East, the North, the Middle and the West of China. It is widely known that the East is better developed than the other regions of China. Most top 10 universities are integrated in the East. If NTTCs were all set up in the East, the gap might be further widened. According to China Statistic Yearbook 2000, technology transfer activities were more dynamic in the Eastern regions than the Middle and Western regions. The Eastern regions have a higher capability to absorb the transferred technology. Firms there tend to adopt new technology, especially in some regions where private economy is very active. Supposing all NTTCs were located in the East and they performed successfully, it would mean no doubt that the "Matthew effect" would emerge among regions. To overcome the existing regional imbalance in terms of economic development, previous research suggests that the government should take measures, like offering assistance to create UTTOs, to improve the lower levels of R&D and economic activity in some regions. The establishment of UTTOs would facilitate the emergence of specialist teams for different industrial sectors and enable the development of a critical mass of expertise and experience (Chapple *et al.*, 2005). The distribution of NTTCs among Chinese universities seems to adopt the research result of Chapple *et al.* (2005). Two NTTCs are located in the West (Chengdu and Xi'an), the other located in the Middle (Wuhan). The three other NTTCs are distributed in the East (Beijing and Shanghai). NTTCs essentially serve local firms, but some NTTCs explore activities outside their local regions.

2) The early birds get worms

All these 6 universities with NTTCs are research-oriented universities, ranked in China's top 100 universities. But they are not all positioned in the top 6 universities, as in the case of China East Polytechnic University and Sichuan University, with regard to the number of patents, the amount of technology transfer income and other criteria. One officer of the

NTTC in China East Polytechnic University told us that their university was the first one who built a high-tech technology transfer center in 1987 among all Chinese universities. After over a decade of performance, they have accumulated experiences in the commercialization of university technology. Besides, China East Polytechnic University is the most famous Chinese university in chemical engineering. It merged 5 universities' chemical engineering departments in 1952. The combination strengthened its research power in chemical engineering. Meanwhile, the university leaders recognize the importance of NTTCs. Therefore, when the plan for creating NTTCs in universities was disclosed by the Ministry of Education and the former State Economic & Trade Commission, China East Polytechnic University was proactive to be candidate and finally gained the authorization.

3) The attitude of University top leaders toward NTTCs

Some university top leaders do not recognize the importance of NTTCs. In their opinions, a NTTC is in no way different from a university S&T achievements commercialization office (STACO) or similar. The NTTC is just new name for a structure based on the STACO. The passive attitude hampers their universities from taking active measures to get governmental authorization for the establishment of NTTCs. Zhejiang University is in this case.

4) Industry policy

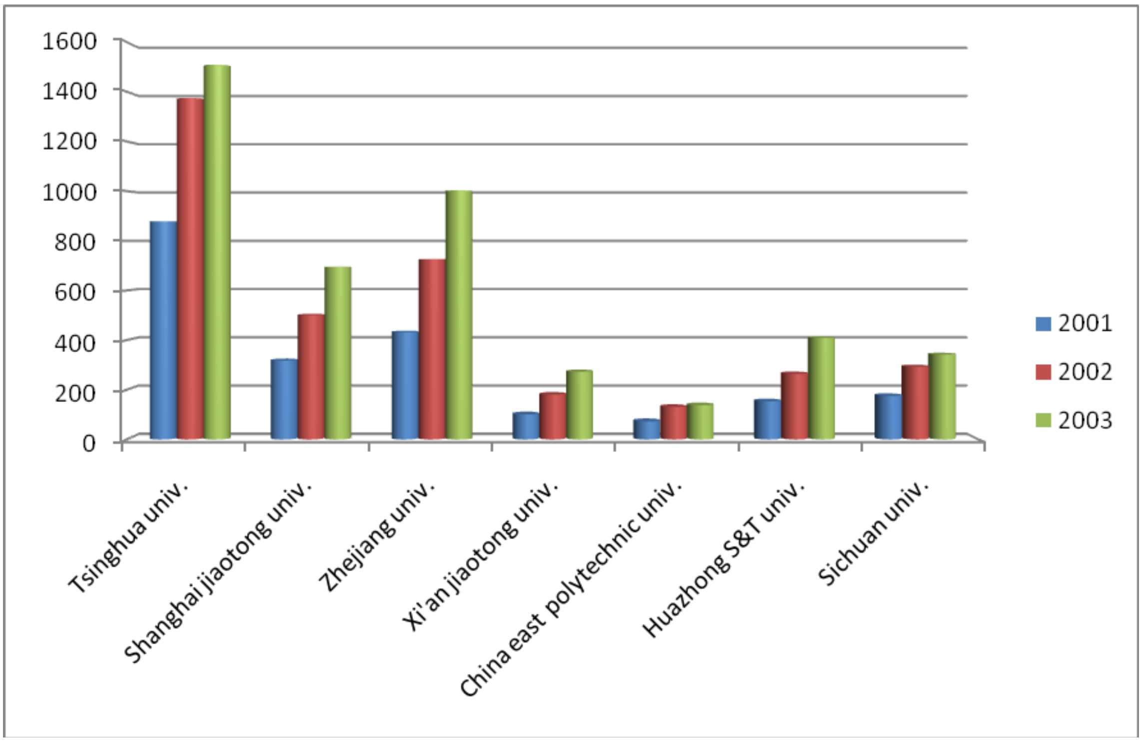
The outline of 10^{th} five-year plan (2001-2005) lays the emphasis on optimizing, upgrading the industrial structure, and strengthening China's international competitiveness. The plan prioritizes the development of equipment manufacturing and high-technology industry. The 6 chosen universities hold advantages in such priority fields. The initial funding of NTTCs came principally from the former State Economic & Trade Commission (later renamed National Development and Reform Commission). The Commission manages many national key industries. University's specialties were taken into consideration when the Commission chose the locations of NTTCs. For example, Sichuan University specializes in medical science; Xi'an Jiaotong University in electronics, engineering and machinery; China East Polytechnic University in chemical engineering, Huazhong S&T University in machinery manufacturing and electronics, Shanghai Jiaotong University in new material, electronic information, environmental engineering, machinery and biotechnology, while Tsinghua University in engineering, chemicals, electronics and material. The government hopes the NTTCs in these 6 universities will promote the commercialization of research findings arising from the university's specialties and meet the needs of industry policies.

One strange thing is that 2 NTTCs settled in Shanghai. One is in Shanghai Jiaotong University, the other in China East Polytechnic University. According to the statistics on patent applications of Chinese universities between 1985 and 2000, Shanghai Jiaotong University took the 11th place and China East Polytechnic University ranked 33th. However, in terms of actual technology transfer incomes in 2000, Shanghai Jiaotong University jumped to the 3rd place and China East Polytechnic University moved up to the 18th place. This means that these two universities are strong in marketing inventions. In addition to the above reasons 2), 3), 4), this may be connected to the importance of Shanghai in the Chinese national innovation system. Shanghai is one of the most dynamic regions in China. Abundant foreign direct investments, a long history as a commercial and industrial center and a strong capability to pool resources have turned Shanghai into the knowledge and technology innovation center. The favorable geography of Shanghai and preferential policies of governments may facilitate the diffusion of research results. Shanghai Jiaotong University and China East Polytechnic University are two key universities under the control of the Ministry of Education. And these two universities are also favored by the local government.

Assertion 2: The existence of NTTCs has improved university research outcomes and facilitated the commercialization of university S&T findings.

Failing to find the same indicators which are used to test assertion 1, we adopted the number of published academic papers collected by the Science Citation Index (SCI), the patent applications, and issued patents, patent transactions and the incomes of university-run technology firms to evaluate the performance outcomes of NTTCs. We assume that the existence of NTTCs promotes the information exchange between university researchers and firms. Through the interactions with industry and NTTCs, researchers may get new ideas to produce more qualified academic papers. And the growth of university patenting activities is supposed to be related to the performance of NTTCs whose responsibility is to manage IP activities and exploit research findings. Figure 2.13 below shows that all the sampled universities have increased the published papers collected by SCI.

Figure 2.13: Comparison of university published papers collected by SCI (2001-2003)



Source: data collected from www.cutech.edu.cn
Note: data in 2001 represent the number of university papers published in SCI-collected foreign journals. They do not include 14 SCI-collected Chinese journals. The data between 2002 and 2003 refer to the number of SCI-collected papers whose first author is Chinese. And Hongkong, Macao and Taiwan are out of the calculation.

With respect to patenting activities, the sampled universities have made progress (see Table 2.10). The number of both patent applications and issued patents obviously increased, especially after 2002. Between 2002 and 2003, except for Xi'an Jiaotong University and China East Polytechnic University, the number of issued patents doubled in the other sampled universities. Tsinghua University remained the leader with respect to patenting activities from 2001 to 2005, Zhejiang University occupied the 2nd place, and Shanghai Jiaotong University the 3rd one.

Table 2.10: Number of patent applications and patents issued at home in selected universities (2001-2005)

Name of univ.	2001		2002		2003		2004		2005		Total	
	A.*	G.*	A.	G.	A.	G.	A.	G.	A.	G.	A.	G.
Tsinghua unvi.	380	123	526	136	767	376	762	527	930	527	3365	1689
Shanghai jiaotong univ.	188	34	285	41	730	156	829	332	1093	438	3125	1001
Zhejiang univ.	214	61	353	80	660	211	875	321	1244	534	3346	1207
Xi'an jiaotong univ.	56	29	94	37	189	37	183	131	259	123	781	357
China east polytechnic univ.	66	24	64	23	155	44	150	79	198	71	633	241
Huazhong S&T univ.	86	23	102	32	236	82	221	136	180	134	825	437
Sichuan univ.	52	10	111	13	182	57	203	111	237	124	785	315

Source: date collected from S&T Development Center of Ministry of Education
A*: represents the number of patent applications (invention, utility model and design)
G.*: represents the number of granted patents (invention, utility model and design)

Is the observed growth of published papers and patenting expansion linked to the performance of NTTCs? We use Thursby and Kemp's (2002) input-output model to assess the effectiveness of NTTCs. The age of NTTCs and the number of NTTC staff are used as the inputs of NTTCs, and the patent applications and issued patents are viewed as the outputs of NTTCs. Our linear regression results (see Table 2.11 and 2.12) indicate that the number of NTTC staff has a significant influence on the number of patent applied and issued. And our correlation analysis (see Table 2.13) shows that the number of NTTC staff has a more important correlation with published papers, patent applications and issued patents than the age of NTTCs. Our research result is in line with Thursby *et al.*'s (2001) and Friedman and Silberman's (2003) findings.

Table 2.11: Linear regression results (patent applications)

Regression statistics

Adjusted R square	0.4758
Observations	6

	Coefficients	Probability
Age of NTTC	-67.9110	0.4129
Number of NTTC staff	93.2491	0.0893*

Significance: *$\rho<0.1$

Table 2.12: Linear regression results (patents issued)

Regression statistics

Adjusted R square	0.7885
Observations	6

	Coefficients	Probability
Age of NTTC	-14.0214	0.5342
Number of NTTC staff	42.5364	0.0272*

Significance: *$\rho<0.05$

Table 2.13: Correlation coefficients

	1	2	3	4	5	6
1. Age of NTTC	1					
2. Number of NTTC staff	0.5874	1				
3. R&D expenditure	0.5943	0.9287	1			
4. Published papers	0.5060	0.9453	0.9829	1		
5. Number of patent applic.	0.2031	0.7689	0.8086	0.8527	1	
6. Number of patents issued	0.4257	0.9232	0.9534	0.9746	0.9417	1

Another indicator to assess the productivity of NTTCs is the amount of licensing income (Anderson *et al.,* 2007). Licensing has traditionally been the most efficient mode of university technology transfer in western countries (Chapple *et al*., 2005; Siegel *et al*., 2003b). However, patent licensing only accounts for a very small part of all technology contracts in China. Technology development contracts are the most frequent transaction mode in technology markets, which embed joint research projects between industry and university (Xue, 2006). The data we collected about patent licensing are limited to a very short period between 2001 and 2002 (see Table 2.14). Thus, we use the income of university-affiliated technology firms as a complementary indicator to analyze the productivity of NTTCs (see Figure 2.14). Fostering academic technology-based firms is identified as the role of NTTCs.

Table 2.14: Comparison of university patent transactions in 2001-2002

Name of university	2001 Three kinds of patents		2002 Three kinds of patents	
	Num. of patent licensing contracts	Patent licensing income (million €)	Num. of patent licensing contracts	Patent licensing income (million €)
Tsinghua univ.	137	7.176	133	6.685
Shanghai jiaotong univ.	9	1.25	5	0.423
Zhejiang univ.	45	2.01	74	1.028
Xi'an jiaotong univ.	8	0.188	9	0.21
China east polytechnic univ.	18	0.9	18	0.631
Huazhong S&T univ.	7	0.635	5	0.557
Sichuan univ.	0	0	5	0.12

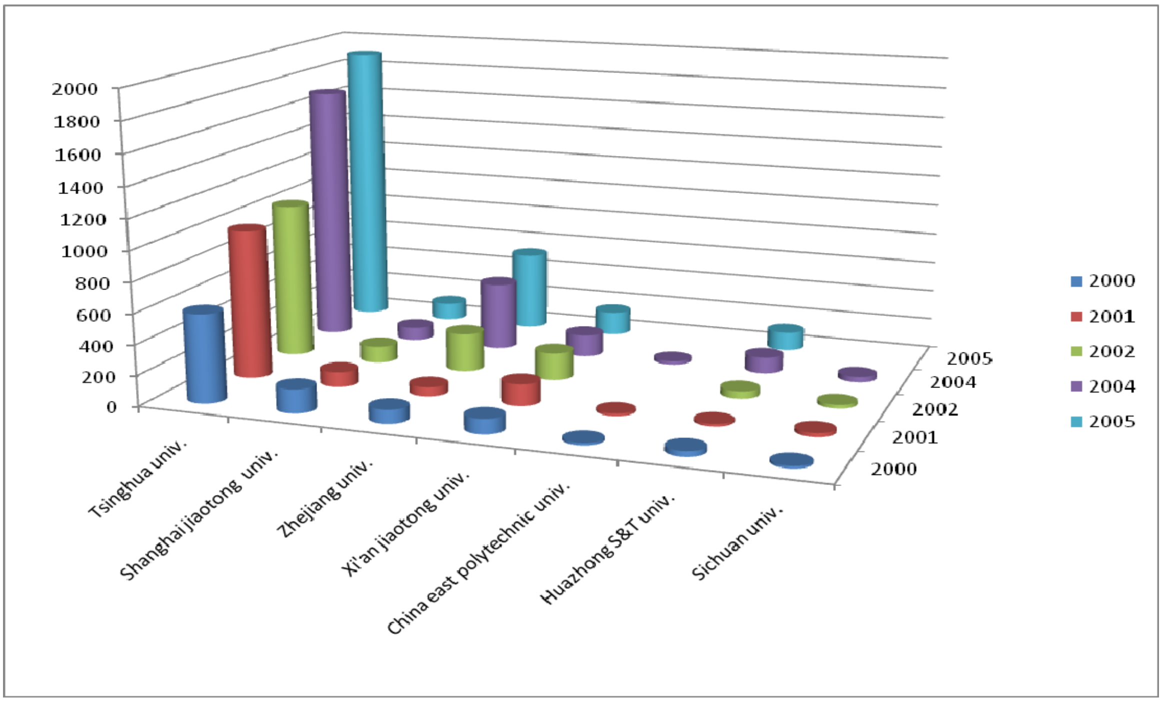
Source: data collected from www.cutt.edu.cn/paiming.
Note: 100 RMB = 10 EURO

Table 2.14 illustrates the progress achieved by NTTCs in Xi'an Jiaotong University and Sichuan University. The number of patent licensing contracts and patent licensing incomes both increased. Sichuan University made a historical breakthrough in terms of patent licensing activities. Huazhong S&T University is a little special. Although its patent licensing number and income decreased from 2001 to 2002, the patent licensing income per contract increased from 90710€ to 111400€, much higher than the average patent income received by other universities in the sample. It proves that a few patent licensing contracts can bring a large sum of revenue. Why could not the existence of NTTCs improve the patent licensing activities in all the sampled universities? The question is addressed by NTTC directors from Huangzhong S&T University and Sichuan University as follows:

"University technology-transfer activities usually focus on a minority of S&T achievements. The majority of findings have never been transferred in spite of the rising licensing contracts."

"We are not allowed to become an independent office. NTTC is subordinated to the university S&T division. We lack flexibility in terms of management and performance. Although insufficient funding hampers our sustainable development, we are not authorized to conduct for-profit activities."

Figure 2.14: Comparison of the incomes of sampled university-affiliated technology firms (money unit: million €)



Source: data collected from Science and Technology Develop Center of the Ministry of Education.
Note: 100RMB = 10 EURO

Figure 2.14 shows that Tsinghua-run technology firms are the unique ones which maintain growing incomes. The incomes of the other university-run firms did not always sustain an upward tendency. For example, the technology-based firms run by Sichuan University got less income in 2002 than in 2001. And Shanghai Jiaotong University did not attain its revenue level in 2000 after the creation of NTTC. It appears that NTTCs do not necessarily bring more income to university-run technology firms. But the revenues generated by university-run technology firms were much more than university's patent licensing incomes.

Although the former results arising from our linear regression model and correlation coefficients indicate that NTTCs have a significantly positive effect on the expansion of university patenting and growing published papers, the unstable income of university-run technology firms and patent licensing income prove the inefficiency of NTTCs. From this point of view, the assertion 2 has not been fully supported.

Assertion 3: Universities without NTTCs cannot get the same achievements as those with NTTCs in terms of publication, patenting and exploiting research findings.

This assertion is denied when we review the performance of Zhejiang University (see Figures 2.12, 2.13 and Tables 2.10, 2.14). It has no NTTC, and nevertheless it has achieved greater success in publications and marketing university findings than the other 5 universities where NTTCs are located.

Zhejiang University follows Tsinghua University and is ahead of Shanghai Jiaotong University, Xi'an Jiaotong University, China East Polytechnic University, Huazhong S&T University and Sichuan University in terms of published papers, patent licensing revenues and incomes created by university-run technology firms. Zhejiang University has largely explored patenting activities in recent years. In 2005, its number of patent applications and issued patents both surpassed that of Tsinghua University. A director in charge of technology transfer activities in Zhejiang University explains the reasons why his university can achieve such remarkable success without NTTC as follows:

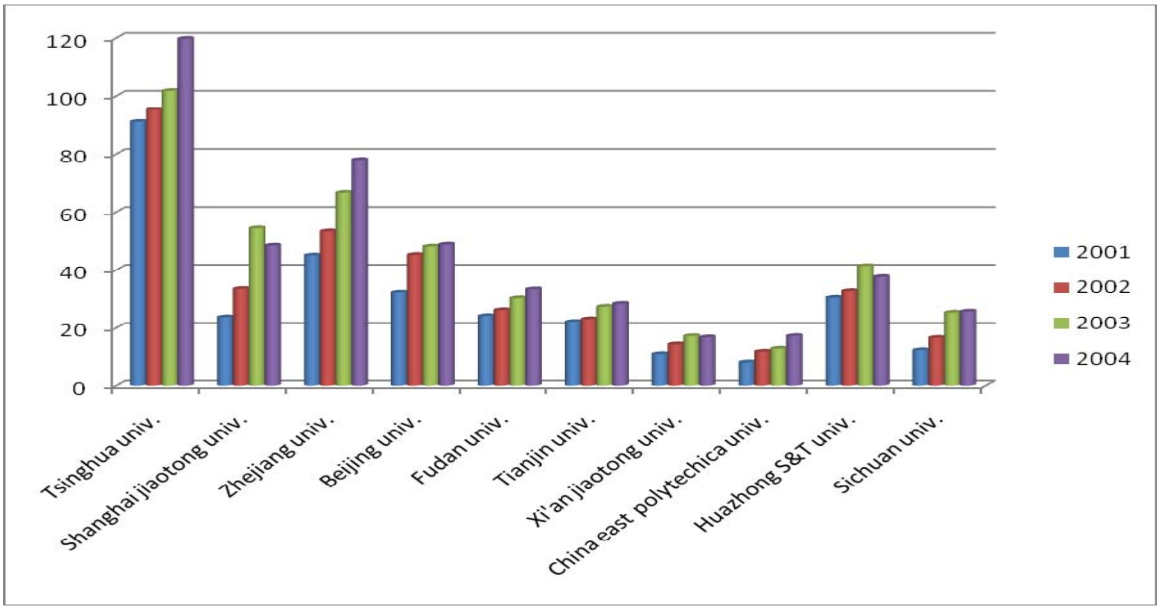
“Our university has no NTTC but we have has a similar office, called S&T development and transfer office, since the beginning of the 1980s. Now the office has a staff of 15 persons who manage over 3000 technology contracts. Continuously increasing R&D expenditure, more cooperative research projects with enterprises, cumulative practices in exploiting S&T findings and strengthening IPR management, all these factors contribute to our strong capability to commercialize S&T findings.”

Apart from the above factors, the incentive policy on IPR of Zhejiang University is another important factor. The university organizes training courses on IPR to improve researchers’ awareness of IPR protection. It also provides inventors with subsidies to cover the patenting cost. The two measures stimulate the enthusiasm of inventors for patenting activities. Besides, Zhejiang University keeps close contacts with local governments, domestic and foreign firms, especially local key firms. The university-government S&T cooperation projects cover over 20 cities and counties. An innovation infrastructures platform has been created, consisting of technology transfer centers, product innovation and technology development centers. Thousands of researchers are employed as technical directors or advisors by firms. And thousands of master degree students engage in technical consulting services. To sum up, these measures to encourage researchers to generate and diffuse innovation promote the success of Zhejiang University in commercializing S&T findings.

Actually, Zhejing University is not a unique exceptional case. Other universities, such as Beijing University, Fudan University and Tianjin University, have showed stronger capability to commercialize academic outputs than some of the universities with NTTCs. For example, Beijing University is very successful in running technology-based spinoffs. In 2005, it took the first rank in terms of revenues created by technology-based spinoffs among all Chinese universities. Fudan University ranked fourth and Tianjing University fifth in terms of patent applications during the period 2001-2004, ahead of Xi'an Jiaotong University, China East Polytechnic University, Huazhong S&T University and Sichuan University.

The reasons which explain the greater success of Beijing, Fudan and Tianjin universities without NTTCs in commercial activities than some universities with NTTCs are similar to those of Zhejiang University. These universities have organizations similar to NTTCs to manage IP issues and technology transfer activities. And they have succeeded in nurturing innovation, IPR protection and entrepreneurship. Moreover, the R&D expenditures of these universities were higher than those of Xi'an Jiaotong University, China East Polytechnic University and Sichuan University from 2001 to 2004 (see Figure 2.15). As Table 2.13 on page 188 shows, R&D expenditure has a significant influence on publications and university patenting activities. More patenting probably creates more opportunities for universities to conduct commercial activities.

Figure 2.15: R&D expenditure in selected Chinese universities (2001-2004), money unit: million €



Source: data collected from Bureau of Finance of the Ministry of Education.

In addition, the yearly-disclosed unofficial ranking of universities in China influences public attitude toward the image of university. A number of academic performance indicators are used as ranking criteria, like academic reputation, academic resources, academic achievements, quality of both students and faculty, and material resources (Xue, 2006). Since access to university has become much easier after the late 1990s and the university registration fee has increased heavily, students prefer to choose the most prestigious universities in teaching and research, which may provide better employment opportunities in the future. To attract brilliant students and teaching/scientific staff and demonstrate their return on public funding, universities are motivated to expand patenting and exploit research outputs. Researchers are also motivated to engage in patenting and commercial activities because these activities are linked to workload assessment and compensation. Zhejiang, Beijing, Fudan and Tianjin universities are historically and currently prestigious higher education institutions in China. A large bulk of R&D expenditure, abundant research human resources and an attractive incentive system provide these universities with a strong capability in technology innovation and technology transfer in spite of the absence of an NTTC.

Assertion 4: The 5 other NTTCs have the same effectiveness in university technology transfer as Tsinghua NTTC.

The assertion is not supported when we go over Tables 2.10, 2.14 and Figure 2.13. Tsinghua NTTC shows more effectiveness than other NTTCs. The effectiveness of NTTCs is determined by several factors, such as the age and staff of NTTC, (Thursby *et al.*, 2001; Thursby and Kemp, 2002; Siegel *et al.*, 2003a; Friedman and Silberman, 2003; Chapple *et al.*, 2005; Markman *et al.,* 2005b; Anderson *et al.,* 2007), the performance mode of NTTCs, university research capacity (Chukumba and Jensen, 2005), university-industry linkage and the location of university (Friedman and Silberman, 2003). The following part focuses on explaining the reasons why Tsinghua NTTC operates better than other NTTCs. Table 2.15 on page 201 offers a general overview of the comparison.

Age of NTTC: The creation of NTTCs results from formerly existing S&T achievements commercialization offices (STACOs or similar). Compared with other universities, Tsinghua University is the earliest one to formally manager technology transfer activities. Most universities set up technology transfer offices in the late 1990s, while Tsinghua started in 1983 and Huazhong S&T University in 1989. Previous research indicates that the age of a university technology transfer office (UTTO) has significant positive effects on licensing activities (Owen-Smith and Powell, 2001a; Friedman and Silberman, 2003; Markman *et al.*, 2005b; Chukumba and Jensen, 2005). However, our linear regression model does not support previous research findings. The number of NTTC staff influenced the patent licensing revenues during the period of 2001-2002 significantly rather than the age of NTTCs. However, the limitation of our research outcome is that the observations are constrained to 6 universities with NTTCs and the period of observation is very short.

Staff of NTTC: Compared with other NTTCs, Tsinghua NTTC is more heavily staffed with 40 persons. It is also the unique one employing full-time business professionals. Other NTTCs are mainly composed of engineers. Except Sichuan NTTC, the other 5 NTTCs employ lawyers. It indicates that research-oriented universities have raised the awareness of IPR protection. China East Polytechnic University, Huazhong S&T University and Sichuan University are lightly staffed with less than 10 people. Shanghai Jiaotong University and Xi'an Jiaotong University have 12 and 11 staff respectively. Many NTTC staff members come directly from universities and a few staff is outsourced. The common weakness of NTTC staff demonstrates the lack of skilled business experiences, except the case of Tsinghua NTTC. Numerous studies have proved that staffing practices determine the success of performance of UTTOs (Thursby and Kemp, 2002; Siegel *et al.*, 2003; Owen-Smith *et al.*, 2003; Chapple *et al.*, 2005). Unlike in other NTTCs, very few Tsinghua NTTC staff is appointed by Tsinghua University. The majority of its staff is selected from outside campus. The candidate must have a sound commercial working background. The literature shows that the department managers in Tsinghua NTTC hold at least a master's degree and working experiences in multinational firms. Moreover, Tsinghua University is one of the most prestigious universities in China. The geographic and administrative proximity to Tsinghua assists NTTC staff in getting easier access to university physical and intellectual resources. In short, Tsinghua NTTC draws more advantages stemming from the staff capabilities than other NTTCs.

Recent sources of funding: Unlike other NTTCs, Tsinghua NTTC benefits from its special organizational structure which generates business incomes. It owns two firms which can conduct for-profit services whereas other NTTCs have no such advantage. In addition to funding from Beijing government and Tsinghua University, these two NTTC-affiliated firms provide NTTC with financial support. Tsinghua NTTC also runs an industry-university club which creates some revenues arising from value-added services provided to member firms. Various funding sources improve the welfare of NTTC staff and facilitate the productivity of NTTC. Previous research achievements have illustrated that the reward system influences the efficient performance of NTTCs positively (Siegel *et al.*, 2003a; Link and Siegel, 2005; Anderson *et al.*, 2002). Directors of NTTCs in Huazhong S&T University and Sichuan University complain that they receive no financial support from university, government and firms after the creation of NTTC. Many business trips have to be cancelled due to a constrained budget. From this point of view, the shortage of financial resources hinders the performance of NTTC.

University-Industry relation: Tsinghua NTTC focuses its role on assisting both domestic and foreign small and medium-sized firms in exploring technology transfer activities on foreign and domestic markets. A committee subordinated to the NTTC is in charge of university-industry cooperation. The excellent image of Tsinghua University to the public attracts many firms at home and abroad to cooperate with Tsinghua NTTC. Up till now, 138 domestic and 38 foreign firms have registered as permanent members of the committee. Over 20 foreign firms are ranked in the world top 50. The committee provides various services to firms, e.g. business intelligence service, development strategy research, technology diagnosis, consulting on finance & investment, talent training, and information service. Such services are available at a reasonable price. The income from services is partially used to support the sustainable development of the NTTC. With the help of the NTTC, informal and formal technical information is circulated amongst registered members. Moreover, Tsinghua NTTC takes advantage of wide contacts with firms and strong technology support from Tsinghua University to facilitate technology transfer activities. If small and medium-sized domestic firms have difficulty to absorb foreign licensed technology, Tsinghua NTTC can assist them with technical consulting. From this viewpoint, Tsinghua NTTC acts not only as an import-export agent but also as an accelerator of technology absorption and diffusion. According to the statistics (Tsinghua NTTC), 70% of Tsinghua S&T findings have been used in industry and 20% have achieved outstanding success. Each year, Tsinghua, together with domestic industry, undertakes nearly 800 projects with a contract value of more than 40 million €.

Sichuan NTTC has a similar university-industry committee as Tsinghua NTTC. But it centres on creating joint R&D centers and transferring domestic technology between university and industry. Apart from launching joint research projects with industry, the NTTCs in Xi'an Jiaotong University, Shanghai Jiaotong University and Huazhong S&T University emphasize the incubation of innovative projects. The NTTC of China East Polytechnic University targets large and medium-sized firms to be partners. Amongst the 6 NTTCs, only Sichuan and Tsinghua have a permanent organization to manage university-industry linkage. The different missions and organizational structures of NTTCs lead to different performances of NTTCs. A director of one of the NTTCs describes the relationship between university and industry as follows:

"The university-industry linkage in our NTTC is rather loose. Because of limited budgets, we are seldom out of the office and just wait for firms to come to us…"

Actually, the 6 NTTCs usually choose the following modes to contact industry:

♠ Websites: university S&T findings are disclosed in university websites and some other websites at the national level. It is free of charge to log into the websites. If firms are interested in the findings, they can easily find the contact method. The websites provide indications about how to reach the NTTC staff, such as names of NTTC staff, fax and telephone number, electronic mail address and postal address.

♠ High-tech exhibitions: NTTC staff often participates in university S&T achievements exhibitions. Through the exhibitions, NTTCs may meet firms who are interested in their inventions.

♠ University-industry club: it is very typical of Tsinghua NTTC. The club acts as a bridge between university and industry. NTTC staff, university researchers, and member firms get together to discuss technology issues regularly. If firms have technological problems or other demands for technology, they come to the club and the NTTC help them. The NTTC also present the new technology to firms through the club.

♠ Joint R&D projects: firms may propose a research project to NTTCs or NTTCs actively recommend to industry a certain kind of technology related to an industrial R&D project. If the project attracts industry's attention, the NTTC organizes the joint work between university S&T researchers and firms. NTTCs can represent university to invest inventions in a start-up in return for equity of the new firm. Sometimes, the university, together with industry, applies for government's research projects through NTTCs.

Close university-industry linkage promotes the effectiveness of NTTCs.

Number of affiliates and subordinated corporations limited: Some NTTCs explore technology transfer activities outside local regions. For example, Tsinghua NTTC, Shanghai Jiaotong NTTC and China East Polytechnic NTTC have one affiliate in Guangzhou, Jiangsu and Henan respectively. Guangzhou geographically and economically is close to Hongkong and Taiwan. The earliest economic reform took place in this province. Taiwan and Hongkong have become increasing important sources of imported technology in China. In the 1990s, patents from Taiwan increased rapidly and they exceeded those from other foreign patentees in 1999 (Sun, 2003). An affiliate of NTTC located in Guangzhou may be a strategy to trace the development of advanced technology from home and abroad. Shanghai Jiaotong NTTC has an affiliate in Jiangsu where an industry cluster of electronic information has formed. As we mentioned before, Shanghai Jiaotong University specializes in electronics and prioritizes hi-tech start-ups incubation. The affiliate of Shanghai Jiaotong NTTC in Jiangsu province can facilitate technology transfer between university and industry. It is also not surprising to find that an affiliate of China East Polytechnic University NTTC is located in Henan. This is because Henan is rich in oil resource and China East Polytechnic University is strong in chemical engineering. Exploring technology transfer activities in Henan helps improve the productivity of oil output. However, NTTCs in Huazhong S&T University, Xi'an Jiaotong University and Sichuan University develop their business the local regions. NTTCs with affiliates seem to perform better in terms of patent licensing incomes. Table 2.14 supports our research results. Concerning the question whether NTTC can conduct for-profit business, there is no law to explicitly prohibit NTTCs from getting engaged in such activities. The attitude of the university seems important to influence whether NTTC can create corporation limited. Tsinghua NTTC is the only one to have made an experimental test. It has set up two companies. One is called Kewei, responsible for transferring North American and European technology to domestic firms, the other is called Luying, undertaking technology transfer from Russia to Chinese firms. The directors of Sichuan and Huazhong NTTCs complain that:

"… Of course, we cannot perform as well as Tsinghua NTTC. Tsinghua NTTC has two companies but we are not allowed to do that. The for-profit business of the companies facilitates the development of NTTC… "

“The success of Tsinghua NTTC depends on its strong financial capacity Funding is a bottleneck for the performance of other NTTCs. The initial investment from government was only around 100000€. We seldom receive funding after the establishment of NTTC and have had to be self-sustained. Universities have no long-term strategies to support the development of NTTCs.”

Table 2.15: A comparison of NTTCs in different universities

Name of NTTC	Foundation year	Staff source (number of staff)	Superior organization	Initial source of funding	Recent source of funding	U-I* relationship	N.*of affiliates /location	N.*of subordinated corporation limited
Tsinghua	1983	Engineers, lawyers, business talents (40 staff)	Scientific research institute	Ministry of Education SETC*	Local government, university, subordinated companies	strong	1/Guangzhou	2
Shanghai Jiaotong Univ.	1999	Engineers, lawyers (12 staff)	S&T development research institute	Ministry of Education SETC*	Local government university	strong	1/Jiangsu	No
China East Polytechnic Univ.	1987	Engineers lawyers (7 staff)	S&T division	Ministry of Education SETC*	University	moderate	1/Henan	No
Huazhong S&T Univ.	1989	Engineers lawyers (6 staff)	S&T division	Ministry of Education SETC*	No investment	loose	No	No
Xi'an Jiaotong Univ.	1999	Engineers lawyers (11 staff)	S&T division	Ministry of Education SETC*	Local government university	ordinary	No	No
Sichuan Univ.	1999	Engineers (2 staff)	S&T division	Ministry of Education SETC*, local government	No investment	ordinary	No	No

Source: information above comes from questionnaires, interviews and telephone contacts with directors of NTTCs.
U-I*: refers to university-industry.
N*.: represents number.
SETC*: refers to former State Economics & Trade Commission

Table 2.16: A comparison of different Chinese universities

Name of univ.	Foundation year/location	Type of univ.	N.*of national key subjects	N*.of national key lab	N*.of national engineering research center	N*.of website cooperation center	N*.of academicians*	N*.of professors (doctors included)	N*.of graduates
Tsinghua univ.	1911/Beijing	C/R/P*	49	26*	5	7	65	1176	10623
Shanghai jiaotong univ.	1896/Shanghai	C/R/P	22	6	4	1	35	743	18100
Zhejiang univ.	1897/Zhejiang	C/R/P	24	13	5	1	22	1100	17000
Xi'an jiaotong univ.	1896*/Shaanxi	C/R/P	20	4	1	1	16	680	12735
China east polyte.univ.	-* /Shanghai	C/R/P	3	2	2	No	23*	1000	5550
Huazhong S&T univ.	- /Hubei	C/R/P	15	4	5	1	16	1025	18884
Sichuan univ.	1896/Sichuan	C/R/P	15	2	3	2	31*	1047	16129

Source: data collected from each university's website.
N.*: represents number.
Academicians*: include academicians in China Academy of Sciences and China Academy of Engineering.
C/R/P: C represents comprehensive, R for research and P for public university. All the universities in table 11 belong to top 100 Chinese universities.
28*: It includes 12 national key labs and 14 key labs subordinated to the Ministry of Education.
1896*: Shanghai Jiaotong University was the predecessor of Xi'an Jiaotong University. According to the government's strategy "developing the west" in 1956, the main part of Shanghai Jiaotong University moved to Xi'an. In 1959, it was officially renamed Xi'an Jiaotong University.
-*: We cannot confirm the exact foundation year only knowing it has a history over 100 years.
23* and 31*: it means that the number of academicians embeds the number of invited academicians.
N* of professors: data collected in 2006; N* of graduates: it includes Ph. D students.

Table 2.16 indicates the differences among universities. All universities with NTTCs have a long history in China and belong to comprehensive, research-oriented public universities. Tsinghua takes the first place with respect to the number of academicians, national key subjects and labs. Together with the former data on patents, R&D expenditure and published papers, Tsinghua is obviously ahead of the 5 other universities. Given that Tsinghua has no NTTC, its strong research capacity and active commercial activities may help it get the same achievements as it holds a NTTC.

2.3.3.3 Determinants of the effectiveness of NTTCs

Based on the questionnaire, open-minded interviews, telephone contacts and published documents, some determinants of the effectiveness of NTTCs are consistent with previous research findings: the size of NTTCs and NTTC staff capability (Thursby *et al*., 2001; Thursby and Kemp, 2002; Siegel *et al*., 2003a; Chapple *et al.,* 2005; Anderson *et al*., 2007). Since all universities with NTTCs have set up a compensation system for faculty members and are motivated to conduct commercial activities, the size of NTTCs and staff practices play an important role in the productivity of NTTCs. Tsinghua NTTC is the biggest one staffed with 40 people, functioning more professionally in comparison with other NTTCs. These advantages help Tsinghua NTTC perform better than its counterparts. However, NTTC staff benefits little from the university reward system which decreases their motivations in terms of technology transfer. And the lack of a clear labor division between NTTC and STACO leads to overlaps and shuffling off duties which brings about low efficiency of NTTC.

Besides, R&D expenditure of the university, rising awareness of IPR protection, funding of NTTC, university-industry linkage and performance mode of NTTC are proved to impact on the outputs of NTTCs. R&D expenditure and the awareness of IPR protection have a positive and significant influence on university patenting expansion. And the funding of NTTCs, university-industry linkage and performance modes (whether NTTCs have a company) determine the productivity of NTTCs in the commercialization of research achievements.

The above determinants converge to show that the establishment of NTTCs is only one of the factors which facilitate the rising university patenting and commercial activities. The effectiveness of NTTCs depends on a series of supportive elements. Universities without NTTCs can achieve similar success in technology innovation and technology transfer as those universities with NTTCs if they meet the requirements of the determinants. Zhejiang University is an example in that respect. It has no NTTC but succeeds in managing university IP issues and exploiting research findings. From this point of view, NTTCs do not seem to be an efficient political tool in promoting university technology transfer.

2.3.4 Conclusion

NTTCs have been operating for 6 years. Our study provides evidence that NTTCs do not seem to be an effective political tool in accelerating the commercialization of university inventions. Universities without NTTCs can achieve the same or even greater success than universities with NTTCs in terms of the commercialization of S&T findings. Zhejiang University provides us a sound proof. And NTTCs play an important role in university patentability and the creation of spin-offs more than in licensing activities.

According to our linear regression and correlation analyses, the number of NTTC staff has a significantly positive impact on the rising university patenting. Besides, other factors are found to have influenced the outputs of NTTCs (measure by publications, patenting and economic revenues) positively: R&D expenditure, rising awareness of IPR protection, staffing capabilities, university institutional inventive systems, funding of NTTCs, university-industry linkage and performance mode of NTTCs.

Although universities with NTTCs are prestigious ones, the outcomes of NTTCs are different. The differences are proved to be related to the disequilibrium in research capability and regional innovation capability which existed before the creation of NTTCs, also to financial resources, university-industry relationship and performance mode after the establishment of NTTCs.

For the future performance of NTTCs, we suggest that there should be a clear division of labor between STACO and NTTC in the same university. Universities should provide a reward system to NTTC staff for stimulating their efforts in marketing patented technology. For example, universities can use technology transfer incomes as one of the criteria to evaluate NTTC staffing capability. It is recommended to bind the workload of NTTC staff to their salary, tenure and position promotion. Besides, universities can authorize NTTCs to provide industry with affordable services in order to compensate for constrained funding. Finally, NTTCs should enhance connections with other components of national innovation system, i.e. technology markets, technology business incubators, science parks and Innofunds, to develop the mechanism for technology marketability.

Section 2.4 Conclusion

When talking about recent growing university patenting activities, we often think of the US Bayh-Dole Act enacted in 1980. The influence of the Act spread not only in the U.S. territory but also across the Asian and European continents. This chapter has discussed whether the Chinese version of the 'Bayh-Dole Act' enacted in 2002 played a similar role in university patenting and licensing expansion and the effectiveness of NTTCs in the commercialization of university S&T findings.

Our findings indicate that the Chinese 'Bayh-Dole Act' has a similar effect as the US Act on the growth of university patenting but it is only one of the factors behind the rising patenting activities. Before the effective date of the Chinese Act in 2002, universities had begun to expand their activities in patenting. The series of legislation before 2002, institutional innovation (e.g. establishment of STACO, IPR office) and internal incentive mechanisms (e.g. patent funds, assessment workload related to patents) in universities promote the increase of patenting. In general, research universities, who had a patenting history before the Chinese 'Bayh-Dole Act', seem to have become more and more active in patenting and to have been more aware of IPR protection after the effective date of the Act in 2002. However, the effect of the Chinese Act on licensing is not as efficient as on patenting. In spite of the growing licensing agreements, licensing contracts account for a very small part of four university technology contracts categories. Technology development contracts are the most efficient mechanism for universities to transfer technology toward enterprises in technology markets. This is because, the difficulty of evaluating the patented invention and the weak capacity of domestic firms to exploit the patented technology, especially when the technology is at the early stage of proof of concept but no prototype.

Since the Act, together with other factors, brings about more university patents, how to deal with these patents? University technology transfer centers (NTTCs) were created to commercialize university innovation. NTTCs take responsibility for managing university IP issues and exploiting university research findings. Our quantitative and qualitative analysis indicates that NTTCs play a moderate role in promoting the commercialization of university inventions. Universities without NTTCs can be ahead of those with NTTCs in terms of patenting activities, patent licensing incomes and revenues generated by university-run technology firms. Zhejing University confirms our research results.

Concerning the determinants of success of NTTCs, our linear regression model shows that the number of NTTC staff has a significantly positive effect on the outputs of NTTCs (the number of patent applications and issued patents) rather than the age of NTTCs. But the staff number acquires more importance in determining issued patents than patents applications. At the same time, our correlation analysis shows that the inputs of NTTCs (age of NTTCs and the number of NTTC staff) have a positive correlation with the outputs of NTTCs (published papers, patent applications and issued patents). The number of NTTC staff has a more important correlation with the outputs of NTTCs than the age of NTTCs. Apart from the inputs of NTTCs (age and staff number of NTTCs), R&D expenditure are significantly and positively correlated with the outputs of NTTCs. According to our qualitative analysis, other factors, like increasing R&D expenditure, growing awareness of IPR protection, staffing capacity, university attractive incentive system and university's location, have significant positive effects on the performance of NTTCs.

Moreover, the differences in productivity of the 6 NTTCs are proved to be related to a previous disequilibrium in research capability and regional innovation capability before the creation of NTTCs.

All in all, the Chinese 'Bayh-Dole Act' and NTTCs facilitate the growth of university patenting activities. But the Act and NTTCs do not seem efficient in promoting university licensing activities.

Concerning the "unintended" effect of the Bayh-Dole Act, we find that Chinese universities have suffered a little in terms of teaching quality and some professors' unwillingness to share research information. The R&D resources shift from basic research to applied research marked by western scholars does not exist in Chinese universities for the time being. But we are concerned that universities spend a lot of money to support the growing patent activities but a small part of patented technology has been exploited by firms. If universities merely pursue patent numbers but neglect marketing the patented technology, the role of universities oriented to serve the economic development of society is doubtful. More patents without exploitation merely signal more intangible assets of universities but not marketable products. Society can benefit from the patents only when the inventions turn into products or services. Another thing we are concerned about is that a few universities start to use patents in academic evaluation process. In the short-term, this measure appears to have promoted professors' enthusiasm in patenting but in the long-term, it may lead to the reduction of teaching quality because of professors' active involvement in a commercial world.

Chapter 3

University incubators

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Supported by the Bayh-Dole Act in 1980, universities have expanded their commercial activities with marked increase in patents and licensing agreements. The 1980s also witnessed the upward tendency of formation of university incubators to help the growth of university spin-offs. Although established firms are the entities that license most university intellectual property, new ventures are created to exploit approximately 14 percent of all university inventions (Shane, 2004). University incubators (UIs) are instituted to typically offer faculty and student entrepreneurs a diversified set of services ranging from library access, use of laboratories, access to faculty staff and student labor, cutting-edge research results, business expertise as well as financial resources to run their own business based on university technology. Since widely recognizing UIs as an instrument to strengthen the tie between basic research and science and development, many developed and developing countries have set up university incubators to commercialize academic findings.

In this chapter, section 3.1 gives a general introduction of university incubators, ranging from the evolution of UIs in developed and developing countries, research literature review on UIs and methodology of case studies, the contribution of UIs to new technology ventures, and to their role orientation in developed and developing countries.

Section 3.2 overviews the evolution of non-university incubators (non-UIs) in China and emphasizes a comparative study on UIs and non-UIs, with respect to incubator sponsorship, mission orientation, location, type of entrepreneurs and services. Chongqing University incubator and Caohejing incubator are sampled to conduct our case studies. We employ Chan and Lau's assessment framework as an analytical tool to compare the quality of services and the performance outcomes of these two sampled incubators, and discuss the contribution of universities to the development of new technology ventures. The results of the assessment will be displayed in a qualitative and quantitative way.

Section 3.3 focuses on a cross-nation comparative study on university incubators in China and in France. It gives a brief introduction of the context of their emergence in both countries, and uses Mian's three sets of variables (management and operational policies, services, and performance outcomes) to assess the similarities and differences existing between both incubation systems and to provide some explanation concerning their performance. We sample Chongqing University incubator and Alsace university incubator SEMIA to make our case studies.

Section 3.1 The role of university incubators

This section aims to analyze the role of university incubators. Section 3.1.1 outlines the evolution of university incubators (UIs) in developed and developing countries. Section 3.1.2 represents research literature on UIs and our methodology of research. Section 3.1.3 maps the contribution of UIs to the development of new technology ventures and the role orientation of UIs in developed and developing countries.

3.1.1 The evolution of university incubators

The emergence of university incubators is associated with the changes of university missions. When the evolution of national innovation system requires universities to transfer new scientific discoveries into industry, the fundamental missions of universities in students training and scholarly research are expanded to economic contribution to the society. In response to the third mission, universities create incubators and technology transfer offices to disseminate knowledge/technology through fostering start-ups and licensing agreements (O'Shea *et al*., 2005; Becker and Gassmann, 2006). Indeed, the concept of UIs employs the original meaning of incubators and adds more economic factors like talent, technology, capital, know-how and business networks. The United States is an initial pioneer in generating university incubators. The worldwide spread of UIs is a contagion effect resulting from the US successful stories.

3.1.1.1 University incubators in developed countries

When people talk about incubators, we may imagine a farm with hens hatching eggs. In fact, the fundamental meaning of incubators is to hatch chicken eggs. According to the Webster's Dictionary, the term "incubator" refers to:

a) An apparatus by which eggs are hatched artificially;
b) An apparatus with a chamber used to provide controlled environmental conditions especially for the cultivation of microorganisms or the care and protection of premature or sick babies.

The concept of incubators has been employed in the economic world since 1960s, which extends from the nurturing of ordinary new firms to technology-based new ventures. The evolution of the development of incubators reflects the objectives of economic development (to increase employment, advance technology and create wealth).

The most widely recognized birth date for ordinary business incubation is in the United States, in 1959, when Joseph L. Mancuso of Batavia, New York, opened an 850,000 square feet incubator in a Massey-Ferguson facility that had been closed a year earlier (Allen and Bazan, 1990). The beginning of business incubators emerged in US communities as non-profit organizations in the 1960s because of the 'rust belt' recession[82]. Several states in the United States, including Pennsylvania and North Carolina, sponsored community incubators to promote economic development and job creation through government funding. The economic depression spread from USA to Europe in the late 1970s and early 1980s. France, Italy, Portugal, the United Kingdom and other European countries suffered a rapid rise in unemployment rate primarily due to falling down traditional industries. Further, the manufacturing industries, since the 1980s, have begun to move from developed countries to labor-intensive countries (Storey and Tether, 1998; CSES, 2002). In order to revitalize crisis sectors, government-sponsored business incubators including technology business incubators were created, acting as instruments to support innovation and technology transfer.

From a more conceptual point of view, the rationale behind the build-up of incubators is associated with the "market failure" of small start-ups. Compared to large and medium-sized firms, small start ups lack access to financial support, technology, consulting service, staff recruiting, marketing, administrative and legal affairs and other factors for growing up (Storey and Tether, 1998; Colombo and Delmastro, 2002). Incubators seek to help start-ups remove such market barriers and become healthy independent enterprises. During the period of the 1980s and the first half of the 1990s,

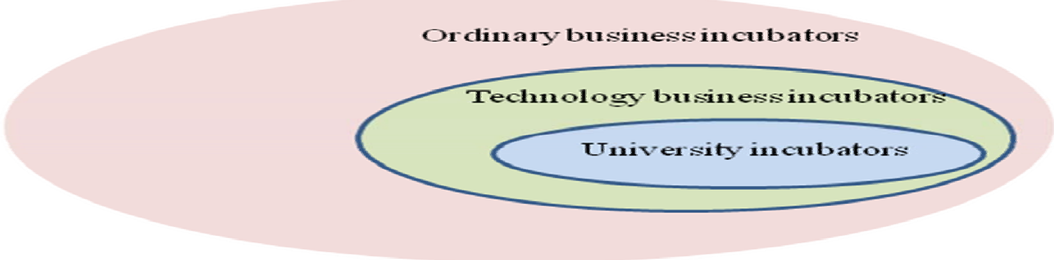
[82] Rust belt recession: a description of the declining heavy manufacturing industries in a geographical area of the United States, mainly in Pennsylvania, West Virginia, and the industrial Midwest, where iron and steel is produced and where there is a concentration of industries that manufacture products using iron and steel. The term of rust belt is used broadly to mean traditional American manufacturing with its largely unmodernized plants and facilities.

public incubators spurred an exponential growth (Beck and Gassmann, 2006). University technology business incubators follow the development tide of public incubators.

University's contribution to economic competitiveness through its knowledge creation and innovation has been more and more recognized at the same period and government policy-makers pushed them to create incubators for fueling national and regional economic development (Mian, 1994, 1996; VonZedtwitz and Grimaldi, 2006). Decentralized US universities, which blended financial autonomy, public funding from state and local resources with federal research support, adapted to the changing market demand through incubator creation (Mowery and Sampat, 2005). In the early 1980s, more than 50 American universities set up new technology business incubation facilities in and around their campuses (NBIA, 1992; Becker and Gassmann, 2006).

The spillover effect of university incubators (UIs) quickly spread from USA to Europe. The number of European university incubators has grown rapidly in the 1980s and 1990s (Colombo and Delmastro, 2002). Although UIs share some common characteristics with other business incubators, such as providing residence room, electricity, telephone, receptionist service, consulting service, financial resources and so on, they focus on nurturing technology-based start ups in or around campuses and promote the commercialization of R&D findings. Tenant firms can benefit from a university's physical facilities and intangible resources, e.g. libraries, research laboratories, qualified teaching staffs and students, academic environment, university image, etc. Universities play a critical role in incubating new technology-based firms (Mian, 1997). The relationship between ordinary business incubators, technology business incubators and university incubators can be probably pictured as the following (see Figure 3.1):

Figure 3.1: Relationship between general business incubators, technology incubators and university incubators



Source: by the author herself

The boundary of ordinary business incubators is larger than technology business incubators and university technology business incubators. Most ordinary business incubators programs aim to increase the rate the new business formation, expansion, development, and to improve the survival chance of tenant firms which are not necessarily technology-based start-ups. Technology business incubators are subordinated to ordinary business incubators but embrace university incubators. They merge the concept of fostering new business development with the concepts of commercialization and transfer of technology. Universities and other research organizations are generators and diffusers of technology and entrepreneurship so that they have been unsurprisingly major developers of technology incubator programs (Phillips, 2002). In contrast to ordinary business incubators, technology incubators provide very specific and high value-added services to focus on the formation of new technology-based ventures (OECD, 1997, Mian, 1997). Technology business incubators are known under various names in OECD countries - innovation centers, science parks, and technology centers. University incubators are university-sponsored technology-based incubators, usually built in or around university campuses. They are characterized by the fact they link talent, technology, capital, and know-how to leverage entrepreneurial talent, accelerate the development of new technology-based firms, and speed the commercialization of technology (Smilor and Gill, 1986). Universities contribute significantly to the formation of new technology-based ventures (Mian, 1996, 1997).

After a period of initial booming growth of public incubators, the 1990s witnessed the development of for-profit business incubators that were often set up without government funding as independent or corporate incubators inside a corporation (Becker and Gassman, 2006). The Internet boom in the late 1990s accelerated the growth of profit-oriented private, virtual and technology incubators, especially in the United States, but some incubators shrank or even disappeared after the recession of doc.com (vonZedtwitz and Grimaldi, 2006; Becker and Gassmann, 2006). The attraction of internet incubators and private incubators has diminished since, but universities, governments and large corporations continue to explore incubators as a means to spur innovation and employment in adverse economic conditions (vonZedtwitz and Grimaldi, 2006).

3.1.1.2 University incubators in developing countries

The spillover effect of incubators also spreads in many developing and restructuring countries, like China, Brazil, Egypt, India, Indonesia, Korea, Malaysia and Uzbekistan. These countries have implemented incubation programs, typically focusing on fostering technology ventures during the late 1990s and the early 2000s (Lalkaka, 2001). Incubators are conceptualized as a new component added to national and regional innovation systems which could generate employment and contribute to economic development. For industrializing countries, technology business incubators, particularly university technology business incubators are significantly important. Because theoretical and empirical studies on the process of industrialization which occurred throughout much of Europe, starting in the middle of the nineteenth century, put forth the fact that continental industrialization involves the formation of new firms in the creation of new industries, technology advancement and the presence of entrepreneurs willing to take risks in non-conventional fields (Flinn, 1966; Trebilcock, 1981; Bruland, 1989). The creation of university incubators is helpful for developing and restructuring countries to realize industrialization through fostering new technology ventures, nurturing innovative entrepreneurs and conducting endogenous innovation. China is in this case.

Experiencing the transitional period from a hybrid economy (agricultural-industrial mixed economy) to an industrial economy, China has tried to foster new industries through technology innovation for adapting to the changing context. However, depending heavily on imported technology eliminates domestic firms' motivation for doing endogenous innovation. Universities are exposed to political pressure to improve weak absorption capability of domestic firms and strengthen business competitiveness both in the interior and overseas markets. University incubators are employed as a policy tool to fulfill the target.

The first generation of incubators in China was technology-oriented and built in Wuhan (capital of Hunan province) in 1987. The "Torch Program" launched by the

Ministry of Science and Technology (MOST) in 1988 accelerated the booming of technology business incubators. Like developed countries, the development of Chinese incubation industry was initially characterized by government-sponsored technology business incubators (TBIs) at the early stage (1987-1999) and gave way to profit-oriented private TBIs during the period 2000-2005. However, the majority of TBIs are non-for-profit public organizations. University incubators emerged along with the creation of university science parks (USPs) in the late 1990s. Supported by the MOST and the Ministry of Education (MOE), some leading research universities, like Tsinghua University and Beijing University, started legally to establish university science parks with incubation facilities.

Although the concept of incubator was introduced to China over 20 years later, Chinese incubation industry has been developing at a very fast speed. Almost all categories of incubators existing in western countries can be found in China, but focus on technology business incubators: for-profit TBIs and non-for-profit TBIs, or virtual TBIs (incubation process is done through the Internet) and non-virtual TBIs (must have physical facilities), or ordinary business incubators (accommodating all types of new ventures) and specific technology business incubators (only host specific start ups, like biotechnology start ups), etc.

Up till 2005, 534 TBIs including 135 at the state-level, have been established in China, occupying 19.699 million square meters and housing 39491 tenant firms. 15815 firms have graduated from the incubators and 50 of them have gone to the stock market. Amongst them, 50 are state-level university incubators (Chinatorch, 2006). Even though university incubators do not share the dominant percentage of total business incubators[83], they are among the most promising and fast growing new segments in Chinese incubation industry. China, like USA, the Europe Union and other mentioned developed countries before, employs university incubators as a policy tool to promote economic growth and job creation.

[83] In China, university incubators represented 9% of total technology business incubators in 2005. In North America, there are approximately 950 business incubators with an increase of 160% over the last years. Thirty-seven percent are classified as technology incubators and 25% are sponsored by academic institutions (Linder, 2003).

In fact, China's 11th five-year plan (2006-2010) displays the continuous support to university incubators. The emphasis on university incubators shifts from pure quantity enlargement to service quality improvement. More university incubators together with other TBIs are expected to integrate the regional and national innovation systems in order to promote indigenous innovation capabilities and develop hi-tech industries.

To sum up the evolution of incubators, we quote Rustam Lalkaka's[84] conclusion:

"The 'first generation' incubators in the 1980s were essentially offering affordable space and shared facilities to carefully selected entrepreneurial groups. In the 1990s the need was recognized for supplementing the work space with counseling skills enhancement and networking services to access professional support and seed capital, for tenants within the facility and affiliates outside. This has led to the 'second generation' incubator, although many in the developing countries are still struck in the original mode. Starting in 1998, a new incubation model emerged in parallel. This is intended to mobilize ICT and provide a convergence of support, towards creating growth-potential, tech-based ventures."

Although Lalkaka's conclusion does not focus on the evolution of university incubators, the history of university incubators has been epitomized in his remarks.

3.1.2 Relevant literature and study methodology

Incubator studies accompany the evolution of incubators themselves. Most of these studies are primarily descriptive, generally embracing different understandings of business incubator's concepts and functions (Allen, 1985; Allen and Levine, 1986; Smilor and Gill, 1986; Mian, 1996). More research studies turn to more complex and systematic assessments on university incubators (Mian, 1996a, 1996b, 1997; Lee and Osteryoung,

[84] Rustam Lalkaka: He is presently President of Business & Technology Development Strategies, International Consultants, New York, and has been involved in various aspects of planning and operating incubators and other SME support services in over twenty countries. Earlier, he was with UNIDO as industry and technology adviser fin Thailand and Turkey, and with UNDP as head of the UN Fund for Science and Technology.

2004; O'Neal, 2005; Chan and Lau, 2005; Becker and Gassmann, 2006). Case study is widely employed as a study methodology in incubation evolution research.

3.1.2.1 Research literature review

The first definition of business incubator dates from the mid-1980s. In 1985, three academic papers presented at the conference held by the journal "Frontiers of Entrepreneurship Research" specified that an incubator must have a physical plant with low market rents, shared service, logistical support, and business consulting services (Gatewood, Ogden and Hoy, 1986; Allen, 1985; Peterson *et al.*, 1985). Smilor & Gill (1986) explore the concept of business incubators. They asserted that the incubation concept seeks to link effectively talent, technology, capital and know-how to leverage entrepreneurial talent; accelerate the development of new technology-based firms, and speed the commercialization of technology. Other researchers complete the concept by describing the incubators' role and services. Incubators hatch new ideas by providing new ventures with physical and intangible resources (Allen and Bazan, 1990) and speed up new ventures' establishment and increase their chances of success (Hansen *et al.*, 2002). They help entrepreneurs develop business and marketing plans, build management teams, obtain venture capital, and provide access to professional and administrative services (vonZedtwitz and Grimaldi, 2006). According to the definition given by the National Business Incubator Association in the United States, a business incubator should lay emphasis on the incubation process rather than the support of infrastructure and services provision:

A dynamic process of business enterprise development. Incubators nurture young firms, helping them to survive and grow during the start-up period when they are most vulnerable. Incubators provide hands-on management assistance, access to financing and orchestrated exposure to critical business or technical support services. Most also offer entrepreneurial firms shared office services, access to equipment, flexible leases and expandable space – all under one roof.

In sum, the above definitions of business incubators extend the initial focus on physical space with basic facilities to value-added services and systematic incubation process.

Technology incubators, also called property-based ventures, have become an important policy tool in OECD and non-OECD countries for helping new technology-based firms increase their chances of survival and generate wealth and jobs. More recent research studies focus on technology incubators. Allen and Bazan (1990) point out the potential of incubators for regional development and define incubator organization types based on sponsorship and service categories provided to tenant firms. Rice's study (1993) contends that managerial intervention is the key in incubation support and success is measured by proactive, direct intervention. The availability of time and lack of responsiveness of tenant firms are factors limiting the effectiveness of direct intervention.

Numerous studies on university incubators (UIs) have started since the 1980s (Allen, 1985; Smilor and Gill, 1986; Campbell *et al*., 1988; Mian, 1991, 1994, 1995, 1996, 1997; O'Neal, 2005). Some studies focus on introducing different types of incubator models and try to design an assessment framework for UIs. VonZedtwitz and Grimaldi (2006) characterize five incubator archetypes (including university incubators) in Italy and conclude that differences in competitive scope and strategic objectives influence the nature and quality of incubation services and the way incubators are managed. Public-funded incubators are generally managed by people without business experience and financial skills so that their competence profiles, service levels, and performance outcomes are different from private-funded ones which are often run by professionals. In the same vein, Philips (2002) compares university incubators to private and hybrid types of incubators in the US and finds that the first type did not significantly influence technology transfer despite their goal to do so. The reasons probably stem from the conflict interest consideration between universities and faculty members and the conflict of interest provisions between university labor and startup self-employment for faculty members. Colombo and Delmastro (2002) show that Italian science parks managing to attract entrepreneurs with high educational attainments and prior working experience contribute to the higher growth rate and better performance of on-incubator firms in terms of management and adoption of technologies, and of collaborations with universities rather than off-incubator firms, although input and output measures of innovative activity are only marginally different between on-and off-incubator firms.

Nevertheless, these researchers investigate and screen the factors influencing the effectiveness of university incubators from different views rather than a systematic and comprehensive analysis framework. Mian's studies compensate this weakness. He focuses on U.S. university incubators through case studies and concludes with a comparatively complete evaluation framework on university incubators. Mian (1991, 1994) provides a checklist for successful facilities and develops an assessment framework for university incubators. He has tried to assess value-added contributions of university incubators to tenant firms (Mian, 1996a), provides insights into key elements which make university incubators successfully help the development of new research/technology based firms (Mian, 1996b) and designs an integrative framework for assessing and managing university incubators as a tool for new venture creation (Mian, 1997). The results of his studies can be summarized with three implications. Firstly, besides several university incubator services (shared office services, business assistance, access to capital, business networks, rent breaks, etc), some of the university-related inputs such as university image, laboratories, equipment, and student employees add major values to tenant firms. Secondly, successful university-sponsored business incubator programs in the U.S., despite public or private sponsorships, have certain common elements, ranging from the objectives, management practices, typical shared offices services, value-added services and provision of a milieu for technology-based entrepreneurship. Thirdly, three sets of variables are composed of university incubators performance assessment (Mian, 1997): management and operational policies, services and performance outcomes. Our section 3.3 in this chapter will use Mian's three sets of variables as an analytical tool.

Several researchers (Chan and Lau, 2005; O'Neal, 2005) continue to propose critical success factors for university incubators on the basis of selected case studies. Chan and Lau (2005) broaden Mian's framework with nine sets of variable, like pooling resources, sharing resources, consulting, public image, networking, clustering, geographic proximity, costing and funding. They sample three university incubators (technology incubators located in three university campuses) and three off-university incubators (technology incubators located in three science parks) in Hongkong, and find university-technology start-ups relationship is more useful than the science park-technology start-ups with regards to the product development process. Universities can provide technology start-ups with both software support, i.e. consulting advice on product, and hardware support, i.e. laboratory equipment and facilities. Chan and Lau's assessment criteria are used in our section 2.2 of this chapter to analyze university incubators and non-university incubators in the Mainland of China. O'Neal (2005) highlights the success factors which facilitate university incubators to incubate tenant firms: integrate clients in the larger technology development system; foster interactions between a client and other clients, incubator management, other staff, outside individuals, and the incubator advisor panel; provide access to external funding sources, university resources, community/local government economic development economic development agencies, and other entrepreneurial support organization. The case studies on university incubators are going on not only in one nation but also across nations. Lee and Osteryoung (2004) compare university incubator's performance in the United States and Korea. They discover that the clarity/achievement of goal and concreteness/realization of operation strategy are perceived to be more important to the director of a university incubator in the United States than to her Korean counterpart. Other key successful factors, more or less like the above mentioned assessment frameworks, are not statistically significant.

In spite of continuous researches on the evaluation framework of university incubators, no signal framework is seen as effective (Mian, 1991). Some success factors are critical in some cases but may not be key factors in other cases. For example, entrepreneur training and virtual networking play a critical role in operating European university incubators whereas company financing and management functions are emphasized for the performance of US university incubators (CSES, 2002). The reasons partially come from different contexts regarding culture, institutions, and routines in different countries. Therefore, research studies tend to benchmark business incubators and technology incubators.

Tornatzky *et al.* (1996) describe the best practices for each of the following technology incubator domains: management, business planning, finance and capitalization, research and technology, legal and regulatory, physical infrastructure, markets and products, and structure/operations. The European Commission's Enterprise

Directorate General launched a research program on benchmarking of business incubators in 2002. The findings of the program defines ‘headline’ benchmarks for business incubators relating to their performance in terms of management and promotion and the means for achieving the ‘headline’ benchmarking performance. The measures suggested to meet the benchmarking criteria are defined as for business incubators: integrate the regional and national economic development programs; explore broader partnership of public and private sector stakeholders; enhance selection for incubator operations; provide appropriate physical space and value added service to tenant firms; specify target market and admission criteria (CSES, 2002). Becker and Gassmann (2006) demonstrate how university incubators can learn best practices from corporate incubators, such as clear mission orientation, structure in terms of advisor board, entrepreneurial activities to support new ventures and best use of resources (physical resources and know-how network).

Another type of study focuses on the role of university linkage on the incubation performance. Several research findings illustrate positive impacts of university linkage on technology-based tenant firms. University incubators have been found to increase the survival rate of new ventures, to promote higher growth than off-incubator firms, and to accelerate the time-to-market, and likelihood of success (Mian, 1997; Colombo and Delmastro, 2002; Ferguson and Olofssonm 2004; Rothaermel and Thursby, 2005). Mian (1997) demonstrates a high frequency of tenants with positive growth both in sales and in employment in four sampled university incubators. Colombo and Delmastro (2002) display tenant firms in science parks linked to universities hold higher growth rates than their off-park counterparts in Italy. These on-park firms also perform better in terms of adoption of advanced technologies, aptitude to participate in international R&D programs and in the establishment of collaborative arrangements, especially with universities. In the same vein, Ferguson and Olofssonm (2004) investigate survival and growth of new technology business firms located on and off two Swedish science parks linked to universities. They find on-park tenant firms have significantly higher survival rates than off-park counterparts but insignificant differences in sales and employment. Rothaermel and Thursby (2005) specify the ties between tenant firms and universities and observe that strong ties to the sponsoring university, as measured by licensed technology or faculty as senior management, reduce the likelihood of firm failure but also retard graduation from the incubator. Weak ties to the sponsoring university, such as informal interaction with faculty, do not appear to influence outright firm failure or timely graduation.

Since the university incubators' positive impact on economic development has not found sufficient evidence in off-USA countries, a group of researchers doubt the positive effect of incubation industry on economic development (Culp, 1996; Autio and Klofsten, 1998; Sherman, 1999) and are aware of government's support for technology incubators which will damage free market competition. Despite the existence of non-unified voices, the number of researchers finding positive impacts for incubators far outweighs those that find negative effects (Becker and Gassmann, 2006), which encourages governments in OECD and non-OECD countries to continue taking measures to support the development of the incubator industry. Facing continuously fierce market competition, economic entities are forced to conduct innovative activities and small medium-sized firms are proved to be dynamic players in terms of innovation. But market failure hampers the ability of small and innovative firms to survive during the early stages and the ability of entrepreneurs to overcome uncertainty and obstacles associated with firm start-ups. Governments, especially for some transitional countries, like China, are convinced that it is rational for public support of technology incubators to eliminate the barriers (OECD, 1997).

The above literature exhibits that a lot of research on university incubators has been done but most of it focuses on the American and European cases. The cross-nation studies on university incubators in a developing country and a developed country have had little attention, including case studies in developing countries. The aim of this chapter is to fill this gap. It firstly compares university incubators with non-university incubators in China to analyze the role of university linkage in the incubation performance on the basis of case studies. Secondly, it makes a cross-nation comparative study on university incubators in China and in France to assess the similarities and differences existing between both systems and provides some explanation concerning their performance differences and government policy implications. The Chongqing University incubator and Alsace university incubator (SEMIA) are sampled to conduct our comparative studies.

3.1.2.2 Methodology and cases

Several researchers (Campbell *et al.*, 1988; Allen and Bazan, 1990; Mian 1997) have advocated the use of the case study approach for incubator evaluation. To surmount the problem of selective recollection, revisionism, and possible bias, multiple sources of evidence are suggested by Yin (1994) to be used in a case study. Our research study is based on the convergence of information from different sources. Both quantitative and qualitative data is incorporated.

One logical way to assess the performance of university incubators is to compare the performance of their tenants with similar firms not located there. However, this approach has limitations (Allen and Bazan, 1990; Mian, 1991, 1997):

1) There is no reliable and cost-effective way to identify a comparison group because of poor data sources on small start-up firms;
2) There is no reliable way to identify a comparison group because of a strong selection bias of university incubator tenants - along with the often small number of university incubator firms limiting the validity of statistical comparisons;
3) Lack of control on firm variables - such as organizational mission, geographical location, lifecycle aspects, etc. - make direct comparisons of the outcomes misleading due to firm dissimilarities; and most importantly
4) The effects of university incubators are not limited to their tenant firms.

Our study uses two comparative evaluation approaches already applied and recommended in assessing university incubators. The section 3.2 and section 3.3 in this Chapter 3 apply Chan and Lau's and Mian's assessment framework respectively to conduct the two different types of case study. One type of case study is to compare the quality of services and the performance outcomes of university incubators (Chongqing University incubator) with non-university incubators (Caohejing technology business incubator) in China. A semi-structured survey based on Chan and Lau's nine sets of variables was sent to a manager in Chongqing University incubator. The same questions were asked by telephone to a manager in the Caohejing technology business incubator

(Caohejing TBI). Additionally, we visited these two sampled incubators and conducted face-to-face interviews. We visited the Chongqing University incubator in May, September and October 2006. The visit to the Caohejing TBI was organized by the Shanghai Tongji University when we attended an Asialics Conference in April 2006. After that, we also used telephone interviews with directors in these two incubators for further information. Qualitative information employed in the case study is collected from published documents and open-ended interviews.

The other type of case study is to compare the university incubation system and performance in China (Chongqing University incubators) and in France (Alsace university incubator SEMIA) on the basis of Mian's assessment framework. The cross-nation comparative case study was conducted by in-site visit, face-to-face interviews and email contacts. The subject of the interviews with directors and management staff of sampled university incubators were based on the three sets of variables proposed by Mian (1997): management and operational policies, services and performance outcomes. Published documentary evidence and email contacts led to our qualitative information collection. These multiple independent sources of information were reviewed and analyzed together to make our cross-nation case study.

The rationale behind sampling the Chongqing University incubators, Caohejing TBI and Alsace university incubator SEMIA is firstly linked to our accessibility of information collection. Secondly, both the Caohejing TBI and Chongqing University incubator are state-level technology business incubators which are truly comparable. Thirdly, my teaching position in Chongqing Jiaotong University and recent PhD study at Louis Pasteur University in Strasbourg helped me gain an easy access to in-site visits and face-to-face interviews because of geographic proximity to the Chongqing University incubators and SEMIA.

To sum up, the following three incubators were selected to employ Chan and Lau's and Mian's proposed performance assessment framework:

- Chongqing University incubator located in Chongqing University campus (Chongqing)

- Caohejing technology business incubator (Caohejing TBI) located in Caohejing Science and Technical Industrial Park (Shanghai)
- SEMIA (l'incubateur d'entreprises innovantes d'Alsace) university incubator located around Louis Pasteur University campus (Strasbourg)

The characteristics of the sampled three incubators are pictured in the Table 3.1 below.

Table 3.1: Diversity of selected university incubators and non-university incubator

Incubator facility	Year established	Incubator sponsorship	Number of tenant firms (2005)
Chongqing University Incubator	2000	Chongqing University Shapingba district government	122
Caohejing TBI	1997	State-owned company	100
SEMIA	2000	Universities public research institutions	45

Source: published documents and open-ended interviews.

3.1.3 The role of university incubators

After reviewing the evolution and research literature of university incubators and presenting our research methodology, this section 3.1.3 focuses on the role of university incubators. Section 3.1.3.1 maps the contribution of university incubators to the growth of new technology ventures and section 3.1.3.2 discusses the role orientation of university incubators in developing countries and developed countries.

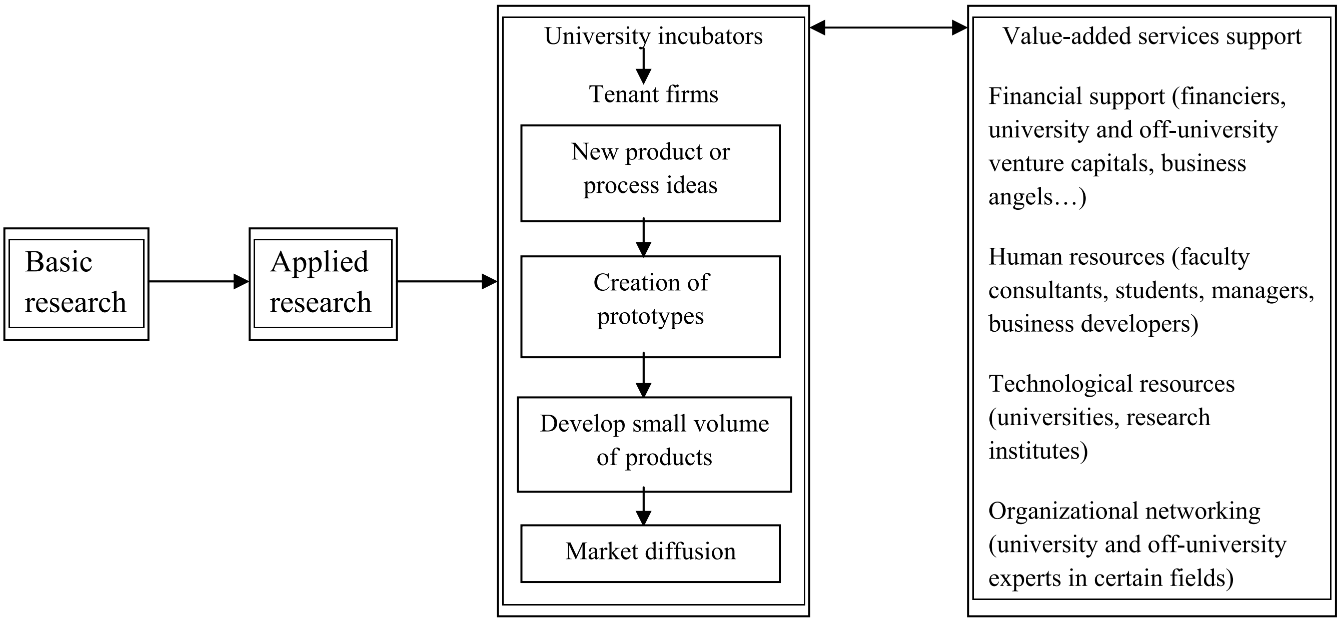
3.1.3.1 Creation of new technology ventures

The main differences between university incubators and other types of incubators are found in the linkage with universities. University incubators are university-sponsored, located in or around university campuses, give preferences to university spin-offs and provide new ventures with easy access to university resources. These features determine that university incubators emphasize the nurturing of new academic technology ventures.

Firstly, the close linkage between sponsored universities and university incubators assists new technology ventures in getting university frontier technology. Indeed, the technology of university spin-offs directly comes from university laboratories.

Secondly, university incubators promote the transformation of university inventions into innovations. Most university inventions are embryonic technologies (Thursby *et al.*, 2001). Further development of these technologies is often necessary before the technologies are ready to be exploited commercially (Pries and Guild, 2007). University incubators provide value-added services[85] to tenant firms for the further development of their core technology (see Figure 3.2)

Figure 3.2: Innovation process in university incubators



Source: done by the author herself.

Figure 3.2 shows how university incubators embrace the key process of innovation and help tenant firms turn new concepts into marketable products or services.

[85] Value-added services refer to those specific services that an incubator program improves the ability of its tenants to survive and grow in business (Allen and Bazan, 1990). According to Mian (1996b), university incubators provide value-added services along with university-related input to tenant firms: faculty consultants, student employees, university image conveyance, library services, labs/workshops and equipment, mainframe computers, related R&D activity, technology transfer programs, employee education and training, and sports and other social activity.

The value-added services are provided on the basis of the university incubators' wide networks. The broad networks overcome linear information flows during the innovation process and university incubators are practitioners of a Chain-link model (Kline and Rosenberg, 1986). The multiple accesses to external resources contribute to the interactions among various actors involved in the innovation process, adapting to the lifecycle[86] of tenant firms and also decreasing the operation cost of tenant firms.

Thirdly, university incubators provide a strategic option for university start-ups which fail to commercialize new technology through technology markets. University start-ups can not only commercialize university research inventions through product markets but also through technology markets (Pries and Guild, 2007). When market failures associated with information asymmetry and uncertainty create problems in licensing transactions through technology markets, university start-ups can go to university incubators and exploit new technology by themselves into products or services.

Fourthly, university incubator programs foster university-technology-entrepreneurship linkages as a means to attract and support the development of firms (Mian, 1996a). Because of geographic proximity to universities, the spillover effect of successful tenant firms encourages more university professors and students to become entrepreneurial.

In short, the linkage of university incubators with universities plays an important role in providing the infrastructure support and the necessary value-added services to nurture new academic technology ventures.

3.1.3.2 Maintenance or building-up of innovation competitiveness

University incubators (UIs) in both developed and developing countries are a part of their national innovation systems. They undertake the same role in technology transfer and innovation by fostering new technology ventures. However, UIs are used as an

[86] Clarysee B. and Bruneel J. (2007) introduce several lifecycle models of new technology ventures in their paper "nurturing and growing innovative start-ups: the role of policy as integrator".

instrument to maintain innovation competitiveness in developed countries whereas to build up innovation competitiveness in developing countries. Innovative firms in UIs of developed countries emphasize the commercialization of technologies embedded not only economic but also social needs, i.e. health, security and risk aversiveness. New firms in UIs of developing countries focus on those technologies to upgrade traditional industries and develop high-tech industries. These differences of UIs are associated with the specific contexts of developed and developing countries. Developed countries realized industrialization over 150 years ago. The challenges from some newly industrialized economies push them to maintain innovation competitiveness in the world market. The ultimate objective is to keep their leading places in income and wealth. Those developing countries which miss the opportunity of industrialization, like China, they need to compensate the vacancy development stage for catching up.

The countries today called "developing" held a leading place at the forefront of applied science for about 2000 years, from say 300 BC to 1770AD, and many significant innovations moved from east to west. For the next 200 years[87] following the industrial revolution, countries today called "developed" began to pull ahead, technologically and thereby economically and militarily (Lalkaka, 2001). Later industrializers, such as Japan in 1960s-1970s and South Korea in 1980s, have caught up technologically with the former industrializers, largely on the basis of initially imported technology (Freeman and Soete, 1997). However, many countries are being left further behind because of insufficient technical infrastructures and skills for innovation (Lalkaka, 2001). The other countries, like China, are trying to catch up.

Nevertheless, the changing conditions for catching up are different from those in the 1960s-1980s. Developed countries have strengthened intellectual property rights protection on advanced technology. The more complex hi-tech intensive products are becoming more difficult to imitate. Furthermore, the effective assimilation of imported foreign technology depends on the country's and the domestic firm's absorptive capability (Freeman and Soete, 1997). Hence, the importance of endogenous R&D activities is increasing to improve a nation's innovative competitiveness. University

[87] According to Shiue and Keller (2004), the industrial revolution started around 1770 in Britain and spread to US and Wester Europe by the mid-19th.

incubators play an important role in endogenous innovation. They provide assistance to university entrepreneurs for commercializing original university technologies. These university technologies may not be at the world frontier level. But they are new to firms or to their country. The commercial exploitation of these technologies promotes entrepreneurship training and accumulates innovation experiences. The theoretical and empirical studies on industrial revolution conclude on the emergence of new industries and innovative entrepreneurs are one of the important preconditions for industrialization (De schweinitz, 1964; Trebilcock, 1981; Bruland, 1989). Following this research conclusion, university incubators in developing countries are more oriented to strengthen university technology-entrepreneurship-industrialization linkage.

3.1.4 Conclusion

The emergence of university incubators is a consequence of the changes of university missions, which add economic contribution to its traditional missions (i.e. education and research). Policy makers, private sectors and scholars view worldwide university incubators as a policy tool to conduct innovation, technology transfer and realize an ultimate target of employment and wealth creation. Although the contribution of university incubators to economic growth reserves an open question, numerous studies demonstrate that university incubators have a positive effect on new technology ventures: increased survival rate, higher growth than off-incubator firms, accelerated time-to-market, and likelihood of success.

In this chapter, we discussed the role of university incubators in developed and developing countries. The common features of university incubators in both countries are found to be characterized by: assisting new technology ventures in getting university frontier technologies, promoting university innovations, providing a strategic option for university start-ups which fail to commercialize new technology through technology markets and fostering university-technology-entrepreneurship linkages through university incubator programs. However, the role orientation of university incubators in developed countries is a little different from that in developing countries. The former stresses the role of UIs in maintaining innovation competitiveness, and the latter emphasizes the building-up of endogenous innovation capabilities and catching-up. China is in this case.

Section 3.2 University incubators and non-university incubators

This section focuses on a comparative study between university incubators and non-university incubators in China. Section 3.2.1 outlines the evolution of non-university incubators. Section 3.2.2 compares university incubators and non-university incubators in terms of sponsorship, types of entrepreneurs, location, and services. Section 3.2.3 samples the Chongqing University incubators and Caohejing TBI as case studies. We would like to compare the performance of these two types of technology business incubators, and then discuss the role of university linkage on the incubation performance.

3.2.1 The evolution of non-university incubators

In this section, we use the term non-university incubators to refer to non-university-sponsored technology business incubators located in national-level science & technical industrial parks (STIPs). Local bureau of science & technology, STIPs and state-owned enterprises are usually sponsors of non-university incubators. Similarly to university incubators, these types of incubators are under the umbrella of the "Torch Program". However, non-university incubators have a longer development history than university incubators and dominate Chinese technology business incubator industry today.

3.2.1.1 The initiative of non-university incubators

After a decade of open policy (1978-1988), continuous inflowing of foreign direct investment helped China improve its output productivity. China has become a big labor-intensive manufacturing production base but not an innovative country. To meet the challenge of the world's new technology revolution and to be responsive to the S&T system reform in 1985, China employed technology business incubators as a new strategy to stimulate innovation and entrepreneurship. The "Torch Program" (1988) is a key policy tool devoted to the creation of a favorable environment for fostering hi-tech companies.

The Torch Program Office of the Ministry of Science & Technology (MOST) is responsible for organizing, developing, financing and guiding China's official technology incubator program. Provincial, county, municipal and district Science and Technology Commissions are responsible for implementing the program and establishing incubators in their local jurisdiction (Ma *et al*., 2003). National-level STIPs are part of the MOST structure, designed to promote innovation and new hi-tech businesses. In fact, many multinational companies are attracted to reside in STIPs and make export-oriented production in a large scale. The establishment of STIP-sponsored non-university incubators in and around STIPs aims to link incubation and production together in the same park and develop hi-tech industries. Tenant firms in this sort of non-university incubators are also expected to benefit from the spillover effect of multinational companies located in STIPs. Given that tenant firms could become component suppliers for multinational companies, it would be helpful to form an industrial clustering in STIPs.

Between 1988 and 2005, 53 national-level STIPs were set up across China, except in the Tibei, Tinghai, Ningxia and Taiwan provinces (see Figure 3.3).

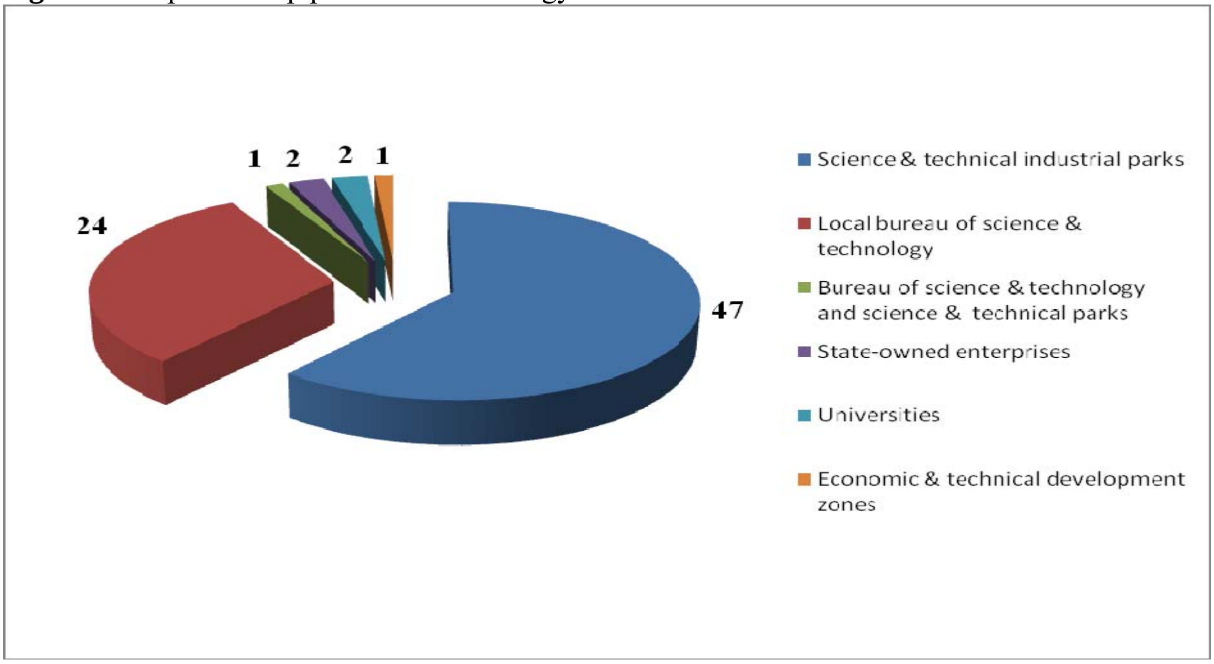
Figure 3.3: Spatial location of 53 China's national-level science & technical industrial parks established under the Torch Program

Source: website of Ministry of Science and Technology, http://220.194.57.124/default.aspx
Note: each red point represents a national-level science & technical industrial park.

3.2.1.2 The development of non-university incubators

Most non-university incubators are sponsored by the bureau of science and technology and STIPs (both are parts of the MOST structure). During the period of 1987-1997, these two types of non-university incubators represented the mainstream of TBIs in China. In 1997, the bureau of S&T and STIP-sponsored non-university incubators accounted for 31% and 61% of total Chinese TBIs respectively. Other institutions such as universities, state-owned enterprises and economic & technical development zones also became sponsors of Torch incubators, but shared a very small percentage (see Figure 3.4).

Figure 3.4: Sponsorship pattern of technology business incubators in 1997

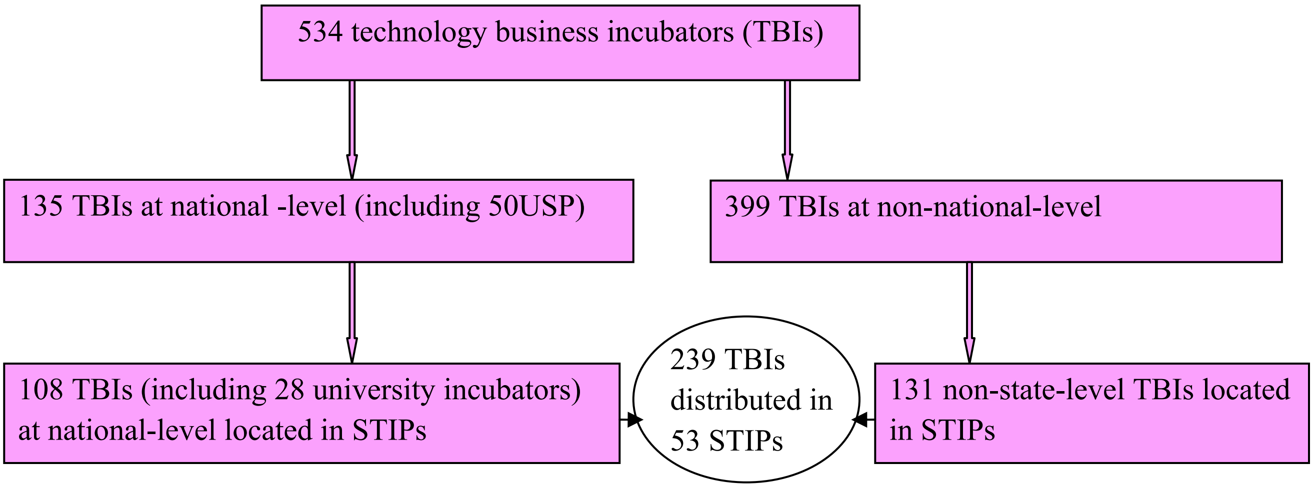


Source: data collected from Lalkaka *et al*., 2003

Starting from the second period of 2000-2005, sponsors of non-university incubators displayed a more pluralistic pattern. The Ministry of Personnel collaborated with the Ministry of Education and the MOST to set up overseas Chinese scholars' parks[88]. The majority of these parks are integrated in STPIs and share personnel and facilities with established non-university incubators. Private corporations also got involved in creating non-university incubators. However, the majority of non-university incubators are non-profit incubators. Up till 2005, 211 non-university incubators were set up (see Figure 3.5).

[88] Overseas Chinese Scholars' Parks: are incubator-like institutions which provide a supportive environment for Chinese students returning home after advanced technical education (Ma *et al*., 2003).

Figure 3.5: Distribution of Chinese technology business incubators (2005)



Source: data collected from http://www.chinatorch.gov.cn/yjbg/200610/101.html

Concerning the funding of non-university incubators, it is associated with the sponsorship of incubators.

Government-sponsored ones are principally financed by the government. Apart from the initial support of central government through Torch program, the local authorities are the principal fund providers. The local government allocates incubators free land and covers the total or a large part of the construction costs. The covering of the operation costs of these incubators depends on the agreement between the incubator and the government. The uncovered funds may partially come from bank loans and incubators' self-funds (service income, accumulative saving…). The incubators are expected to become fully self-sustaining after an initial period, typically 2-3 years (Ma *et al.*, 2003).

State owned enterprise-sponsored ones are financed by state-owned firms. They function between for-profit incubators and non-profit incubators. On one hand, they are expected to perform a social function; on the other hand, they are expected to be economically viable. The Caohejing technology business incubator is in this case. It was financed by the Caohejing New-Tech Development Zone Corporation (state-owned enterprise) but is run on the basis of a corporate management model.

Privately sponsored ones are run strictly as a for-profit business.

3.2.2 Comparison between university incubators and non-university incubators

After mapping the evolution of non-university incubators, we would like to compare university incubators and non-university incubators in terms of mission orientation, types of entrepreneurs, location and services.

3.2.2.1 Mission orientation

While the ultimate goal of university incubators and non-university incubators is job creation and economic growth, they have different focuses linked to the mission of incubator sponsors.

The current mission of universities emphasizes on the commercialization of academic research outputs (endogenous innovation) and entrepreneurship training. University incubators support their sponsors' objective by offering a favorable environment for fostering mainly university technology-based start-ups and by receiving students to do internships in tenant firms. However, exposed to economic pressure, university incubators tend to accommodate non-academic tenant firms with less technology-based ventures but with industrial production potential. This tendency makes university incubators' objective orientation approach that of non-university incubators.

Government and state-owned enterprises are the main sponsors of non-university incubators. Increasing employment and production outputs is the target of the government. Hence, government-sponsored non-university incubators meet the target by creating more new ventures with large industrial production potential. The goal of State owned enterprises (SOE) is to upgrade traditional technology, develop new hi-tech industry and strengthen market competitiveness. Similarly to university incubators, SOE-sponsored incubators provide supportive infrastructures to nurture new technology ventures but focus on industrialization of high technology. Non-university incubators privilege both foreign and domestic technologies with commercial potential.

3.2.2.2 Types of entrepreneurs

The types of entrepreneurs of university incubators and non-university incubators are relative to the mission orientation of these incubators.

University incubators focus on nurturing university research finding-based start-ups and promoting entrepreneurial activities, while non-university incubators privilege overseas technology and industry research achievement-based start-ups. The creators of incubated projects in university incubators are principally professors and students. Venture entrepreneurs in non-university incubators are mainly overseas Chinese scholars, engineers from enterprises and scientists leaving public research institutions.

The different background of tenant firm founders indicates that university incubators emphasize on fostering domestic innovation-based new ventures and non-university incubators tend to nurture both foreign and domestic technology-based start-ups.

3.2.2.3 Location

University incubators are usually located in or around research university campuses, while non-university incubators are often built in science & technical industrial parks (STIPs).

The geographic proximity to universities facilitates professors and students to engage in full time or part-time business creation activities. University-background identification assists academic tenant firms to share university resources: libraries, laboratories, university venture capitals, university technology experts and university reputation. In return, universities enjoy tenant firms' student recruitment and training, potential for faculty consulting and entrepreneurship, and economic contribution recognition by participating in regional innovation capability construction.

Tenant firms in non-university incubators are expected to enjoy STIPs' positive public image in terms of hi-technology, probably more professional incubation services than university incubators, large physical space for potential industrial production and also possibly the spillover of foreign companies[89]. In return, STIPs enjoy image building by participating in regional economic development and correct its deviation towards accommodating large production units of export oriented high-tech manufactures, often funded abroad (Sutherland, 2005). The establishment of non-university incubators makes STIPs back to their original orbit as an institution for innovation and promotion of new high-tech businesses.

3.2.2.4 Services

The provision of services to tenant firms by both university incubators and non-university incubators is in the form of:

- The typical shared offices services: reception desk, rental space, photocopier, fax, phone, personal computer, electricity, water, building maintenance and security.

- Business assistance services: business planning, "one shop" administrative services (business registration, tax registration), counseling, financing and other value-added services.

Although the categories of services are the same, the services provided by university incubators are characterized by university-related resources: access to university library/information database, laboratories/workshops, student employment, faculty consulting and university image conveyance (Mian, 1997). Non-university incubators compensate the disadvantages of off-university by developing a wide network with external actors: universities, public research institutions, industry laboratories and experts in certain fields.

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[89] Chinese Science and Technical Industrial Parks (STIPs) have attracted many multinational foreign companies to make large-scale exported-oriented manufacturing production. Geographic proximity to advanced foreign multinational company production facilitates information exchange and knowledge dissemination between tenant firms and foreign enterprises in STIPs (Walcott, 2002).

3.2.3 Case studies: Chongqing University incubator and Caohejing technology business incubator

After examining the common traits and differences between university incubators and non-university incubators, we sample the Chongqing University incubator and Caohejing technology business incubator as a case study to assess the quality of services and the performance outcomes of these two incubators and discuss the role of university linkage on the incubation performance.

3.2.3.1 Background of two sampled incubators

The Chongqing University incubator and the Caohejing technology business incubator are both national-level technology business incubators and under the same umbrella of the "Torch Program". The common ultimate objective of these two incubators is to increase job creation and economic growth through nurturing new technology ventures. But they have different mission focuses. The Chongqing University incubator focuses on commercializing academic R&D results (domestic) and on fostering entrepreneurship, while the Caohejing incubator emphasizes on the industrialization of hi-technology (either domestic or foreign).

The Chongqing University incubator is co-sponsored by the Chongqing University and the Chongqing Shapingba district government, located near the Chongqing University Campus (Chongqing). Around the campus, two research-oriented universities and some public research organizations cluster there. The incubator was set up in 2000 with a registered fund of 2 million €, co-financed by the Chongqing University, the Jialing Motor Company and the district government Shapingba (much smaller than the Chongqing municipal government, which consists of 6 district governments). At that time, the Shapingba district government did not provide free land as did many local governments in China, because there was no available land near the campus. In consequence, the incubator had to rent some buildings left unused besides the campus. The Jialing Motor Company was invited to restructure these buildings. This increased its operational costs and did not constitute a particular favorable situation. The incubator is open to all technology-based new ventures, but privileges academic-background new ventures. The incubation surface attains 16 443 square meters and the Chongqing University incubator has set up a venture capital fund to finance tenant firms.

The Caoheijing technology business incubator (abbreviated as Caoheijing TBI) is sponsored by the Caohejing New Hi-tech Development Zone Corporation (a state-owned company), located in the Caohejing science & technical industrial park (STIP, Shanghai). The company invested 6.5 million € in the establishment of the incubator in 1997. The local government provided some funding and land at the initial stage. Since its sponsor is a public organization but is run on the basis of a corporate management model, the Caohejing TBI tries to balance the trade off between social function and economic viability. It holds three incubation bases with a total surface of 27 000 square meters. It also has a venture capital investment corporation to fund new technology ventures.

The characteristics of these two samples are pictured in the following Table 3.2.

Table 3.2: The characteristics of Chongqing University incubator and Caohejing technology business incubator

	Chongqing University incubator	Caohejing technology business incubator
Status	National-level technology business incubator	
Objective orientation	Increase job creation and economic growth	
Objective focus	Commercialize academic R&D results (endogenous innovation) and train entrepreneurship	Industrialize high technology (either domestic or foreign)
Sponsors	Chongqing University Shapingba district government Chongqing Jialing Motor Company	Caohejing New Hi-tech Development Zone Corporate Local government
Foundation year	2000	1997
Register capital	2 Million €	6.5 Million €
Incubation surface (m^2)	16 443	27 000
Incubation base	1	3
Venture capital investment corporate	1	1

Source: open-ended interviews and website of the Ministry of Science and Technology http://www.chinatorch.gov.cn/yjbg/200610/101.html

3.2.3.2 Quality of services

We employ Chan and Lau's (2005) assessment framework with nine criteria (see Table 3.3) as an analytical tool to compare the quality of services between the Chongqing UI and Caohejing TBI, but also analyze the factors which influence the quality of their services.

Table 3.3: Assessment framework for Chongqing University incubators and Caohejing TBI

Assessment criteria	Examples of specific indicators	Chongqing University incubator	Caohejing TBI
Pooling resources	Organizing staff training and development activities, marketing events, exhibitions, press conference	Medium	High
Sharing resources	Sharing laboratory facilities, office equipment, testing equipment, administrative support (e.g. meeting room, library, reception area…)	Medium	Medium
Consulting	Provision of legal, accounting, business, technical advices at low cost (or free-of-charge)	Medium	High
Public image	Image of the science park/university /government	Medium	High
Networking	Access to clients/suppliers/subcontractors partnership opportunity with other technology firms within the incubator, knowledge sharing/dissemination	Medium	High
Clustering	Development of a pool of skill labor, externalities from logistics arrangement, externalities from supporting network (e.g. emergence of complementary industry)	Medium	Medium
Geographic proximity	Access to market, research center, universities	High	Medium
Costing	Rental subsidies, subsidies on telecom /computer network access, other subsidies related to cost reduction	Medium	Medium
Funding	Access to venture capital (VC) funding, bank loans, other funding sources	Medium	High

Source: Chan, K.F. and Lau, T., 2005. The assessment results of Chongqing UI and Caohejing TBI were based on semi-structured survey, open-ended interview and published documents.

Pooling resources:

Taking the advantage of the Chongqing University's rich education resources[90], the Chongqing University incubator organizes free training courses for tenant and incubator staff, so as to develop venture entrepreneurs' complementary skills and improve the incubator's management skill. It also organizes tenant firms to participate in the exhibition of High Education S&T Achievements and uses media to present tenant firms and their new products. However, as long as services are payable or even provided on a cost-recovery basis, tenant firms are not proactive to take part in such activities.

As for the Caohejing TBI, it is not geographically near universities and public research institutions (PROs). But it develops a collaborative linkage with them. Professors and business professionals are invited to give lectures or seminars in its specific training center. The training courses are free of charges or token payable for in-house staff and venture entrepreneurs. An exhibition hall is also equipped in the incubator. Tenant firms can show their new products or services without moving outside of the incubator. In parallel to organizing domestic exhibition activities, the incubator sends tenant firms to attend exhibitions abroad. The rapid development of the Caohejing TBI in recent years has attracted the attention of the media. More reports on the Caohejing TBI have appeared in the press and most comments are positive. The favorable feedback of the media is helpful to attract new tenant firms.

Sharing resources:

Geographic proximity to the Chongqing University favors tenant firms to gain an easier access to university facilities. Moreover, the close linkage between the incubator and the sponsored Chongqing University, the formal and informal networks between academic entrepreneurs and the university facilitate tenant firms to share university resources. For non-academic entrepreneurs, some of them have friends who work in the Chongqing University so that the indirect relationship with the university also helps them

[90] Chongqing University is one of the 100 top Chinese universities and ranked in the 33th place among all the Chinese universities. It is a comprehensive university and governed directly by the Ministry of Education.

get an access to university facilities. Others, without any linkage with the Chongqing University, sometimes dislike the university administration and prefer to invest in the necessary facilities by themselves. But they benefit from idea exchange with university professors and students.

Compared to the Chongqing incubator, geographic proximity to public laboratories is not the advantage of the Caohejing TBI. This weakness forces the latter to establish and develop networks with universities and PRO to overcome the barrier. However, comparatively abundant financial resources of the Caohejing TBI assist tenant firms to obtain well-equipped offices.

Administrative support, like “one shop” service, reception area, meeting room, etc., is available both in the Chongqing and Caohejing incubators.

Consulting:

Concerning law and accounting counseling, tenant firms can get it easily both in the Chongqing and Caohejing incubators. Because both incubators host intermediaries, like an accounting agency, an intellectual property rights evaluation bureau, and a law consultancy bureau.

In terms of provision of business advice, university and government-background incubator managers are incapable of satisfying their clients (Lalkaka, 2001; MOST, 2003, VonZedtwitz and Grimaldi, 2006). The Chongqing University incubator is co-managed by local government officers and university leaders. They are civil servants and lack business competence profiles. The Caohejing TBI employs some management staff as civil servants but also employs some business professionals. The different governance structure influences the quality of consulting service. The Caohejing TBI provides more valuable business advice to tenant firms in comparison to the Chongqing incubator.

Concerning financial counseling, both incubators have links with local and national innovation funds, banks and venture capital investment corporations. Nevertheless, the complex funding sources and asymmetrical information between tenants and the incubator somewhat delays the availability of financial support to tenant firms.

The value-added to consulting services in the Chongqing incubator is usually payable because of cost-recovery requirements. In fact, tenants in the Chongqing incubator seldom ask for such a payable service. The reasons result from constrained funds and stagnated mentality[91] on one hand, university entrepreneurs tend to use their personally informal networks with colleagues and external experts for counseling, on the other hand. This prevents the Chongqing incubator from improving management quality and extending its networks for outsourcing external experts. Another reason may stem from person-to-person creditability. Awareness of technology and commercial secrecy leakage hampers the development of consulting services.

On the opposite, benefiting from stronger support of local government and broader networks, the Caohejing TBI offers specific counseling services to tenant firms gratuitously or at affordable cost. Most venture entrepreneurs here enjoy the incubator's counseling services. Obviously, everybody is happy when 'lunch is free of charge'. When the services turn to be payable, there might be more tenant firms which are willing to pay in the Caohejing TBI than those in the Chongqing incubator. This might be because willing-to-pay tenants have an open mind ("good service is worthy of payment") and they can afford the services, or, at the same level of payment, the Caohejing counseling services have higher quality and are available more easily, in comparison to the same quality of services provided by external organizations.

<u>Public image:</u>

Tenants perceive psychologically image benefits from their location. The Caohejing TBI is appraised as "the best practice" of Chinese incubators and the Chongqing incubator is appraised as a "demonstration incubation base" in the West. These two incubators are both regarded as a creditable ***danwei***.

[91] stagnated mentality: influenced by the socialism philosophy, people think that services from government or donor sponsored agencies must be free of charges (Lalkaka, 2001)

Danwei is characterized by specific Chinese features and divided into two categories: ***Shiye Danwei (translated into public service unit)*** and ***Qiye Danwei (translated into enterprise unit)***. Organizations whose activities are neither production-oriented nor profit-oriented but are for-public-profit service and financed by the government, are defined as *Shiye Danwei* (for example, organizations which engage in activities like culture, science & technology, education and health). *Qiye Danwei* refers to legal persons or non-legal persons who conduct profit-oriented activities and should self-sustain. State-owned enterprises, collective enterprises, village & township enterprises and private enterprises, all belong to *Qiye Danwei*. However, state-owned enterprises are ***semi-Qiye Danwei*** instead of pure *Qiye Danwei*, because they are mainly financed and governed by the government so that they undertake a double function in creating wealth and providing social services to meet government's targets (Zhang, 2004). Under a planned economy, *Shiye Danwei* and state-owned enterprises are responsible for building houses, common hospitals and schools for their employees and employee families. That's why Eun *et al*. (2006) point out that ***Shiye Danwei*** along with ***State-owned enterprises***[92] are a microcosm of urban society, into which individuals are born, live, work, and die.

Danwei represents a group of people. The creditability of a group is usually higher than individual creditability, particularly *for Shiye Danwei*. As we mentioned above, *Shiye Danwei* is financed and governed by the government. The government has a higher rating of creditability than firms and individuals. Further, *danwei* members usually reside together in a specific geographic boundary. As a consequence, extended contacts among the *danwei* members during on-and off-duty hours are believed to contribute to strengthening trust among them (Eur *et al*., 2006). Thus, a "*danwei*" is symbol of "trust" or "social capital" in China.

Universities belong to ***Shiye Danwei*** and have always held a high social status in China, except during the period of Cultural Revolution. The recognized contribution of universities to the society helps them gain creditworthiness and reputation as a creditable

[92] Eur, Lee and Wu (2006) define Danwei as a microcosm of urban society, into which individuals are born, live, work, and die. I give a more precise boundary of Danwei here as Shiye Danwei and state-owned enterprises. This is because, other Qiye Danwei, like private firms, function at a different way. For example, they do not obligatorily build a common hospital and residence building for their employees.

danwei and knowledge and innovation center. The Caohejing incubator is sponsored by the Caojejing New Hi-tech Development Zone Corporation (a state-owned enterprise) and supported by the Shanghai government. The identification of sponsor and supporter along with the recognition by international incubator organizations builds up the creditworthiness of the Caohejing TBI.

Tenants feel that their location in these two incubators would gain the trust from potential customers and other actors. From the public side, both the Caohejing TBI and the Chongqing incubator are creditable *danwei* and tenant firms there would be disciplinary players with innovative spirit in the commercial world. The traditional social Chinese culture contributes to the positive image of the Chongqing and Caohejing incubator to the public. But in comparison to the Chongqing University incubator, the Caohejing TBI gains more public attention because of its earlier foundation and established national and international reputation.

Networking:

In the industrially advanced countries, TBI emphasize the establishment and development of networks for tenant firms (CSES, 2002). Networking is viewed as one of the key success factors for university incubators (Mian, 1997; CSES, 2002; O'Neal, 2005; Becker and Gassmann, 2006). The variety of network contacts can include universities, public research institutions, the central/local governments, municipals, cities, industry & commercial chambers, communities, industries, banks, venture capitals and angel funds, which can all enable a transfer of 'know how' and skills through collaboration (Saxenian, 1990). When in-house services are insufficient to meet the tenants' demands, the incubators use their broad networks to outsource experts who have the ability to help tenant firms. Access to networks is important to support the growth of small start-ups (Macpherson and Holt, 2007).

In China, networks have been set up at different levels: city-based, regional, national and international (Wang, 2003). However, the players within the networks are mainly incubators. Lack of other relative actors, like industries - potential customers/suppliers/creditors/**tenants (whose feedbacks are critical to the quality of**

services), decreases the efficiency of networks. On one hand, little commercial experience of incubator management decreases the provision of qualified value-added services, like business plan design, provision of financing and access to market. On the other hand, the awareness of commercial and technological secrecy leakage hinders knowledge dissemination amongst tenants, incubator managers and external experts. Communication among tenants is mostly limited to hellos or head nods when meeting each other. Since both the demand and the supply of the services are insufficient, the management of incubators seems to be an in-house management model instead of an outsourcing of external exports.

In fact, most Chinese incubators survive on building rentals and some basic services income (fax, internet, building management...). Compared to the Chongqing University incubator, the Caohejing technology business incubator does better in terms of network services. It is an active player in city-based, regional, national and international networks. Through the broad networks, it learns good experiences from other incubators to improve its own services. Business-background clients in Caohejing require more specific services so that it facilitates the expansion of the incubator's networking. In consequence, Caohejing clients get an access to more external resources because of wider networks in comparison to the Chongqing incubator. The actual networking of the Chongqing incubator is limited to a regional level. Tenants appear to principally depend on their personal networks. For example, academic entrepreneurs are accustomed to their formal or informal networks with universities in terms of problem-solving counseling and access to laboratories and libraries.

Clustering:

Compared to the Caohejing TBI, the Chongqing University incubator focuses more on developing a pool of innovative talents. Tenant firms, especially academic ventures, receive university apprentices regularly. The Chongqing University incubator finances and incubates student-based innovative projects on the basis of competitive selection. The knowledge and technology is disseminated through the interactions between students and firms. Proximity to university provides actual and potential human resources to tenant firms.

Concerning externalities from logistics arrangement and supporting network, the Caohejing TBI demonstrates more advantages than the Chongqing University incubator. Many hi-tech firms, especially foreign multinational firms, cluster in Caohejing STIP with large-scale outputs. The development of hi-tech industry brings about the cluster of subcontractor/subsupplier/logistic services. Tenant firms are possibly integrated into the industry cluster near the Caohejing TBI. The industry cluster around the Chongqing University incubator is not as strong as that near the Caohejing TBI.

However, the types of start-up activities (see Table 3.4) in the Chongqing and Caoheijng incubators show the trend of industry clustering.

Table 3.4: Types of firms with regard to start-up's activities in Chongqing University incubator and Caohejing technology business incubator (2005)

Types of tenant firms' activities	Number of tenant firms	
	Chongqing University incubator	Caohejing technology business incubator
IT	56	63
Optical, mechanical and electronic integration	12	11
Biotechnology, Pharmacy, medical equipments	10	16
Environment protection and energy saving, new materials	26	5
Science & technology transfer /consulting service	0	5
Modern agriculture	2	0
Others	16	
Total	122	100

Source: open-ended interviews with a Chongqing UI officer and collected archival documents of 2006 from both incubators.

In 2005, the Chongqing incubator hosted 56 IT and 10 biotechnology tenant firms, sharing 46% and 8% respectively of total tenant firms. Past empirical researches show that IT and biotech industries have closer linkages with the academic world in comparison to other industries (Owen-Smith, 2000; Feldman *et al.*, 2002; Bekkers *et al.*, 2006; Geuna et Nesta, 2006). The Chongqing University has a strong capability in IT and biotechnology research, which promotes the creation of new technology ventures.

For its counterpart, 63 IT and 16 biotechnology ventures were incubated in the Caohejing technology business incubator, accounting for 63% and 16% of total new technology ventures respectively. Although the Caojejing TBI has no advantage in terms of physical proximity to academics, it develops a close network with the academic world to compensate its weaknesses. The existing cluster of IT and biotechnology industry in the Caohejing STIP attracts new IT and biotech entrepreneurs to set up ventures in the Caohejing technology business incubator, due to a possibility of learning between new tenant firms and existed IT-biotech firms.

In addition to the trend of IT and biotech industry clustering, these two incubators also present a cluster trend of engineering. The Chongqing incubator held 12 engineering-oriented tenant firms and 11 in the Caohejing incubator. Engineering innovation is viewed as an effective way to realize industrialization so that it is privileged by China's national and regional development strategy. Every technology business incubator in China welcomes tenant firms which get involved in engineering innovation.

Another interesting point is that 26 tenants (21% of total ventures) in the Chongqing incubator are engaged in environment protection, energy saving and new material fields and 2 firms focus on modern agricultural business. The phenomenon links to the regional context and specialty of the Chongqing University. Chongqing industries cluster in automobile, motorcycle and iron manufacturing. Decreasing the pollution, saving energy and developing new materials is very important for its sustainable development. Moreover, peasants account for 57% of its total population. Continuous mobility of rural labors to the urban areas forces the local government to create more jobs in cities and to modernize agriculture for compensating shortages in manpower in the countryside. Besides IT, engineering and biotechnology, the Chongqing University also specializes in environment protection research. The social demand and university specialty influence the activities of tenant firms. The information on the other 16 tenant firms is not available. Their activities may be less linked to hi-tech.

Different from populous peasants in Chongqing, the rural population in Shanghai accounts for about 11% and the third industry dominates the local economic development.

That may be why 5 S&T consulting agencies are incubated in the Caohejing incubator, whereas zero such agencies are in the Chongqing incubator.

Geographic proximity:

Generally speaking, the Caohejing tenant firms have more advantages in terms of geographic proximity to potential hi-tech product markets whereas Chongqing tenant firms gain more advantages in terms of geographic proximity to academic resources.

Tenant firms in the Caohejing incubator and the Chongqing incubator have no problems to get an access to local market. However, when they exploit cross-regional markets, they might meet some local market protections. The introduction of hi-tech products to a market place needs to foster a group of consumers who are innovative product lovers. In 2006, the average controllable income of town inhabitants was 1864.5€ in Shanghai and 1024€ in Chongqing. The potential prospect of market acceptance to hi-tech products seems to be more optimistic in Shanghai than in Chongqing. The income of inhabitants indirectly enhances the attractiveness of the Caoheijng incubator for technology-based tenant firms.

With regard to geographic proximity to universities and research institutes, the Chongqing incubator has more advantages than the Caohejing incubator. In fact, in addition to the Chongqing University, there is a medical university, a communication college and a coal research institution located around the Chongqing incubator. These academic institutions are the main source of academic entrepreneurs. That is why the majority of tenant firms in the Chongqing incubator are academically entrepreneurial. New technology ventures enjoy the advantages arising from geographic proximity to academics.

Costing:

Costing is a very important factor which influences the growth of new technology ventures. New ventures are small and have limited cash-flow. University incubators are designed to reduce transaction costs linked to small start-ups.

At the initial stage, the Chongqing incubator did not benefit from the government's free land. The incubator has to rent three buildings left unused near the Chongqing University campus. It invited the Chongqing Jialing Motor Company (a state-owned enterprise) as a funding partner to monitor the three buildings. The Jiaoling Motor Company invested money in equipping these buildings so as to provide physical infrastructures to tenant firms. This unfavorable situation makes the Chongqing incubator unable to offer tenants "free space". Tenants are required to pay the rent approaching a market price. However, academic ventures usually get an access to university laboratories, library and equipments free of charge and their personal network with university colleagues for problem-solving often does not cost money. Thus, their operation cost is cut down.

The Caohejing incubator receives land donation from the local government and is able to provide free space or charge tenant firms a rent less than market price.

Tenants in these two incubators benefit from free training, simplified administrative service, highly preferential tax rates as well as information in terms of funding and business assistance. These services help tenant firms reduce their costs.

<u>Funding:</u>

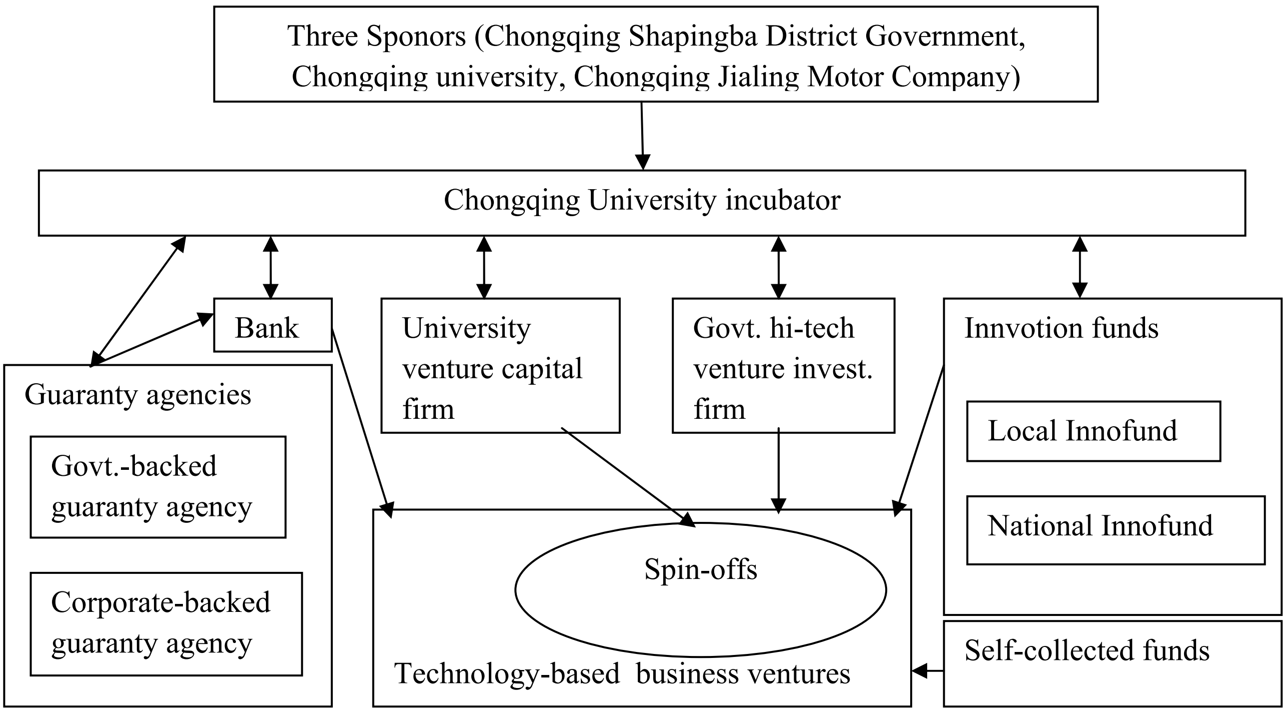
The funding system is linked to the life cycle of start-ups. At the early stage, the venture entrepreneur principally depends on his/her self-collected funds (own money or money from their family members or good friends). Promising academic start-ups can get seed capitals from their sponsored university. Once the ventures enter into the development phase, access to more institutional financial support is needed, such as venture capitals, governmental innovation funds for technology-based small firms (Innofound)[93], bank loans and venture capitals. Both the Chongqing and the Caohejing

[93] Innofund: it is a special government fund set up in 1999 upon the approval of the State Council. The aim of the Innofund is to facilitate and encourage the innovation activities of small technology-based firms and commercialize academic research outputs. The financial provision takes the forms of appropriation, loan interest subsidy and equity investment on the basis of project selection.

incubators assist their tenant firms to get an access to financial support through their funding networks. For example, with the help of the incubator, bank loans are available after the initial stage, guaranteed by a government's or a firm's agency. However, it is not popular to get funding from corporate and foreign venture capitals.

The Chongqing incubator, at the initial stage, was co-financed by the Chongqing University, the district government and the Jialing Motor Company. Its sustainable financial source mainly depends on the local government and the Chongqing University. Concerning the funding for tenant firms, the Chongqing University is a key financial supporter at the initial stage of academic start-ups. It builds a risky asset management company (university venture capital firm) to finance spin-offs with commercial potential. At the development stage of tenant firms, government's funds become the important financial resource. The local government sets up hi-tech venture investment corporations whose funds come from local budget and tax income of successful graduated start-ups, and from a loan guarantee agency to meet tenants' demand for funds. Innofunds at local and national level are applicable for tenant firms through project selection. The incubator helps tenants to get an access to the complex funding system (see Figure 3.6). In 2005, the total available incubation funds reached 0.4 million € in the Chongqing incubator.

Figure 3.6: Funding system in Chongqing university incubator



Source: interviews with a Chongqing UI officer and the brochures about the incubator given by the officer.

In the Caohejing incubator, the funding system source is a little different for the incubator itself and its tenant firms (see Figure 3.7). The government-backed development corporations not only invest in the incubator but also in tenant firms. The corporation can provide seed capital at a maximum of 50,000 € to a start-up at its initial stage and another 50,000€ to a growing start-up if necessary. Its international reputation and networks attract foreign venture capitals to finance tenants. Like the Chongqing incubator, Caohejing helps tenants to get an access to bank loans and Innofunds. The broader network of the Caohejing incubator brought about 3.5 million € incubation funds in 2005, which was equivalent to nine times more than the Chongqing incubator.

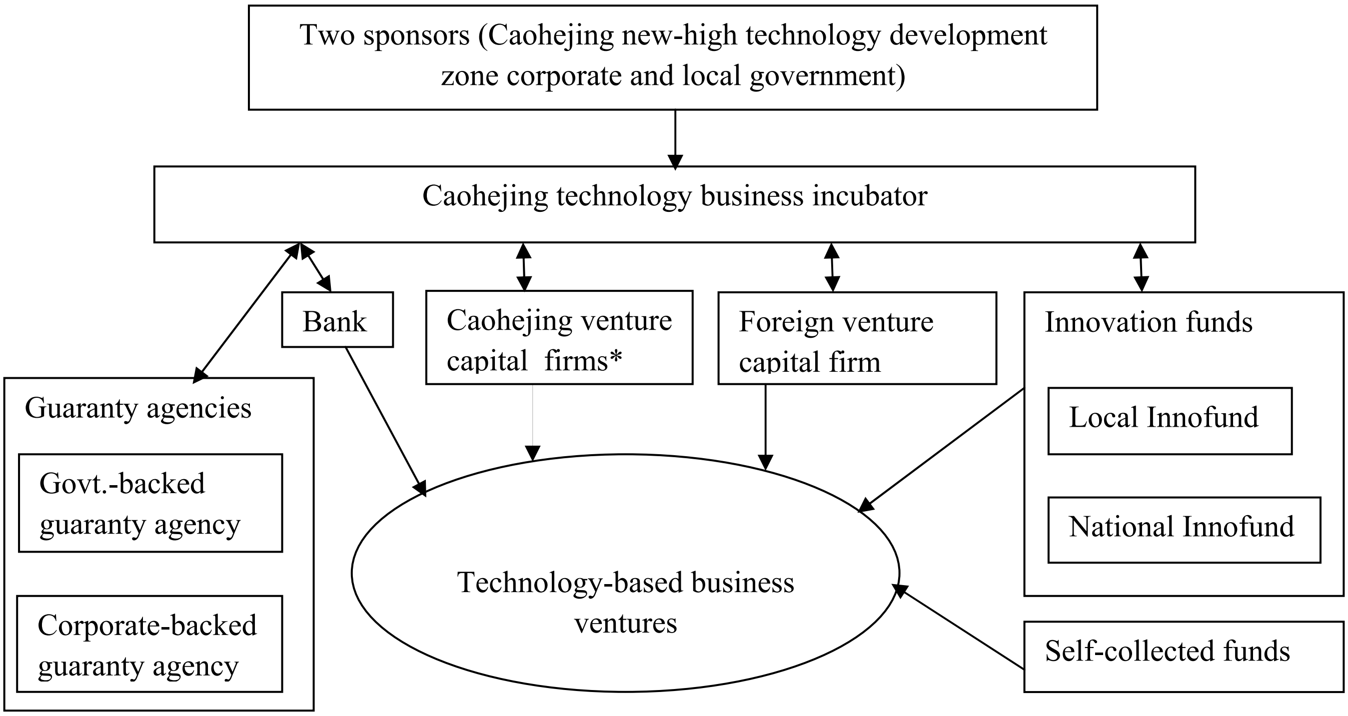
However, in spite of various financing channels, self-collected funds are the principal source for tenants both in the Chongqing and the Caohejing incubators at the early stage. Unlike OECD countries, Chinese public funds get much less involved in the pre-incubation period of tenant firms, but allocated more funds to the construction of incubators at the initial stage. Most tenants have to depend on themselves to collect seed capital. During the incubation period, banks play an important role in financing tenants. Although the venture capital industry in China has developed rapidly since the early 1990s and venture capital has been playing a more and more important role in the development of technology-based start-ups, more than 90% of domestic venture capital funds come from various levels of the government (Fung *et al*., 2005) and venture capital has not dominated the funding source for hi-tech ventures.

Nevertheless, in Europe and in the United States, the vast majority of venture capital funds are from private source. In other words, private investment dominates the funding of hi-tech ventures. According to Fung *et al*. (2005), most venture capital funds in Europe come from retirement insurance funds and investment bank funds, which together account for 50% of the total, followed by reinvestment funds, life insurance, and other funds. Government funds only account for 2% of the total. In the United States, retirement and mutual funds are the biggest sources for venture capital and account for 42% of the total, followed by financial institutional investment, which account for 28%.

The funds from wealthy families and individuals, endowments and foundations, and other investors contribute evenly to the total amount of venture capital (about 30% together).

Perhaps the heavy involvement of public funding support in China offsets the incentive of private sources to finance hi-tech ventures. The complexity and asymmetrical information on the funding system constrict incubators and tenants to gain an access to external financial resources.

Figure 3.7: Funding system in Caohengjing incubator



Source: lecture given by an incubator officer and archival documents about the incubator.
Note: Caohejing venture capital firms* is created and funded by Caohejing new-high technology development zone corporate.

According to the above analysis, the Caohejing and the Chongqing incubators both take their respective advantages to serve tenant firms. Technology-based business ventures in Caohejing benefit from the incubator's broader network and those in the Chongqing incubator profit from university linkage. Compared to the Chongqing incubator, the Caohejing incubator appears to have more advantages in terms of some assessment indicators, such as pooling resources, consulting, public image, networking and funding, because it has developed a broad and complex network with governments, bankers, venture capitals, external business experts, firms and other incubators. The advantages of the Chongqing incubator in terms of geographic proximity to the Chongqing University play a very important role in the development of incubated firms. Tenant firms obtain easier access to well trained students, professors and university laboratory equipments etc. The available physical university resources are often free of charge, which helps reduce the transaction costs for tenant firms. The close contacts with university colleagues provide tenant firms opportunities to get new and frontier knowledge arising from university research outputs. However, the important dependency on sponsored university also restricts the exploration of network for the incubator, especially in consulting service.

3.2.3.3 Performance outcomes

We would now like to compare the performance outcomes of these two sampled incubators in a quantitative way. First of all, we identify the indicators which can be used to evaluate the performance results. The European Commission uses survival rates of tenant firms, average growth in client turnover, average jobs per tenant firm, new graduate jobs per incubator and cost per job as indicators (CSEC, 2002). As statistics on all of the above indicators is unavailable, we use incubation funds, incubation surface, number of staff in tenant firms, number of tenant firms, income of tenants, survival rates of tenant firms and number of graduated tenants as the main criteria (see Table 3.5).

The amount of incubation funds represents the capability of the incubator's pooling funding resources. Incubation surface displays the incubator's capacity to accommodate new technology ventures. The number of staff in tenants, the number of tenants and the income of tenants demonstrate the effectiveness of the incubators in job creation and contribution to local economic growth. The survival rate of tenant firms and the number of graduated tenants exhibit the quality of incubator's service in terms of creating new technology firms.

Table 3.5: Performance outcomes of Chongqing incubator and Caohejing incubator in 2005

Items / Incubator	Incubation funds (million €)	Incubation surface (m^2)	Number of staff in tenant firms	Number of tenant firms	Income of tenants (million €)	Survival rate of tenant firms	Number of graduated tenant firms
Chongqing	0.4	16443	1881	122	5.36	<80%	32
Caohejing	3.5	27000	1092	100	46.92	≥90%	69

Source: http://www.chinatorch.gov.cn/yjbg/200610/101.html
http://www.caohejing.com/infopub/newwindow.asp?news_id=5976&model=586

The Chongqing University incubator held a smaller incubation area than the Caohejing TBI, occupying for 61% of the latter. The difference in incubation surface is relative to the incubator's mission orientation, type of entrepreneurs and location. The Chongqing incubator focuses on transferring university technology and endogenous innovation. The majority of venture entrepreneurs are professors and students. Academic start-ups are usually set up on the basis of new inventions arising from university laboratories. The ventures are quite new and small so that they do not occupy a large space at the initial stage. Moreover, the Chongqing University incubator is built around the campus but in the central city. The land cost is very expensive, since the Chongqing incubator did not receive free land from the local government. Occupying more incubation space means paying more by the incubator and by tenant firms. Caohejing emphasizes the incubation of mature technology and the industrialization of hi-tech. It is located in a science & technical industrial park (outskirts of a city). The Shanghai government endows Caohejing with free land. Thus, it can hold huge incubation surface and reserve exploration space for promising tenant firms. Many venture entrepreneurs are overseas Chinese engineers and researchers who have already left their research institutes. They enjoy the favorable environment in Caohejing and can afford the rental if occupying a large incubation space is necessary.

In 2005, the Chongqing incubator received 0.4 million € of incubation funds, which was approximately equal to one ninth of those for Caohejing. This confirms the qualitative research result that the Caohejing TBI has a stronger capability in pooling resources and funding than the Chongqing incubator because of its wider financial network.

In terms of job creation, the Chongqing incubator performs better than the Caohejing incubator. It housed 22 additional tenant firms and created 789 more jobs than its counterpart, namely 15.4 employments per tenant firm in the former against 9.2 ones in the latter. The number of job creation in these two incubators is higher than the European level with 6.2 jobs per tenant firm (CSES, 2002). In terms of economic growth, the average income obtained per tenant in the Caohejing incubator was much higher than that in the Chongqing incubator, 0.47 million € against 0.04 million €. This may result from more hi-tech tenants in the Caohejing incubator than in the Chongqing incubator.

With respect to the survival rate of tenant firms, tenant firms in the Caohejing incubator held a higher survival rate than in the Chongqing incubator. Higher quality of services in the former than in the latter could explain the difference. Concerning the number of graduated tenant firms, it is hard to say that the Caohejing incubator is more successful in creating new ventures, partly because we should keep in mind that the Caohejing incubator was established in 1997 while the Chongqing incubator was set up in 2000. If we calculate the average number of graduate tenant firms between their respective foundation year and 2005, the result is quite similar: 6.6 per year for Caohejing and 6.4 per year for the Chongqing incubator. Tenant firms enjoy university resources and are reluctant to leave the Chongqing incubator. Thus, the graduation is retarded and the graduation rate becomes low. This result is consistent with Rothaermel and Thursby's (2005) research findings.

In general, the quantitative assessment on the performance outputs of sampled incubators is in line with the results we obtain from the precedent qualitative comparison. The mission oriention, type of entrepreneurs, better services in pooling resources, public image, networking and funding help the Caohejing incubator perform better than the Chongqing incubator in terms of income creation and survival rate of tenant firms. The explanation on the differences will be found in the following.

The Chongqing incubator aims to transfer university technology and to foster innovative entrepreneurship. Creating money is not the university's ultimate objective although it has been currently required to do so. The majority of venture entrepreneurs in the Chongqing incubator are university professors and students. They exploit laboratory inventions and conduct endogenous innovation activities. Academic entrepreneurs have a solid knowledge background but less degree of commercial experiences. The incubator is designed to help the tenant firm get an access to specific commercial advisory. But unfortunately, tenant firms prefer personal informal contacts with sponsored university and have a persistent attitude toward payable value-added services. These behaviors save cash flows to some degree but constrict the improvement of the Chongqing incubator's consulting service and the exploration of the network. Furthermore, the institutional framework authorizes professors to keep their positions in the university when establishing hi-tech start-ups. The fact that professors play on both sides makes it impossible for them to fully contribute to the development of new ventures[94].

The Caohejing incubator aims to industrialize hi-tech and pursue economic income through incubating technology-based firms. Most entrepreneurs here have an industry background or have already participated in the commercial world for a few years. They have acquired both technology and marketing skills. Unlike university entrepreneurs, they usually have no administrative affiliation and are independent legal persons. The independency strengthens their willingness to develop successful businesses. The ambition of entrepreneurs along with their business experience helps the Caohejing incubator to upgrade the quality of consulting service and explore its network. In fact, the Caohejing incubator has recruited some professional managers and developed a multi-level network at city, regional, national and international level. The wide network helps Caohejing continuously learn from best practices. The majority of tenant firms are satisfied with Caohejing services.

The differences between the sampled incubators are partially a reflection of location-specific factors due to the history, economy and policy nature. Longer open history, sustainable political and economical supports from the government and continuous foreign direct investments promote the regional innovation competence of Shanghai. The specific context is in favor of the development of the Caohejing incubator and its incubated firms. Chongqing is an emerging region in the southwest of China, and

[94] In Sweden cases, Ferguson and Olofsson (2004) find that founders holding university employment reduce the need for income from their start-ups. And their firms grow slowly than those run by full-time entrepreneurs.

its economic growth depends on domestic manufacturing firms in automobile and motorcycle industries. Fostering tenant firms by the university incubator is an appropriate way to compensate the lack of indigenous innovation-based Chinese firms. However, it will take some time for the academic world to get used to being entrepreneurial. And the sustainable development of the Chongqing university incubator needs the involvement of more other public and private actors.

3.2.4 Conclusion

This section compares university incubators and non-university incubators in terms of mission orientation, type of venture entrepreneurs, location and services. It samples the Chongqing University incubator and the Caohejing technology business incubator to make a comparative study.

Based on Chan and Lau's (2005) qualitative assessment framework on the services of technology-based incubators, we find that the Caohejing incubator has more advantages in pooling resources, consulting, public image, networking and funding than the Chongqing incubator. The Chongqing incubator has more advantages in terms of geographic proximity to the university. We also used a quantitative assessment framework on the performance outcomes of the two sampled incubators. Our research results show that the Caohejing incubator is superior to its counterpart in terms of incubation funds, incubation surface, income creation of tenant firms, survival rate of tenant firms as well as the number of graduated tenant firms. The Chongqing incubator has an overwhelming advantage in the number of staff in tenant firms and the number of tenant firms. In short, the differences between the sampled incubators are found in line with those at a general level.

Although the ultimate objective of incubators converges in building-up innovation competitveness, different types of incubators focus on different missions. For university incubators, transferring university technology, fostering innovative entrepreneurships and conducting endogenous innovation activities are more important than economic incomes. The university sponsorship of incubators suggests that university incubators cannot behave as firms maximizing their profits. University incubators function as an experimental base for academic entrepreneurs to accumulate innovation experiences and promote innovation capabilities. Academic entrepreneurs gain easy access to university technology, laboratory facilities and other university-input related resources. The university linkage helps tenant firms reduce transaction costs but retards the graduation. Besides, the dependency on university resources makes academic entrepreneurs against for payable value-added services provided by the incubator. They prefer to develop personal informal contacts with university colleagues for problem solving. These routines hold back the incentive of university incubators to improve consulting service and develop wider network for tenant firms. And tenant firms are influenced by sponsored university specialty and regional history, economy and policy nature.

For non-university incubators, industrializing hi-tech and creating wealth are the key pursuing points. The corporate sponsorship of non-university incubators requires economic returns to investments. To attain these objectives, non-university incubators improve incubation services to attract venture firms with promising market potential. In the Caohejing incubator, the majority of the venture entrepreneurs have both commercial experiences and technology skills. When they ask for help from the incubator, they want to get qualified specific services. Thus, tenant firms push the Caohejing incubator to develop broader network with external institutions (universities, public research institutions, specific experts, foreign venture capitals, etc.) if they themselves cannot meet the demand of clients. The wide network helps the Caohejing incubator hold a strong capability in pooling resources, consulting and funding.

Moreover, the Caohejing incubator is located in a science & technical industrial park where it has formed an export-oriented industry clustering. Many foreign multinational companies conduct large-scale manufacturing productions there. The possibility of spillover effect from multinational firms may attract more technology-based ventures with scale production potential to reside in the Caohejing incubator. In fact, foreign and domestic technology-based tenant firms have displayed higher sales incomes than those in the Chongqing incubator. The higher economic income may result from more hi-tech inputs and larger scale production. Longer open history, sustainable political and economical supports from the government and continuous foreign direct investments promote the regional innovation competence of Shanghai. The specific context contributes to the development of the Caohejing incubator and its tenant firms.

Finally, the Chongqing incubator privileges the fostering of domestic technology-based firms for upgrading endogenous innovation capabilities, whereas the Caohejing incubator gives preference to both foreign and domestic (mixed) technology-based firms for high-tech industrialization.

Section 3.3 Cross-nation comparative study on university incubators

China and France have been influenced, as many other countries, by the successful stories of U.S. university incubators. Both countries have implemented policies to foster science-industry relations and regard university incubators as an important means for turning academic research achievements into technology-intensive products/services. In this section we compare and assess the respective performance of Chinese and French university incubators at a general level but also sample a university incubator in both countries by adapting Mian's assessment approach (1997) to our analysis. Section 3.3.1 analyzes the context of university incubators' emergence in China and France. Section 3.3.2 assesses the similarities and differences existing between both systems and provides some explanation concerning the performance differences. Section 3.3.3 samples the Chongqing University and Alsace University incubator (SEMIA) to make a comparative study in terms of management and operational policies, services and performance outcomes.

3.3.1 Background of university incubators in China and in France

The R&D system in France and in China has been centralized and mission-oriented since a longtime. A specific institution undertakes the large part of fundamental research, like CNRS (national center for scientific research) in France and CAS (Chinese Academy of Sciences) in China. Public research centers and universities in France have not been forced to move downstream toward the market and to become technological entrepreneurs until the 1970s (Chesnais, 1993). In China, the centralized planning economy blocked science-industry interactions for a very long time. New institutional settings were structured to encourage science-industry linkages from the 1980s. Since the late 1990s, the legislative frame in France and in China allows universities to create incubators for commercializing academic technology. The initiative of university incubators in both countries aims to strengthen university-industry linkages and capitalize public research results towards the society.

3.3.1.1 The emergence context of Chinese university incubators

The establishment of Chinese university incubators was initialized by the adjustment of a national development strategy launched in the 1980s. The Chinese S&T system, based on the Soviet Union model, contributed to the formation of comparatively complete S&T organizations and infrastructures as well as some great achievements, like developing atomic and hydrogen bombs and launching satellites in the 1960s -1970s. But the command oriented S&T system hampered the interactions between industries and academics. Research and production activities were conducted separately and controlled tightly by the central government. Industries and academics enacted R&D activities on the basis of a centralized plan rather than market demand. The rapid development and wide application of the Internet, the computer, biotechnology and other high technologies in the late 1970s further enlarged the S&T gap between China and developed countries. At the same time, the open policy made China aware of the gap and the importance of S&T innovation to revitalize the economy. Several policy actions have been taken to integrate the R&D system with the economy system, aiming to overcome the separation problem of production and research (Huang *et al*., 2004):

- Adjust funding allocation mechanism: program-based competition funding instead of planned appropriation
- Cut down government grants to push the R&D institutes to exploit the market with their S&T findings
- Create a "technology market" to legitimize paid transactions for technology and establish the agencies to support the transactions
- Reorient S&T structure: smash "vertically and horizontally distributed power" among a large number of research institutions, universities and governmental sectors and strengthen university-industry-public research organizations linkages
- Upgrade agriculture technology and facilitate technology diffusion toward the rural area through the Spark Program[95]

[95]The Spark Program: It was formally implemented in 1986. The major task of the Spark Program is to rejuvenate the rural economy by relying on science and technology, popularize advanced and

- Promote the autonomy of R&D institutions and mobility of the S&T personnel
- Encourage R&D institutions to be incorporated into enterprises.

The above measurements seem to give a good remedy to activate isolated university-industry linkages. However, university and industry are not accustomed to playing the game under a market mechanism. Some research staff suffers from the radical institutional changes which offset part of the achievements resulting from the S&T system reform. Moreover, uncertainties due to technological innovation, inexperience of users and underdeveloped market institutions lead to the failure of technology market (Gu, 1995). The merging of R&D institutions into firms proves to be harder than expected because it is difficult for inexperienced enterprises to incorporate an appropriate R&D institute (Greeven, 2004).

Since the measurements seemed not to root out former routines which had insufficient university-industry cooperation, the Ministry of Science and Technology (MOST) enacted an institutional innovation by launching the Torch Program[96] in 1988, which provided a supportive institutional context for technology transfer through the creation of incubators. University incubators are under the umbrella of the Torch Program to nurture new technology-based ventures.

The first Chinese university incubator was created in a completely decentralized way and not in the frame of an existing public policy. North East University, located in Shenyang, was the first one to establish a university science park in 1989. The aim of the university science park was to compensate the sharp cutting-down public budgets from

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applicable scientific and technological findings in the rural areas and lead the township enterprises to develop in a healthy way.

[96]The Torch Program: Launched in August 1988, Torch Program is China's most important program of high-tech industries. As a guiding program of China, it includes: organizing and carrying out projects of developing high-tech products with high technological standards and good economic benefits in domestic and foreign markets; establishing some high-tech industrial development zones around China; exploring management systems and operation mechanisms suitable for hi-tech industrial development. The program mainly includes projects in new technological fields, such as new material, biotechnology, electronic information, integrative mechanical-electrical technology, and advanced and energy-saving technology.

the government, by creating university-run firms. Seeing no disapprovals from the government, other universities successively established their science parks and incubators. Pushed by the bottom-up spontaneity and the target of developing hi-tech industries, the State Council disclosed the regulations on accelerating the commercialization of S&T findings in 1996 and the "determination on strengthening S&T innovation, developing high technology and industrialization" in 1999, manifesting the government's approval and support towards the development of university science parks and incubators. According to the laws, academic professors are authorized to leave their jobs for two years and create technology-based ventures based on university research achievements in university incubators. Some non-academic entrepreneurs, hoping to get an easy access to university resources, choose to accommodate in university incubators (UIs).

Another reason, which pushed government policy-makers to support the development of UIs in the late of 1990s, arised from China's dependency on foreign technology imports and stronger intellectual property rights protection from developed countries. University incubators along with other technology-based business incubators[97] are expected to be a part of national and regional innovation systems, targeting to improve China's endogenous innovation capability. In 2005, there were 534 technology business incubators (TBIs) in China and university incubators represented 9% of the total (see Table 3.6).

Table 3.6: Characteristics of technology business incubators and of university incubators

	2002		2003		2004		2005	
	TBIs	UIs	TBIs	UIs	TBIs	UIs	TBIs	UIs
Number of incubators	378	58	431	58	464	46	534	49
Incubation area (10000m2)	632.6	145	1358.9	578.4	1515.1	485.3	1969.9	500.5
Number of tenant firms	20993	2380	27285	4100	33213	5037	39491	6075

[97] Technology-based business incubators: The first technology-based business incubator was created in Wuhan in1987. Since China concentrates on technology enterprises, few incubators are set up to address social issues. Tianjin and Zhejiang have created incubators for laid-off workers, independent of Torch Program (Lalkaka *et al*., 2003).

Number of staff in tenant firms	363419	51576	482545	70855	552411	69644	717281	110240
Number of new entrants	7635	867	8792	1099	8933	1156	9714	1213
Cumulative number of graduated firms	6207	720	8981	584	11718	1256	15815	1320

Source: data collected from the Ministry of Science and Technology website 2006 (http://www.chinatorch.gov.cn/yjbg/200610/101.html;http://www.chinatorch.gov.cn/yjbg/200610/102.html

Due to failure in an annual performance evaluation organized by the Ministry of Science and Technology, some university incubators lost their state-level label which led to a decrease of university incubators: from 58 in 2002 to 49 in 2005. The occupied incubation surface per tenant in UIs was larger than the average level in technology business incubators but the former created less employment than the latter, except in 2002. UIs incubated more firms than TBIs on average from 2003 to 2005 and the number of new coming firms per UI surpassed that of per TBI since 2004. It seems that more and more firms are interested in accommodating in UIs rather than in other TBIs and the intensity of high-tech tenant firms in UIs is higher than the average level of TBIs. However, in terms of cumulative graduated tenants per incubator, UIs were lower than the average level of TBIs, except in 2004. This difference might be explained by a cumulative 20-year experience for TBIs. UIs at a national level only have 5 years of history. In sum, being specific hi-tech business incubators, UIs will continue attracting clients who want to benefit from the university physical and human resources. At the end of 2005, 50 national UIs have been set up. The official statistics available on the MOST website focus on 49 UIs instead of 50. This might result from the unavailable information on the 50^{th} one. We hereafter use the data on the 49 national UIs.

3.3.1.2 The emergence context of French university incubators

The creation of university incubators in France is linked to the challenges faced by the French public research system. The French public research system consists of public research institutions, universities and *the grandes écoles* (engineering schools, business schools). During the 1970s-1980s, unlike the CNRS's (National Centre for

Scientific Research) own laboratories, the university laboratories (even those “associated with CNRS” status) have not been granted the EPST (Etablissements Publics à Caractère Scientique et Technique) status which hampered them to establish R&D contracts with the industry. The laboratories of the Grandes Ecoles were much better endowed than those of the universities and their relationships with the industry were naturally much stronger than university-industry linkage, although the laboratories were nearly empty (Chesnais, 1993). The absence of an incentive mechanism to develop the interactions between academia and industry was the main obstacle to the French public research system (Llerena *et al*., 2003).

At the end of the 90's, the French State created a powerful public research system. Some agencies and institutional mechanisms have been set up for technological diffusion, like ANVAR (Agence Nationale Pour la Valorisation de la Recherche), which manages a portfolio of patents and finds industrial partners for CNRS and university laboratories, the CRITTs (Centre Régionaux d’Innovation et de Transfer de Technologies), which are joint venture organizations with private and public (mainly regional) financial participation, and finally all those which are responsible for enhancing regional innovation-related networks between laboratories, firms, and local governments (Chesnais, 1993). However, the connections are inadequate between the research and the technology systems.

France has had many difficulties in creating a system of intermediation between the research and the economic world. The inadequate connections between the research and the technology systems were explained by different reasons: few researchers from the public system moved towards industry; there were a limited number of joint laboratories between public research and industry, and researchers from the public sector had no incentives to diffuse their results as the effort devoted to those activities were not recognized and valued in their careers.

To address these problems, the French government set up an innovation law in 1999. Its main aim is to enhance university-industry linkages and to accelerate the transfer of public research results towards the society. In the context of the innovation law, the government also launched the “incubation and seed capital for technology-based firms” program, which authorized universities, grandes écoles and public research organizations (PRO) to create incubators. The objective is to foster the creation of innovative technology-based companies which are able to commercialize the research potential of public laboratories. The new start-ups supported by this initiative should be innovative, based on public research results and should have a high potential of economic growth and job creation. This incubation program is also a means to coordinate relations and actions among the different research actors at the local and regional level. To be selected, the incubator should be a joint project between universities, PRO and Grandes Écoles. The implementation of incubators should also stimulate public research actors to establish "Technology Transfer Offices" (cf. Innovation Law).

Like Chinese regulations, the French innovation law encourages researchers to take part in high-tech start-ups and they can leave universities or PRO to create their own companies. Researchers can keep their original positions for 2 years in general. If the start up fails, they are allowed to go back to universities or PRO. When researchers declare research results to universities, TTOs assess whether they need to file for patents and how to transfer the results of their research. If TTOs propose inventors to create start-ups in university incubators, property rights should be identified between universities and inventors. In France, such start-ups are usually intellectual property-based spin-offs. Universities do not manage and invest money in spin-offs.

According to Castellani (2006), the number of university incubators dropped from 31 to 28 between 1999 and 2005. One incubator failed, two incubators merged and one was restructured. During that period, 28 incubators hosted 1415 firm projects. 45% were based on public research results, 52% were external to public research but were linked by collaborations with public research labs. Only a very small part of the projects, namely 4%, emanated from private research. From that point onwards, French UIs acted as a basis for commercializing science & technology findings. Up till 2005, 1415 projects have been incubated and 844 companies have been created, among which 746 (88.4%) still survive and employ 3560 staff (4.8 employment/active firm). 22% of the project creators come from universities and 13% from public research organizations. The 28 incubators have contributed to the creation of 160 innovative enterprises per year on average.

3.3.2 Comparison between the university incubation system in China and in France

The objective of this section is to compare Chinese and French university incubators along the different dimensions borrowed from the literature review. Based on Mian's framework, we organize our analysis around three sets of variables: (i) the management and operational policies of incubators (governance, funding of UIs and new ventures, selection and graduation), (ii) services, and (iii) performance outcomes.

We would first like to emphasize the fact that the central government is directly involved in the implementation and the monitoring of university incubators both in China and in France: university incubators are non-profit organizations, highly based on public funding and their function is to foster new high-technology ventures, commercialize academic research outputs, with the ultimate goal of creating jobs and wealth. In a more conceptual point of view, the economic justification behind incubators might be related either to market or to systemic failures. Market failures are linked to property rights problems, moral hazard and imperfect information on the capital market.

Chinese and French universities are allowed to file for the patents of public supported research findings since the late 1990s. The market for trading university patents and licenses is not as active as in US, where the Bayh-Dole Act was implemented in 1980. This partially leads to the creation of intellectual property-based start-ups when licenses cannot be delivered directly to the industry. In the case of university technology licensed through technology market, the probability of moral hazard from the licensee or licensor hampers the successful execution of technology transfer. Asymmetrical information on demanders and suppliers of funds hinders financial investors to put money in new ventures, especially in an undeveloped financial market, like China. New ventures are often very small and short of cash-flows. Fund lenders are reluctant to give loans to them because of the uncertain market prospect of new ventures. Lack of knowledge about new ventures also creates barriers for lenders to lend money to new firms. For new technology-based venture, to keep technical or business secrecy, they hesitate to disclose full information to lenders which may influence the lender’s loan decision. Systemic failures are due to the lack of coordination and networking of actors in the innovation system but also to difficult access to complementary resources, knowledge and technologies. The main idea developed in this part is that UIs should help overcome these barriers, and thus reach a higher level of performance, by implementing an effective management system and by providing appropriate services.

Like many European countries, French and Chinese university incubators depend mainly on public funding. In France, the central government provides funds, but is also in charge of the follow-up (collects data from the different incubators) and monitors the whole incubation program by defining the strategy, the general orientation of the program and by organizing workshops for the incubator directors. Since 2004 the Regional Direction for Research and Technology (DRRT – they are in charge of executing the national policy within Regions in terms of research and technology) are part of the incubators, thus ensuring a closer follow-up from the State. In China, the local governments are directly involved in financing university incubators whereas the central government acts as a policy maker and a supervisor for university incubators at the national level. The support of central government for UIs focuses on tax breaks. The Ministry of Science and Technology and the Ministry of Education take the responsibility of making policies and development plans for national university incubators, and evaluate their performance every 3 years on the basis of statistics collected by mandated investigation agencies and statistics submitted by incubators themselves. Unqualified incubators should improve their operation in a given period. Otherwise, their national title will be cancelled, including a series of preferential policies. In this part, university incubators refer to the ones at state level. Here we should mention that the French Innovation Law in 1999 requires UIs to privilege the incubation of public research output-based projects and of projects which commercialize industry research findings. The legislation guarantees that UIs nurture new technology-based ventures. In China, recent rules underline that over 50% tenant firms should have an actual linkage with university technology, research findings and human resources. It means that tenant firms without such a university linkage can be accommodated in UIs. This is associated with the huge incubation surface of Chinese UIs, constrained funding and the objective of nurturing more technology-based ventures to realize industrialization.

3.3.2.1 The management and operational policies of incubators

In this part we characterize the Chinese and French incubators in terms of governance structure, funding system, selection, graduation procedures and duration.

Governance structure

In China, university incubators, at the macro-level, are under the direction of the central government, namely the Ministry of Science & Technology (MOST) and the Ministry of Education (MOE). But at the micro-level, they are governed by universities and local governments, sometimes including firms. These founders and funding institutions send their representatives to organize a board of directors, which designs the development plans and policies: entrance and exist criteria for tenants, budgets and personnel recruitment of UIs. Under the board of directors, a management committee and an administrative office are usually set up to carry out identified policies. The former mainly represents the UI to interface with universities and communities, monitor incubator staff and manage the construction plans in the incubator. The latter is in charge of daily operations: interacts with clients, provides external funding access and maintains physical facilities. The selection of tenant firms is organised within the incubator. Outsourcing experts is a common practice to assess the business plans.

In France, the governance of incubators is guided by the Ministry of Higher Education and Research (MHER). Public research organizations and higher education institutions (universities, engineering schools etc.) are the main founders of incubators (sometimes private firms are part of them). The board of directors (or the like) governs the organization, the management and the functioning of the incubator. It is composed by members of the founders and by funding institutions. It votes the budget, chooses the president, the treasurer and appoints the director. The director ensures the functioning of the incubator and reports to the board of directors. A selection and follow up committee is created within the incubator and consists of the founders, the different funding institutions such as OSE Anvar (a public organization devoted to support and fund innovation in SMEs, somehow similar to Chinese Innovation Funds), people from the industry, banks, and venture-capital. It selects the projects, is informed about their evolution and provides advices. The decision of this committee has sometimes to be validated by the board of directors. The managing team is often lightly staffed: on average, incubators employ 4.8 persons. Directors usually complain that the lack of budget forbids employing additional persons needed to support incubation activities.

In general, the management team in Chinese university incubators is bigger than in their French counterparts because of their impressive larger size. Despite some investment from firms, the incubator is mainly managed and governed by university representatives and government officers in China whereas more external professional persons get involved in the management and governance of French university incubators. Voluntary mentoring organizations, which are composed of retired industry experts, ex-tenants and post-tenants, transfer know-how and help French new ventures to learn from the mistakes of more experienced business people (CSES, 2002). Compared to its French counterpart, the Chinese society lacks voluntary organization culture and people get used to being organized to take actions. These routines are deeply influenced by the long-term centralized planned economy.

Funding system of UIs

Due to unavailable statistics on how much funds from the Chinese government are invested in university incubators, quantitative comparison with the French case is difficult. However, the literature underlines that the local governments contribute a lot to the creation of university incubators in terms of free land and initial funds. Besides, the development of UIs is integrated into the regional economic development plan. The local governments' yearly budgets are required to cover a part of financial resources to support the development of university incubators. For instance, municipal Bureau of S&T and Bureau of Education establish a specific fund for financing UIs. The central government allocates a very small amount of money to the incubators through the Torch Program. In addition to the main support from the local governments, universities are the other important funding institutions. Sometimes, bank loans are very accessible at the early stage of the incubator construction. Once the UI is established, financial supports seem to principally depend on the incubator's self-management income. However, the Chinese UIs get very few service incomes so that they tend to host firms without university linkage for self-sustaining.

In France, the central government can compensate 50% at maximum of the university incubators' internal and external expenditures (personnel expenditures, overheads, exploitation of incubators and expenses specific to incubated projects). A three-year contract between the incubator and the MHER determines the number of firms to incubate and the funding allocated by the State (Bussillet *et al*., 2006). Other funds come from local governments (Region, Department) and from the European Union. Between 2000 and 2003 the central government allocated 25.54 M€ for 964 projects in 31 incubators (26.5 k€ per incubated project). During the second phase (2004-2006), the government allocated 19.6M€ to 28 incubators to incubate 776 projects (25.2 k€ per incubated project). Since 2004, the European Social Funds have been regionalized and incubators refer directly to the Region for funding (Castellani, 2006). Local authorities (Regions, Department, but also municipal governments) intervene in different domains: funding of incubators, participation in their governance, and funding actions related to the incubation process. Local authorities increasingly fund incubators and in some cases the contribution of the State does not exceed 25% of the incubator budget.

The above comparison displays that both local governments play an important role in financing the development of UIs. The French central government provides more funding to UIs than its Chinese counterpart. In addition, Chinese universities are another important financial supporter for UIs but not in the French case. However, French UIs can gain the European Union's financial support to compensate the blankness of French universities' investment.

Funding of new venture creation

In China, new ventures may benefit from different types of funding provided by a variety of actors:

1) From the MOST. With the assistance of university incubators, tenant firms can apply for Innovation Funds for Technology-based Small and Medium Enterprises (Innofund) given by the MOST, through a project competition selection. Innofund is used as a leverage to attract other investments to incubated firms. In 2005, firms in university incubators received 103 programs financed by the Innofund with 7 million €. The average

support from Innofund per project reached 76 961.2 €[98] which is lower than the financial support from the French National Competition for Creation of Technology-based Innovation Firms. Innofund is distributed through non-refundable, refundable basis or favourable loans.

2) From the local government actors. The local department of finance, bureau of S&T together with bureau of industry, commerce and tax get involved in the incubation process. These governmental actors are directly involved in pooling funds, identifying investments and channeling funds into new ventures. For instance, government-backed guarantee companies have been created to guarantee bank loans to local ventures (White *et al*., 2005). Tenant firms benefit from tax holidays, rental rates lower than market price, "one shop" administrative services and other preferential conditions given by the local governments. The graduated firms can continue to benefit from favorable tax policies. Compared to the French ones, Chinese tenant firms have an easier access to legal and registration services because of these administrative services available in the incubators.

3) Investors. Instead of the French government's direct support for new ventures at the early stage, Chinese universities play the critical role at this stage, providing seed capital for new ventures. During the incubation process, financial supports may come from domestic and foreign venture capital, regional and national Innofund. But the funds principally depend on self-collected funds and bank loans. Tenant firms get access to bank loans under the guarantee of local government agencies. Regional and national Innofund are very limited, and venture capital funds are rather difficult to obtain due to strict selection. After graduating from university incubators, tenant firms can benefit from local favourable tax policies and get financial support from the market.

Compared to their Chinese counterparts, French university entrepreneurs obtain financial support in a little different way.

1) From the MHER. Part of the funds coming from the MHER and going to the incubators is devoted to the incubated projects. These expenses are related to economic,

[98] 100 RMB = 10 Euros

industrial or commercial feasibility studies, services and advice provided by the incubator to the incubated company during the incubation period.

2) From the local authorities. They support actions related to the pre-incubation, incubation and post-incubation phases. Some Regions have developed in collaboration with OSEO Anvar[99] specific funds that support the maturation phase of promising innovative projects. An increasing number of Regions provide grants to the entrepreneurs. For municipal governments, the creation of hosting structures constitutes the main support: company "nursery", science parks etc.

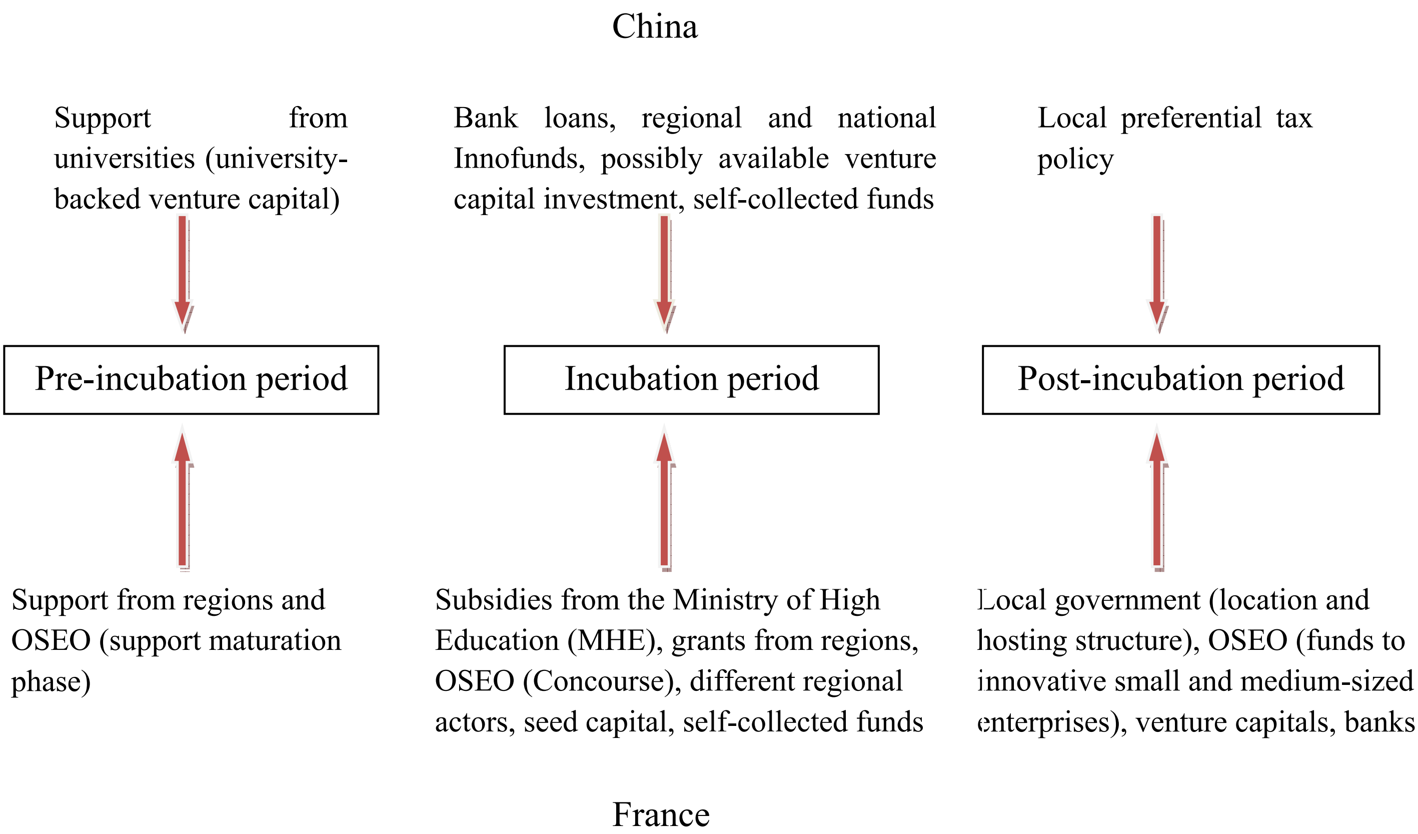
3) From other organizations, such as OSEO Anvar, European Centers for Entreprises and Innovation, Industrial and Commerce Chamber, "pépinières" ("nursery"), "technopoles", etc. Incubators belong to a regional network of actors that sustain innovation and firm creation. These different organizations may participate in the different governing board, provide external services to incubated projects, co-incubate projects, fund projects of firm creation etc.

4) Investors. The financial needs of a new company vary with its stage of development. Before the company is created, the entrepreneur needs to fund the capital of its venture, complementary scientific, legal, marketing analysis, develop prototypes etc. OSEO Anvar supports up to 70% of the external expenses linked to the demonstration of the project feasibility. The National Competition for Creation of Technology-based Innovative Firms (implemented by the MHER) provides a contribution to the capital (45 000€ on average) to help create the company. This contribution can be seen as a leverage effect to collect other funds. Despite these measures in 2005, 91% of the capital of the 844 created companies came from the entrepreneur (i.e. personal, family and friends), 4.7% from business angels, 1.3% from seed funds, 2.6% from venture capital and 1.7% from banks. During the creation phase, the firm will have to commercialise its product/service and increase its turnover. The National Competition for Creation of Technology-based Innovative Firms allocates 400 000€ on average to the winners. OSEO

[99] OSEO Anvar: it is a French public agency for technology transfer from government and university research laboratories to industry. It provides financial support and value added services to help the development of innovative small & medium-sized enterprises.

Anvar provides different types of funds for the development of SMEs. This phase also benefits from Seed-Capital Funds, created jointly with incubators, and from venture capital generated by national, regional and local venture-capital companies and by business angels. The funding for post-tenants is collected through regional capital investors and the financial market.

Figure 3.8: Funding system of new ventures in China and in France



Source: Matt and Tang, 2007.

Figure 3.8 shows that the governmental authorities play a critical role in supporting the incubation process both in China and in France. It also underlines the fact that a high proportion of the capital used to create new ventures originates from Chinese and French entrepreneur themselves. Venture capitals (VCs) play too little a role in the funding process, especially in early phases. Chinese venture capitals were initiated in the mid-1980s and most venture capitals are government-backed companies. The lack of exit mechanism in Chinese Stock Exchanges for venture capitals hampers VCs to invest in new ventures. French VCs emerged at the beginning of the 1970s and the sources of VCs principally come from investment banks and retirement insurance funds (Fung *et al.*, 2005). The French Ethics Commission prevents venture capitalists from taking a majority position in an academic-background venture (Llerena *et al.*, 2003). It may decrease the incentive for VCs to finance new ventures. Additionally, both funding systems are very complex. Given this complexity, the ability of incubators to help tenant companies find the appropriate source of funding becomes crucial. UIs should play the role of coordinating the external information on the funding system (actors, types of funds, application procedures etc.) and thus help reduce the high information asymmetry which exists in the system.

Detection and selection procedure, link with TTO, duration and graduation

In China, the selection is often organized within university incubators, focusing on the incubation project and tenant firm itself. The selection team is composed of incubator staff and external experts. The linkage between TTOs and incubators is not systematic. At the organizational level, some TTOs are directly subordinated to the management committee; others are in parallel with the incubator management level. Furthermore, TTO staff is not convinced of enough professional skills and the commercial potential of created projects may cause conflict between project founders, TTOs and incubators. Therefore, when selecting a business plan, incubators may not necessarily ask for the intervention of TTOs in the latter case. The selection criteria related to the incubated project are the following: belong to high-tech field, have intellectual property rights, be a mature technology with a commercial potential and produce environmental-friendly goods. Concerning the tenant firms, the selection criteria pay much attention to the legal status (clear ownership and independent economic entity), R&D activity and production orientation, the qualification of the project creator as well as the team members of the tenant firm. It also imposes an initial capital threshold to the incoming companies: a minimum requirement of registered capital, varying from 3 000€ to 50 000€. The average incubation period is no more than 3 years depending on the industrial sector, signed lease contract and incubation agreement. When asking for graduation, the firm should provide administrative documents such as: balance sheets, resource declaration sheets, management report and so on. On the basis of these documents and in-site investigation, the incubator identifies whether the firm should graduate, semi-graduate (one or two graduation criteria unattained), extend the incubation period or stop the incubation. Firms which graduate from the incubator should meet some exit criteria with respect to sales income, R&D expenditure and highly qualified team members. A graduated company will be entitled with "a certificate of graduation" and benefit from preferential tax policies provided by the local governments.

In France, the detection of projects coming from public research is essentially done by the technology transfer offices (TTOs) of the PROs/universities, with some help of the incubators in terms of information diffusion and training. TTOs also help the project mature. They negotiate the valuation contract between the PRO/universities and the newly created venture and provide incentives to researchers to create their companies. However, very few TTOs have an explicit or active valuation policy and conduct pro-active detection of projects. This constitutes a major limit in the system. The projects not directly issued from public research but linked to it are detected by different actors such as OSEO Anvar, European Centers for Entreprises and Innovation, "pépinières", "technopoles", Chambers of Commerce and Industry etc. The role of incubators is to create links and collaborate closely with these important actors. The incubator organizes a first selection, which can last 2 to 6 months. The selection is done by the Committee of selection and follow-up. The core selection criteria are the following: innovativeness of the technology (competitive advantages linked to the technology), the degree of maturity of the technology (mature enough), visibility of a market potential and intellectual property (free to exploit the technology). Another selection criterion privileges projects coming from public research labs or linking with public research findings. Each selected project signs an agreement with the incubator that specifies the role of each actor, the services provided by the incubator, the modalities of reimbursement of expenses supported by the incubator, the duration of incubation etc. The average incubation period in France is 16 months. There is no formal graduation assessment of companies wanting to exit the incubators. The exit is validated by the end of the contract or by the signature of an exit contract. Exit is sometimes validated by the selection and follow up Committee. In sum, the pre-assessment of TTOs and strict selection process prevent UIs from attracting firms without the purpose of converting S&T findings so that the initial aim of UIs has not been biased.

It seems that the selection and graduation criteria in Chinese UIs focus on high-tech property of tenant firms rather than the source of tenant firms' technologies. For French UIs, they underline the technology linkage between universities and tenant firms. French start-ups enter the incubator at an earlier stage than the Chinese ones. French innovators use the incubation stage to create the company (capital, legal status, production plan etc.) while Chinese start-ups are closer to the creation stage (capital creation requirement). French start-ups leave the incubator at an earlier stage and go to "pépinières" (or company "nursery") that will provide additional material services for one or two more years. The Chinese incubation system seems to correspond to the French incubation plus the "pépinières" one. This largely explains the difference in terms of incubation period between both countries.

In both countries, the link between the TTOs and the incubators should be tightened in order to ease the technology transfer procedures and to help the tenants develop the technology. A more pro-active action of TTOs in collaboration with the incubator could also improve the detection of valuable projects.

3.3.2.2 Services

The Chinese and French university incubators provide different types of services: access to physical resources such as office space, common meeting hall, IT infrastructure; business operation support services such as secretarial and mail services, security systems, firms registration; access to capital, including seed money, venture capital, etc; business development support such as mentoring, coaching, consulting but also legal advice and book-keeping; networking services such as contacts with customers, collaborators, and potential investors. In spite of similar services, the quantity and quality of services provision is different between the Chinese university incubators and the French ones.

In the Chinese UIs, most incubation services remain at the infrastructural and administrative dimension, like physical space, facilities, building maintenances and firm registration (Zhang *et al*., 2004; Sun *et al*., 2005). UIs have developed the networking at different levels: city-based, regional-based, national-based and international-based level (Wang, 2003). The aim of the network is to build a know-how transfer platform, pool resources, systemize incubator management and promote the development of incubators. Various incubators, investment institutions, lawyers, firms and intermediary agencies are members of the network. Some incubators have signed twin-sister agreements for closer interactions. However, follow-up and network services for tenant firms are not actually widespread, except for top level university incubators, like Tsinghua UI. Academic entrepreneurs tend to develop personally informal and formal contacts with sponsored universities, which hinder the development of UI network. Qualified business support services are insufficient only now being recognized. The services that are provided in UIs are typically not on a cost-recovery basis. Tenant firms boycott payable services because of constrained cash flows on one hand, and the concept of market economy seems not to have been totally rooted in clients' mind on the other hand. Besides, working staff in UIs is generally composed of civil servants who have little or no entrepreneurial experience. This limits their quality and sustainability (Lalkaka, 2003).

The French university incubators are aware of the real needs of tenant firms and use internal and external resources to support them. Intra-firm networking is sometimes encouraged by incubator management, sometimes spontaneously, for information exchange and potential cooperation between tenant firms. Specialist advisory services, such as legal and patents advice, capacity-building, and entrepreneurship development programs, are provided by a network of external consultants (CSES, 2002). The French UI managers usually hold commercial experiences and emphasize the establishment of a broad network which helps tenant firms obtain easier access to external resources. It is very common for the incubator staff to get engaged in the management of tenant firms. It appears that the clients either trust the incubator management to protect their technologies or do not consider such protection necessary at the early unproven stage (Mian, 1996). However, the incubation surface of UIs is small and sometimes cannot provide enough space to tenant firms.

University incubators in China and in France provide a diversified set of services, ranging from basic infrastructure to value-added services. Chinese tenant firms enjoy "one shop" administrative services and sufficient incubation space whereas French tenants complain that they have to spend a lot of time on dealing with these complex services and sometimes have insufficient residency space. However, incubator management in the French UIs with entrepreneurial experience is helpful to maintain the quality of specific business support services and explore the network with external actors. The quality of incubation services in the Chinese UIs is challenged by internal management skills, narrow network and tenant firms' persistence to payment. Hence, the Chinese UIs should employer skilled managers, improve follow-up services and develop the established network to meet the real demand of tenant firms. The French UIs should simplify the administrative services and enlarge the incubation area to host tenant firms.

3.3.2.3 Performance outcomes

In this part, we briefly look at some outcomes which characterize the performance of both systems. The first criterion focuses on the location and then the potential impact on the local community. The second set of variables focus on the number of incubated companies, the number of jobs created, the sectors, the high-tech nature of firms etc.

Location

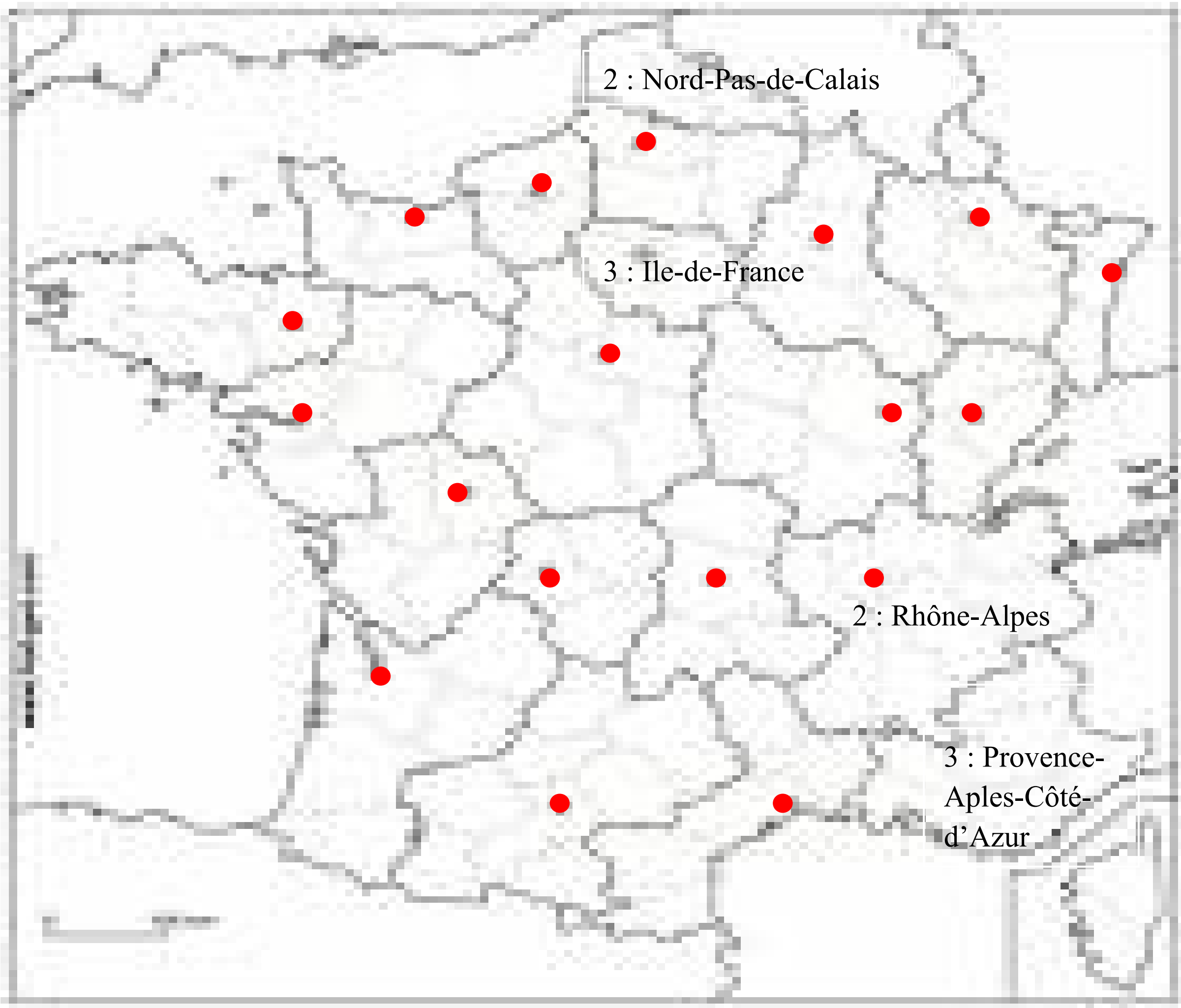
In China, the Ministry of Science & Technology and the Ministry of Education play a key role in determining the location of university incubators. The Chinese UIs are usually located around or on university campuses. If a region has more than a research university, it is not surprising to find two or more university incubators there, like in Beijing and Shanghai. In general, the distribution of national university incubators is associated with the location of Chinese top leading universities. Even though the incubators spread almost all over the country (23 regions), most of them are located in well economically developed regions with important research resources (see Figure 3.9): Beijing(9), Shanghai(6), Sichuan (4), Shanxi (3), Jiangsu (3), Ha'erbing, Liaoning, Tianjin, Shangdong, Zhejiang, Guangdong, Chongqing (2 respectively). Encouraged by the achievements of some incubators, a new development plan is designed to reach 80 university incubators until 2010 with a surface of 10 million square meters, aiming to incubate 15000 hi-tech ventures.

Figure 3.9: Distribution of 50 national university incubators in China

Source: by the author herself
Note: the red point represents the region which has a national university incubator.

In France, between 2000 and 2003, the MHER with the Ministry of Economy, Finance and Industry and the State Secretariat of SMEs selected 31 incubators that were implemented in different French regions and they sustained 964 incubation projects (100 projects more than expected). In 2003, the MHER evaluated each incubator and decided to renew its support to the 28 incubators for the period 2004-2006. The objective is to support 776 new projects. A new phase should be implemented for 2007-2009. All the public research actors of a same region, namely universities, public research organizations, engineering schools and business schools, coordinate their actions to create a unique incubator (there are 22 Regions in France, see Figure 3.10). However, in some large regions with a high concentration of public research institutions more than one incubator has been set up: Ile-de-France (3), Nord-Pas-de-Calais (2), Provence-Alpes-Côté-d'Azur (3) and Rhône-Alpes (2).

Figure 3.10: Distribution of 28 French university incubators



Source: by the author herself
Note: the red point represents the rest of 18 regions which a university incubator respectively.

In comparison to the location of French UIs, 60% of the Chinese UIs concentrate in the east of China. Given that the Chinese UIs succeed in commercializing academic research outputs, the development of new ventures would create more wealth and jobs in the east regions which are richer than the other regions of China. The unbalanced distribution of UIs may increase the already existing economic gap between the East and the West. In France, there seems to be a willingness to spread the potential impact of UIs on the entire territory.

Outcomes

Table 3.7: The development of university incubators in China and in France (2002-2005)

Item	2002		2003		2004		2005	
	C*	F*	C*	F*	C*	F*	C*	F*
Number of university incubators	58	30	58	29	46	28	49	28
Number of tenant firms*	2380	635	4100	964	5037	1139	6075	1415
Number of staff in tenant firms in China and active firms in France*	51576	1854 (267)	70855	2665 (426)	69644	3126 (566)	110240	3560 (746)

Source:http://www.chinatorch.gov.cn/yjbg/200610/101.html and bureau DTC2, France
Note: C* hereafter refers to Chinese university incubators. From 2004, university incubators refer only to the state-level ones. F* refers to French university incubators. Number of tenant firms*: it means the number incubated companies. The number within ()* represents the number of created active French firms.

The number of Chinese UIs dropped from 58 in 2002 to 50[100] in 2005. However, the number of tenant firms and the number of staff in tenant firms kept an upward tendency. Over 2.5 times new ventures were created in 2005 in comparison to those in 2002 and these new ventures doubled job employment. However, the average job creation per tenant firm decreased from 22 jobs per tenant in 2002 to 18 jobs per tenant in 2005. New ventures might become more technology oriented than before. The accommodation capacity is different among Chinese UIs. The Shanghai Jiaotong University incubator incubated 645 tenant firms, accounting for 10.62% of the total new ventures. There were 21 Chinese university incubators which held over 100 tenant firms. Among the 6075 tenant firms, only 1746 were assessed as hi-tech firms (28.74%) and 63.57% of these hi-tech firms were created by university professors and students. It seems that Chinese UIs do not implement the selection criterion strictly. Non technology-based ventures are hosted in parallel with technology-based ventures. Chinese UIs nurture not only academic ventures but also those without university linkage which need the favorable environment provided by UIs.

The number of French UIs remained rather stable, around 29 during the period from 2002 to 2005. Similarly to their Chinese counterpart, the French UIs increased the creation of new ventures and jobs. The creation of new ventures was 2.2 times more important in 2005 than in 2002. These ventures provided 1.9 times more jobs. The

[100] In 2005, the total number of national university incubators was 50 in China. But the statistics is only available on 49 such incubators.

average job created by each new venture dropped from 2.9 in 2002 to 2.5 in 2005. It might be linked to more technology input into tenant firms which decreased the demand of manpower. With respect to hosting capacity, the majority of French UIs never hosted 100 new ventures, except for the Créalys incubator in Rhône-Alpes which had 142 tenant firms. Concerning the type of venture entrepreneurship, university entrepreneurs accounted for 22% of the total. However, most tenant firms are engaged in innovative activities. There are 32 created firms in human and social sciences and services. The remaining 812 firms (96%) are involved in hi-tech fields, such as life science and biotechnology (36%), ICT (33%) and engineering technology (27%).

In general, Chinese UIs are larger in size in comparison to their French counterparts. In 2005, Chinese UIs hosted 4.3 times more tenant firms than the French ones. Concerning employment, the statistics are not directly comparable: Chinese figures provide the employment of incubated companies and French statistics underline the employment of created active firms (some of which are not incubated anymore). In China, 18.15 jobs were created per tenant while in France the created active company employs 4.8 persons on average. This may be explained by the fact that French incubated start-ups concentrate more on hi-tech fields than Chinese ones. Actually, 96% of new ventures in French UIs got involved in hi-tech domains whereas only 28.74% of the total were involved in Chinese UIs. The high rate of hi-tech ventures in French UIs can be explained by the French Innovation Law (1999) and the limited incubation surface. The law underlines the fact that UIs should privilege incubation projects linked to public research findings. Limited incubation surface does not provide space for French UIs to host non hi-tech tenant firms. Chinese legislation does not strictly highlight the linkage between the academic world and new ventures. The recent rules require at least 50% of the tenant firms in UIs to have actual linkages with universities in terms of technology, research achievements and human resources. However, when the occupancy of incubation space in UIs is low and self-sustainability depends on building rentals, UIs have to host non-university linkage firms and less technology-based ventures. In fact, former university-affiliated firms are hosted in UIs which are not necessarily hi-tech ventures. The accommodation of less technology-based ventures seems to be against the initial objective - nurturing hi-tech ventures and commercializing S&T findings. However, the access to university frontier technology may transform non high-tech tenant firms into high-tech ones. Thus, the overall innovation capabilities of domestic firms would be probably improved. To sum up, Chinese UIs take the responsibility of building-up endogenous innovation capabilities of domestic firms.

The survival rate[101] of firms in French university incubators reached 88.4% on average at the end of 2005, whereas in China the average rate was not available. Some best practices of incubators keep a high survival rate, like the Tsinghua University Incubator, reaching over 90%. The reasons emanate from a lack of sufficient funds, coaching service and network communications (Zhang *et al*. 2004). In spite of unavailable statistics on incubation surface in France, after our in-site visits and interviews with two French university incubators (ESTIA incubator in Biarritz and SEMIA in Strasbourg), the average university incubation area per tenant firms is assumed to be smaller in France than in China. For example, SEMIA (Alsace University incubator) in Strasbourg cannot provide enough room to accommodate all tenant firms and has to look for space outside the incubator. By contrast, Chinese university incubators provide sufficient space to not only very small ventures but also to some firms which have a potential capacity of a large-scale industrial production.

3.3.2.4 Synthesis of the comparison

Table 3.8: Synthesis of the comparison on university incubators in China and in France

	Chinese University Incubators	French University Incubators
1 Management and operational policies		
Objective	Nurture new high-technology ventures /Commercialize academia research findings/Create jobs	
Nature	Non-for-profit organizations - Government-sponsored - Co-implemented by government and university	
Governance	Central government directly involved in implementation and monitoring; Governed by universities, central and local government, other investors; Board of Directors - Selection Committee	
	Management team rather large Management Committee: interface between universities and community	Management team rather small
Sources of funding of	Universities, local government (free land and initial fund)	Central government (max 50%), local government (increasingly),

[101] The survival rate: according to the French definition, it is measured as the percentage of small and medium enterprises (SME) start-ups which remain in business for longer than a 5 year timeframe (CSES, 2002).

UI		Europe
Funding of new ventures	Very complex system with many potential funding institutions at different level; High proportion of created venture capital comes from entrepreneur themselves; Weakness of venture capital system especially at early stages; Public funds used as a leverage to attract other funds	
	Critical role played by universities at early stages of firm creation	Critical role played by government at early stages of firms creation
Selection	To hold IPR with market potential - To have a qualified entrepreneurial team	
	Requirement of minimum initial capital; Develop environmental-friendly products; To be active in the fields supported by UI and municipality; To be engaged in R&D and manufacture high-tech products	Projects issued from public research; Degree of maturity of technology; Innovativeness of the technology
Duration	no more than 3 years on average French incubation period + "firm nursery"	16 months on average (big variability between incubators
Graduation	A series of formal criteria determined by local and central government	No formal graduation – Exit validated by the end of the contract (sometimes by the selection committee)
Link with TTOs	No systematic link Detection of projects (sometimes)	Detection of projects Help projects to mature Negotiate the valuation contract between PRO and new venture => Few TTOs have active valuation policies
2 Services		
	Physical resources, business operation support, access to capital and investments, mentoring, coaching, consulting, legal advice, book-keeping, networking services (customers, universities, investors etc.)	
	Emphasis on building and administrative services Networking not well developed Few services which focus on competitive advantages	Good quality and variety of services Emphasis on networking
3 Performance outcomes		
Location	Concentrates in economically developed regions On or around university campuses	One incubator per region Around universities and PRO, not necessarily in one building
Outcomes	124 firms/incubators 18.15 employees/incubated firms Incubated ventures less high-tech Lower survival rate	50 firms/incubators 4.8 employees/created ventures Incubated ventures more high-tech Survival rate: 88.4%

Source: Matt and Tang, 2007.

Table 3.8 shows that Chinese and French university incubators have similar features in terms of objective, nature and governance. Both Chinese and French governments contribute to university incubators in terms of financial support and management, and both countries have a very complex system for funding new ventures that is characterised by the weakness of venture capitalist and the important role played by personal funding.

The main differences are to be found in the selection criteria, the duration, the graduation, the link with TTOs and the services. These differences somehow explain the difference in terms of outcomes. Actually, in Chinese UIs the services are more oriented towards building and administration support and less towards networking and value-added services which guarantee competitive advantages. The services are less professionalized as compared to France. In other words, the services provided by Chinese UIs have very little influence on the barriers linked to market and systemic failures, which could explain their lower survival rate. The selection criterion in France is much more oriented towards the innovativeness and the degree of maturity of the technology than in China.

Concerning the location of university incubators, Chinese UIs concentrate in the east costal regions. It might reduce the spillover effects and further broaden the existing gap between the wealthy east regions and the poor western regions. In France, the location of UIs is distributed all over the country. The French government seems to pay more attention to balance the economic development on the whole territory. With respect to performance outcomes, Chinese university incubators host more firms but less hi-technology oriented tenant firms than their French counterparts. Although 64% of new technology-based ventures are created by university entrepreneurs, they account for merely 18% of the total tenant firms. Most tenant firms in Chinese UIs are not high-tech ventures. One reason may be linked to insufficient applicable science outputs arising from Chinese university researches. The other reason may be related to the lack of entrepreneurial culture in the academic world. To occupy the huge incubation surface and keep self-sustainability, Chinese UIs have to accommodate non high-tech firms. These non high-tech firms may turn into high-tech ones because of tapping university frontier technology. The favorable environment in UIs facilitates the development of new firms whether they are originally high-tech oriented or not. From this point of view, Chinese UIs promote the innovation capabilities of domestic firms.

However, both systems could benchmark the good practices of the other in order to improve their incubation process. Chinese UIs should strengthen the links between the incubated projects and the university facilities, focus on more professional and value-added services that would increase the competitive advantages of firms, and help tenant companies establish and develop their networks of clients, investors etc. French UIs should develop physical space in unique places close to the universities and PRO for the development of incubated ventures and to favour the exchange of information between tenant companies. They should also work closer with TTOs to increase the potential number of projects issued from the academic sphere and to avoid problems linked to the valuation contracts that could block the transfer of technology. More generally, the complexity of the funding system and the institutional context in both countries should be rationalized. Many actors are involved at various levels of the incubation system and it seems very difficult for the incubated companies and even for the incubators to get the appropriate information in time. There seems to be a general lack of coordination between the different actors. If incubators might play a coordinating role, as it seems to be the case in France (and much less in China), their effort should be largely sustained by more national political actions (creation of unique offices in charge of funding procedures, network of incubators, common ICT platforms etc.).

3.3.3 Case studies: Chongqing University incubator and Alsace university incubator (SEMIA)

In this section, we use a case study to examine whether our above findings have a general significance in Chinese and French university incubators. The research methodology follows that introduced in section 3.1.2.2. We first briefly outline the background of the Chongqing University incubator and SEMIA, and then compare the sampled incubators on the basis of Mian’s (1997) assessment framework.

3.3.3.1 Background of two sampled incubators

The context of emergence of the Chongqing University Incubator has been presented in section 3.2.3.1. Here we focus on the background of the Alsace university incubator-SEMIA.

SEMIA was co-built by the University Louis Pasteur, other universities, grandes écoles and public research organizations in Alsace Region in 2000. The Ministry of High Education and Research, the Alsace Region and the European Commission are the main financial supporters of SEMIA. Over 90% incubated projects in SEMIA come from public laboratories or come from collaborations with public laboratories. 50% of the project creators are academic entrepreneurs.

SEMIA is located in different sites whereas the Chongqing incubator is much bigger in terms of incubation surface but located in one geographical place. Both the Chongqing incubator and SEMIA are non-profit organizations, aiming to commercialize academic research results, to create jobs and to develop the local economy. These two incubators receive students to do internships. Some Chinese tenant firms supervise student thesis and brilliant students are invited to participate in industry research projects. The mobility of students promotes knowledge and technology transfer between tenant firms and students: firms can get new ideas and knowledge from students; and students can get practical technology from firms. The Chongqing incubator finances and incubates student-based innovative projects on the basis of competitive selection. Since the student enrollment to high education institution was enlarged in 1999, the labor market has become more and more competitive. In 2005, 1.2 million students did not find a job when graduating from high education institutes, accounting for 35.5% of the total number of students who graduated. Self-employment is viewed as a way to solve unemployment. Chinese university incubators act as a catalyst for students in creating jobs. In Alsace, the unemployment was about 8.2% in 2005 and the job market is similarly not good for young graduate students with public university degrees. Hence increasing the chance to find a job by supporting the university incubator is one of the strategies used by the Alsace government.

3.3.3.2 Comparison of the incubation system in sampled incubators

In this part we compare the Chongqing University incubator and SEMIA in terms of management structure, services, selection, graduation procedure, duration and performance outcomes.

In terms of management, the management structure in the Chongqing University incubator appears more complicated than in the French one. The Chongqing University incubator has three management levels (board of directors, a management committee and an administrative office) whereas SEMIA holds two levels of incubator management (board of directors and an executive office). More management hierarchy may delay the dissemination of information among tenant firms and incubator managements. Managers in the Chongqing incubator are appointed by the Chongqing University and the local government. Both have less business experience in comparison to the French side. The manager of SEMIA holds entrepreneurial and academic competences.

As far as services, both sides provide new ventures with a diversified set of services: incubation space, basic infrastructure, specific business support, funding and so on. Tenant firms in Chongqing UI really appreciate its large incubation area and convenient administrative service. However, value-added services, such as professional advice, follow-up services, coaching and funding access, are very limited due to the absence of entrepreneurial managers. In spite of outsourcing experts available, tenant firms in the Chongqing incubator are reluctant to order payable services. In practice, university-sponsorship tenant firms are accustomed to enjoying the Chongqing University's physical and human resources without charges, because university entrepreneurs are often affiliated to a faculty and they have the right to use university facilities. The common university culture helps them develop close personal networks with some colleagues. When problems arise, they tend to ask for help through their personal networks so as to save cash flows. Further, sponsored university itself holds partial or whole ownership of the new venture. It does not criticize its venture, because it uses laboratories and equipments free of charges. In SEMIA, the incubator staff works in groups and accompanies the growth of incubated projects. Benefiting from several years working in the industry, the director of SEMIA helps tenant firms establish and develop contacts with the industry, banks, chambers of commerce and other actors. Moreover, the outsourcing advice is free of charge which reduces the operation costs of tenants. SEMIA has a much smaller incubation surface: 2000 square meters less than the Chongqing UI with its 16443 square meters. It has to transfer some of the tenant firms to other rented buildings. The dispersed location of tenant firms hampers the information exchange between them.

Concerning the selection criteria, there is no systematic and comprehensive assessment framework in SEMIA. The critical criteria focus on the context of the project and the qualification of the founder. Venture entrepreneurs should make a presentation about their project before the selection committee. The decision of selection can be variable from 1 hour to 6 months. But the average time is about 1 or 1.5 months. In-house members, universities, firms, bankers, OSEO Anvar and relative experts are invited to select the projects, accounting for 16 personnel (Bussillet *et al*., 2006). In the Chongqing incubator, the selection criteria focus on the high-technology context of the projects and the clear intellectual property rights. The selection group is smaller than in SEMIA and consists of representatives from universities, PROs, firms and banks. The schedule of decision depends on each case. The incubator has the right to stop incubating the tenant firms if the firms fail to attain the graduation criteria within 3 years or if they deal with non hi-tech businesses.

With respect to performance outcomes, the Chongqing University incubator is bigger than SEMIA. In 2005, the Chongqing University incubator (UI) hosted 122 tenant firms against 45 in SEMIA. Nevertheless, these two incubators have nurtured approximately the same number of graduated companies: 32 graduated firms for Chongqing UI and 34 for SEMIA. Considering the larger size of Chongqing UI, it seems that SEMIA functions more efficiently in terms of the number of graduated ventures. But we have to remember that the incubation period is almost twice as big in China as compared to that in France. In addition, the exit criteria are stricter and more systematic than in the French side.

The average incubation period in the Chongqing incubator is longer than in SEMIA, 3 years in the former against 2.5 years in the latter. The reasons partially emanate from the reluctance to leave from the tenant firm's side and to keep rental incomes from the incubator's side. In SEMIA, there is no problem of occupancy. In fact, it has to look for physical space outside SEMIA to host clients.

In terms of employment, Chinese and French figures are difficult to compare in a strict sense. For SEMIA, the 34 created companies (5 of them have disappeared) employ 150 persons. We have no information about the number of employed persons during the incubation period. In Chongqing UI, the 122 incubated start-ups have created 1881 employment, but we have no statistic about the number of employees in the 32 graduated companies. Thus, the statistics are not directly comparable. In sum, the Chinese incubated companies are bigger in terms of employment than the French created start-ups (after incubation). The average job creations in the Chongqing UI are 15,4 which contrast with the 5,2 positions created by active companies in SEMIA. This dichotomy demonstrates that tenant firms in Chongqing UI are bigger than active created companies in SEMIA. The former might however be less hi-technology oriented than the latter.

3.3.3.3 Synthesis of the comparison

Table 3.9: Characteristics of university incubators in Chongqing and in Strasbourg (2005)

	Chongqing University Incubator	SEMIA
Nature	Non-profit organization	
Ojective orientation	Commercialize academic S&T findings, foster innovative entrepreneurship, promote local economic development, create employment and fuel regional economic development	
Founders	Chongqing University Shapingba district government	Louis Pasteur University Other universities, Grand Ecole and public research organizations in Alsace region
Funders	Chongqing University Shapingba district government. Chongqing Jialing Motor Company	Ministry of High Education and Research Alsace region European Commission
Management	Board of directors (founders) management committee (representatives from university and district government) Administrative office (over 3 persons)	Board of directors (founders) Executive office: 1 director with 3 assistants
Services	Physical facilities and office support; training; few coaching and monitor services; "one shop" administrative services; access to financial resources (Innofunds, venture capitals); few	Physical facilities and office support; training; follow up services and network access to external resources (industry, PROs, universities, ANVAR,

	network with subcontractors, suppliers and buyers	venture capitals)
Selection criteria	Technology-based ventures, clear intellectual property rights, projects both with commercial potential and in accordance with incubator's privileged industries	Academic achievements-based ventures, projects both with commercial potential and in accordance with incubator's privileged industries
Incubation period	3 years	2,5 years
Nbre of incubated firms	122	45
Surface m2	16443	2000
Nbre of sites	1	3
Nbre of graduated firms	32	34
Type of tenant firms	IT (46%), Optical, mechanical and electronic integration (10%), bio-medical (8%); 21% in environment protection, energy saving and new materials; 2% agriculture and 14% in other activities	Life science (42%), information and communication technology (32%), chemistry and engineering (22%), social human science and services (4%)

Source: by the author herself.

Table 3.9 exhibits the fact that the Chongqing University incubator and SEMIA have similar characteristics in terms of nature and objective. Both incubators are supported by sponsored universities and local governments, and both incubators can help tenant firms gain an access to complex funding systems. The main differences lie in the services, selection criteria, the incubation period, the incubation surface and the performance outcomes. The Chongqing UI focuses on facilities provision and administrative services but provides insufficient business support. SEMIA is rather oriented towards network building and specific business support. The selection criterion in the Chongqing UI is more institutionalized than in its French counterpart and the incubation period is six months longer in the former than in the latter. The longer duration may explain why there are more graduated firms in SEMIA than in the Chongqing UI. The incubation surface of the Chongqing UI is 8 times more important than in SEMIA. It also hosts more tenant firms than SEMIA.

The type of incubated firms by sectors illustrates the characteristic of local context together with the university's specialty. Being the youngest municipality, Chongqing lies in the southwest of China. Its manufacturing industry focuses on motor and automobile production, which promotes the development of relative industries, like mechanical, electrical and new material sectors. Despite the rapid urbanization process in recent years, the rural population accounted for 53.3% in 2006. More and more rural labors afflux to cities. Some countryside regions therefore lack manpower. Developing modern agriculture and creating more jobs are put in the agenda of local government. That is why the Chongqing incubator holds 2 tenant firms engaging in modernizing the agricultural field. The huge project of Three Gorges Dam, the China's adherence to the Tokyo agreement[5], the Chongqing's geography (surrounded by mountains) and the industry-based background require local government to pay more attention to environment protection. Environment technology-based ventures are privileged by the Chongqing incubator. In 2005, there were 26 tenant firms which engaged in environmental protection, energy saving and new materials. The Chongqing University is one of the top 100 Chinese universities, specializing in IT, engineering and environment protection. Many university entrepreneurs set up firms in reference to these specialties. When tenant firms have technology problems or need to make laboratory experiments, geographic proximity to universities helps them get the access to university physical and human resources. This promotes technology transfer between tenants and university.

By contrast, bordering on Germany, Swiss and Italy, Strasbourg is infiltrated by cross-nation culture. The high quality of universities (Louis Pasteur University, Robert Schuman University and Marc Bloch University), public research institutes (subordinated to CNRS) as well as strong support of Alsace Region promote the development of SEMIA. Alsace region employs 3.3% researchers at the state level, taking the 9th place in France. The research emphasizes fundamental biotechnology, chemistry, mathematics, information technology and human sciences. Hence, it is not surprising to find that the created companies (34 firms) concentrate on certain fields, such as 14 firms in life science, 11 ones in ICT, 7 firms in chemistry & engineering, and 2 in social sciences and services. In addition, the industries in Alsace are composed of numerous small & medium firms and three big firms (Automobile Peugeot at Mulhouse-Sausheim, General Motor at Strasbourg and INA Rolling Bearings at Haguenau). Since 1998, the unemployment in Alsace has increased and many firms cut down their job offers. Struggling with the climbing unemployment, Alsace region supports SEMIA as a policy tool to create employment and wealth.

In general, the distribution of tenant firms by sectors appears to be dependent on the university's specialty and on the development target of local governments, both in the Chongqing incubator and SEMIA. From the above statistics, the activities of Chinese tenant firms appear to be more diversified than those of French created firms. French firms show more interest in life science whereas Chinese ones are more interested in IT.

3.3.4 Conclusion

Chinese and French university incubators are created to strengthen university-industry linkage. They have similar features in terms of objective, nature and governance. Both Chinese and French governments contribute to university incubators in terms of funding and management. Both countries have a very complex funding system for new ventures that is characterized by the weakness of venture capitalist and the important role played by personal funding.

The main differences between Chinese and French university incubation systems appear in the incubation size, the selection criteria, the duration, the graduation, the services as well as the performance results. Chinese UIs are more numerous and bigger than French ones. The selection criteria and the graduation in Chinese UIs are more institutionalized than those in their French counterparts. However, the French selection criteria are more oriented towards the innovativeness and the degree of maturity of the technology than in China. The institutionalized graduation leads to the longer incubation period in Chinese UIs as compared to French UIs. The services in Chinese UIs are more oriented towards building and administration support and less towards networking and specific business support. French UIs provide more value-added services through wide networking. More high-tech ventures are incubated in French UIs than in Chinese UIs. The role of UIs in commercializing academic research findings seems to be more evident in French ones than in Chinese ones. More incubation projects in French UIs are linked to public research findings in comparison to the Chinese ones. The difference could be partially explained by each country's legislation and specific context of UIs. Our sampled incubators (Chongqing University incubator and SEMIA) confirm our general analysis on Chinese UIs and French UIs.

Section 3.4 Conclusion

Both developed and developing countries use university incubators (UIs) as an instrument to promote university innovations. UIs in developed countries target to retain innovation competitiveness whereas UIs in developing countries aim to build up such competitiveness. UIs of both countries provide a favorable environment to nurture new technology-based firms.

Our research outputs show that Chinese university incubators have promoted academic technology transfer and innovative entrepreneurs training. The majority of high-tech ventures are created by academic entrepreneurs. Compared with non-university incubators, UIs hold an advantage in terms of geographic proximity to sponsored university and the university linkage facilitates the development of academic ventures. However, value-added services are found to be insufficient in UIs, such as pooling resources, consulting, networking and funding. The case studies in section 3.2.3 support our findings.

The cross-nation comparative study on UIs in China and in France displays the similarities and differences between university incubation systems in both countries. French UIs nurture more high-tech ventures than their Chinese counterparts. This is linked to the presence of more professional services, the selection criteria more oriented towards the innovativeness and national legislation underlining the bridge between academic research findings and new ventures in French UIs. Chinese UIs are more oriented toward building and administration support but less towards networking and specific business assistances. Chinese tenant firms enjoy the university linkage to gain an access to university physical and intellectual resources. The university linkage helps tenant firms reduce transaction costs but hampers UIs broaden network with external actors. Chinese legislation does not strictly highlight the linkage between the academic world and new ventures. When the occupancy of incubation space in UIs is low and self-sustainability depends on building rentals, UIs begin to host non-university linkage firms and less technology-based ventures. This could explain why there are less high-tech ventures in Chinese UIs than in the French ones. However, the possibility for non high-tech ventures to be transformed into high-tech ones would promote the overall innovation competitiveness of domestic firms.

For the further advancement of commercializing academic research outputs, policy makers should take more measurements to remove market barriers associated with new ventures. For example, the government can establish new boards for small medium-sized firms in Stock Exchange. This measurement will provide an exit mechanism to venture capitals and encourage venture capitalists to increase investment in new ventures. Besides, the government should build an entrepreneurial culture in the society. In ancient times, China was a leading inventive country generating great inventions, i.e. paper, printing, hydro-mechanical clockwork, gunpower, the magnetic compass etc. But it was backward when the western countries experienced the industrialization between the 18^{th} and 19^{th} century. To catch up with advanced countries, China needs to foster more innovative entrepreneurs and to develop new high-tech industries.

Apart from the governmental support on strengthening the academic world and new ventures, Chinese UIs should learn from non-university incubators and French UIs to employ entrepreneurial managers, focus on more professional and value-added services that would improve the competitiveness of tenant firms, and help tenant firms broaden networks with capital ventures, bankers, potential clients etc. Chinese university incubators should develop closer ties with TTOs to increase the potential number of projects issued from the academic sphere and to avoid problems linked to the valuation contracts that could block the transfer of technology. National political actions are proposed to simplify the complexity of the funding system and the institutional context (creation of unique offices in charge of funding procedures, network of incubators, common ICT platforms etc.).

General conclusion

China is trying to catch up with developed countries by building up its national innovation system (NIS). Although Chinese firms are central to the NIS, their weak absorptive and innovative capabilities hamper them from becoming independently competitive players in fields that used to be dominated by developed countries. Universities play an important role in improving such capabilities of domestic firms. This thesis analyzes how universities transfer technology towards the industry in the Chinese NIS to build up the competences of domestic firms.

Our research methodology is based on the convergence of information from different sources. Quantitative and qualitative data are incorporated. Quantitative data is basically collected from published documents and archival records. The correlation and linear regression analyses are used to deal with the collected quantitative data. Qualitative information is collected from on-site visits, open-ended interviews, questionnaires and semi-structured surveys. Additionally, case studies are used in our thesis.

Starting with a brief introduction of the NIS approach, Chapter 1 focuses on the building-up of the Chinese NIS and the importance of universities in the NIS. Our research findings indicate that the Chinese NIS has evolved along two dimensions. One dimension is linked to technology importations; the other dimension is related to endogenous innovation. Policy makers have carried out a series of institutional and organizational innovations to shape the NIS towards these two dimensions. These active national actions have a positive impact on the growth of China's high-tech industry, scientific publications and patents.

Universities have contributed to the progress achieved by China. The remarkable increase of university student enrollment and the improvement of education quality provide the industry with more engineers and scientists. R&D collaboration and the creation of spin-offs facilitate technology transfers from universities to industries, foster academic entrepreneurs and generate economic returns.

The absorptive and innovative capabilities of domestic firms have been upgraded but still lag behind their western counterparts. These weaknesses are significant obstacles for them to benefit from the spillover effect of foreign direct investment and open science and to convert patents into new products and services. It is necessary for policy makers to continuously increase investment in R&D expenditure and education and to take more properly national actions for promoting endogenous innovation. Being an important institutional actor in the Chinese NIS, universities need further educational reforms to provide industry with sufficient human innovators. The provision of innovative, problem-solving and team spirit graduates is critical to overcome the weaknesses of Chinese firms. Moreover, the transformation of traditional spin-offs (i.e. university-run enterprises) into intellectual property (IP)-based spin-offs should be accelerated with the help of university technology transfer offices. IP-based spin-offs are innovative firms and they are expected to be one of the key elements for promoting the Chinese NIS.

As university technology transfer offices (UTTOs) are an important institution to facilitate university technology transfers, Chapter 2 focuses on UTTOs and the Chinese '*Bayh-Dole*' Act. It first introduces the emergence of UTTOs, the rationale behind the creation of UTTOs and the linkage between UTTOs and the *Bayh-Dole* Act, then assesses the effect of the Chinese '*Bayh-Dole'* Act on university patenting and licensing both at a general level and at a more specific level (in two sampled universities). This chapter finally examines whether the establishment of national technology transfer centers (NTTCs, equivalent to UTTOs) in six Chinese universities is an efficient political tool to promote the commercialization of academic research outputs.

Our research results show that the emergence of UTTOs is associated with the implementation of the *Bayh-Dole* Act, the requirements of policy makers to strengthen university-industry technology transfers and the motivation of university to pursue economic income.

Concerning the impact of the Chinese '*Bayh-Dole*' Act on university patenting and licensing, our findings are consistent with the US research results: the Act is only one of the factors behind the growth of university patenting and licensing. We conclude that a series of legislation before 2002, the organizational innovation (e.g. IPR offices, UTTOs or similar) and internal incentive mechanism (e.g., patent funds, workload assessment relative to patents) in universities promote the increase of patenting and licensing. However, the effect of the Act on licensing agreements is not as efficient as on licensing revenues. Moreover, our study explores the previous US research output according to which the growth rate of patent applications is lower after the Act than before the Act whereas the number of issued patents exhibits a more remarkable expansion after the Act than before the Act. We conclude that the Act has had a more significant impact on the growth of issued patents than on patent applications.

In terms of national technology transfer centers (NTTCs), our quantitative and qualitative analysis indicates that NTTCs play a more important role in promoting university patentability and in creating spin-offs rather than licensing activities. The number of NTTCs staff has a significantly positive effect on the outputs of NTTCs measured by the number of patent applications and issued patents. However, NTTCs are not an efficient political tool to promote university technology transfer activities. Universities without NTTCs can go ahead of those universities with NTTCs in terms of the commercialization of academic findings. Zhejiang University is in this case. NTTCs facilitate the commercial exploitation of university inventions but they are only one of the influential factors. Continuous growing R&D expenditure, rising awareness of IPR protection, staffing capabilities and university institutional inventive systems, all influence positively the capitalization of academic outputs.

Our study also finds that the performance output of six NTTCs is different. These differences are proved to result from pre-NTTC imbalance in research capability, post-NTTC financial resources, university-industry relationships and performance modes.

To improve the effectiveness of NTTCs, we suggest there should be a clear labor division between NTTCs and other related university sectors. The value of the NTTC staff should be recognized and rewarded. NTTCs are also advised to provide industries with affordable services to compensate the constrained funding.

Both the Bayh-Dole Act and NTTCs have a positive impact on the expansion of university patentability. But a small part of patented technologies are commercially exploited by firms. The main reason is found to link with the weak absorptive and innovation capabilities of domestic firms. Thus, Chinese firms need to promote their abilities to benefit from university technology. Another thing we are concerned about is that a few universities start to use patents as an indicator to evaluate the workload of professors. In the short-term, this measure appears to be efficient for the growth of university patentability. But in the long-term, it may cause to the negative effect because of professors' active involvement in a commercial world.

In addition to NTTCs, university incubators are another institutional innovation under the Chinese NIS. They are viewed as an accelerator for endogenous innovation. Chapter 3 discusses the performance of university incubators. We analyze the role of university incubators (UIs), then compare the performance of university incubators and non-university incubators (non-UIs) in China and finally broaden our study to make a cross-nation comparison of UIs in China and in France. The Chongqing University incubator, the Caohejing Technology Business Incubator (non-UI) and the SEMIA incubator (the Alsace university incubator) are used as case studies in this chapter.

Our research results show that the role of UIs in developed countries and developing countries has similarities but also differences. The principal similarity is to foster university-technology-entrepreneurship linkages through university incubator programs. The main difference is that UIs in developed countries stress the maintenance of innovation competitiveness and give preference to innovative start-ups whose technologies are used to improve social welfare and economic income (i.e. health, security and risk aversiveness fields), whereas those in developing countries emphasize the building-up of innovation capabilities and foster new firms which get involved in upgrading traditional industries and developing high-tech industries. Concerning the performance of UIs and non-UIs in China, UIs act as nursery for academic entrepreneurs and they are one of the important supporting institutions for endogenous innovation. Non-UIs pay attention to the innovativeness of technology (whether imported or domestic) and the potential or actual production scale of new firms. UIs are found to hold an overwhelming advantage in geographic proximity to the sponsored university but they should learn from non-UIs in pooling resources, consulting and network building.

Concerning the comparison between Chinese and French UIs, they have similar features in terms of objective, nature and governance. Both Chinese and French governments contribute to university incubators in terms of funding and management.

Both countries have a very complex funding system for new ventures that is characterized by the weakness of venture capital and the important role played by personal funding. The main differences between Chinese and French university incubation systems are the size of incubation, the selection criteria, the duration, the graduation, the services as well as the performance results. These differences can be partially explained by the legislation in each country and the specific context in which UIs have evolved. Our case studies of UIs (the Chongqing University and SEMIA incubator) confirm our general analysis on French and Chinese UIs. We suggest that Chinese UIs should provide more value-added services to tenant firms through a wide network and should strengthen the linkage between the incubation projects and UTTOs.

In sum, the university-industry linkage has been strengthened along with the evolution of the Chinese national innovation system. Universities have become not only knowledge generators but also knowledge exploiters. They help domestic firms build up competences by training innovative talents, by enhancing R&D collaboration and by creating of spin-offs. However, many domestic firms still have weak absorptive and innovative capabilities. These weaknesses create a significant obstacle for China to turn from a labor-intensive manufacturing country into an endogenous innovative power. More institutional and organizational innovations are needed to drive domestic firms to become the major innovation force in China. Universities will continue playing an important role in promoting the competences of firms through technology transfers. University technology transfer offices and university incubators are expected to help their sponsored universities achieve this objective.

Our future research will focus on the additional public policies which shape the innovation process (i.e. the implementation of national medium-term and long-term S&T development plan (2006-2020), government procurement regulations). These policies are viewed as critical elements to promote China's endogenous innovation. Moreover, we will continue to center our analysis on the evolution of university-industry linkages. The university-industry linkages have been enhanced after the S&T reform in China. But when universities get more and more involved in patenting and licensing activities, will there be conflicts between industries and universities? Will the commercial activities of universities have a negative influence on basic research, scientific publications and future research? Given that industries improve their absorptive and innovative capabilities, what kind of technology transfer mechanism will be preferred between university and industry? All these questions are put on our future research agenda. Concerning the research methodology, we will increase our sampled universities and identify a number of domestic firms to conduct our case studies. Econometric methods will be used to deal with our more complete quantitative data. To sum up, we wish to explore whether China's national actions and the closer interactions between universities and industries in the following years will finally help the government reach its target, namely to become "an innovation society" by 2020 and a "world's leading science power" by 2050.

Appendices

Appendix 1.1: Key laws and regulations on FDI

1979: Law on Joint Ventures Using Chinese and Foreign Investment It provided a basic framework for the establishment and operation of foreign economic entities. It specified a variety of incentives and terms for joint ventures.
1983: Regulations for the Implementation of the Law on Joint Ventures Using Chinese and Foreign Investment It provided greater details on the operations and preferential policies for joint ventures.
1986: Law on Enterprises Operated Exclusively with Foreign Capital It formally permitted the establishment of wholly foreign-owned enterprises outside Economic Special Zones.
1986: Notices for Further Improvements in the Conditions for the Operation of Foreign Invested Enterprises and Provisions of the State Council for Encouraging Foreign Investment It provided further incentives, particularly for FDI using advanced technologies, and/or producing for exports. These provisions were subsequently codified in the 1988 Cooperative Joint Ventures Law.
1990: Amendments to the Equity Joint Venture Law and Wholly Foreign-Owned Enterprise Implementing Rules It provided a more complete legal structure to facilitate the operations of these enterprises. Notably, these laws/rules abolished the stipulation that the chairman of the board of a joint venture should be appointed by Chinese investors and provided for protection from nationalization.
1995: Interim Provisions on Guiding Foreign Direct Investment Direction (revised in 1997) It classified FDI into four categories: encouraged, permitted, restricted, and prohibited. In broad terms, projects are encouraged and permitted in designated industries that introduce new and advanced technologies, expand export capacity, raise product quality, and use local resources in the central and western regions. Restricted and prohibited are projects in designated sectors that make use of existing technologies, compete with domestic production or state monopolies, make extensive use of scarce resources, or are deemed to be a danger to national safety and the environment.
2002: The Catalogue for the Guidance of Foreign Investment Industries (revised in 2004, enacted in 2005) It classified FDI into three categories: encouraged, restricted and prohibited. The revised catalogue in 2004 adds new industries and products and upgrades the content of original catalogue to attract advanced foreign technology, such as manufacturing of key components for large color display panels, writable disks and re-writable disks, automotive electronic systems and 300,000MW large-scale circulating fluidized-bed combustion boilers, and key parts for the manufacturing of large-screen color projection displays and CD-ROM copying.

Source: Tseng and Zebregs, 2002; Qian, 2005.
http://www.fdi.gov.cn/pub/FDI_EN/Laws/law_en_info.jsp?docid=51089
http://www.hzbiz.gov.cn/en/0702/1406.htm
Note: after China's accession to WTO, China continues to introduce a number of regulations on FDI. The legislation guides FDI to enter various sectors: telecommunication, cargo transport, civil aeronautics, printing in 2002 and architecture in 2003.

Appendix 2.1: Jensen *et al.'* (2003) modeling the university licensing process demonstrated in Box 1 and Box 2.

Box 1:

R: discounted value of the stream of license revenue paid by the firm.

S: funds provided to the universities for sponsored research at the time the license agreement is signed, while the license revenue (royalties) is not paid unless and until the invention is successfully commercialized.

K: costs associated with adopting and/or marketing the invention which the firm should bear.

Π: discounted value of the stream of profits resulting from the invention if it is a commercial success.

ρ: probability of success at the time the UTTO searches for a partner, then she can sell a license only if $\rho(\Pi\text{-}R)\text{-}S \geq K$. Here we ignore all up-front license payments except those for sponsored research.

$\rho_c(S,\Omega)$: probability of success when the invention is disclosed as a proof of concept. Ω is an index of faculty quality.

$\rho_L(S,\Omega)$: probability of success when the invention is disclosed as a lab-scale prototype.

$U_T(Y_T, f_T, l)$: utility of UTTO. Y_T is her license revenue. f_T is her sponsored research funds. l is an indicator variable when l=1 if a license is executed and l=0 if not.

α_R: UTTO's share of license income. α_S: UTTO's share of sponsored research funds.

β_R: inventor's share of license income. β_S: inventor's share of sponsored research funds.

V_{id}: inventor's utility cost of disclosure. V_{Tl}: UTTO's utility cost of searching for a licensee.

δ: inventor's discount factor, $\delta \in (0, 1)$

P: price of products sold in the market if the inventor succeeds in exploiting the technology.

Q: quantity of products. γ: income paid by the firm when the inventor sells the invention to the firm.

Box 2:

1. At the proof of concept stage, if the inventor chooses to ***disclose the invention*** and UTTO decide to ***market the technology***, then

the expected utility of inventor is:

$EU_{IC}(\beta_R R_C^*, \beta_S S_C^*) = \rho_c(S,\Omega)U_I(\beta_R R, \beta_S S, 1) + [1-\rho_c(S,\Omega)]\ U_I(0, \beta_S S, 1) - V_{id}$ under the condition:

$EU_{IC}(\beta_R R_C^*, \beta_S S_C^*) \geq \max\ [\![\delta\ [EU_{IL}(\alpha_R R_L^*, \alpha_S S_L^*)],\ U_{Ia}]\!]$

$EU_{IL}(\alpha_R R_L^*, \alpha_S S_L^*)$: the inventor's expected utility at the lab-scale prototype stage if the invention is disclosed at that stage.

U_{Ia}: utility received from the inventor's next best alternative research project if he does not disclose.

the expected utility of UTTO is:

$EU_{TC}(\alpha_R R_C^*, \alpha_S S_C^*) = \rho_c(S,\Omega)U_T(\alpha_R R, \alpha_S S, 1) + [1-\rho_c(S,\Omega)]\ U_T(0, \alpha_S S, 1) - V_{TI}$ under the conditions that her expected utility from her share of the license contract is nonnegative and the licensee's expected profit under that contract is nonnegative:

$EU_{TC}(\alpha_R R_C^*, \alpha_S S_C^*) \geq 0$ and $E\Pi_C(R, S) = \rho_c(S,\Omega)(\Pi - R) - S - K \geq 0$

the expected utility of university is:

$EU_{UC}((1-\alpha_R-\beta_R)R_C^*, (1-\alpha_R-\beta_R)R_C^*) = \rho_c(S,\Omega)U_T((1 - \beta_R - \alpha_R) R, (1 - \beta_S - \alpha_S)S, 1) + [1-\rho_c(S,\Omega)]\ U_T(0, (1 - \beta_S - \alpha_S)S, 1)$ under the condition that both UTTO and the inventor's expected utilities are realized.

However, if the UTTO decide to ***shelve the technology*** when the inventor ***discloses his invention***, then

$EU_{IC} = - V_{id}$ (the cost of disclosure) $\qquad EU_{TC} = EU_{UC} = 0$

2. At the lab-scale prototype stage, if the inventor chooses to ***disclose the invention*** and UTTO decide to ***market the technology***, then

the expected utility of inventor is:

$EU_{IL}(\beta_R R_C^*, \beta_S S_C^*) = \rho_l(S,\Omega)U_I(\beta_R R, \beta_S S, 1) + [1-\rho_l(S,\Omega)]\ U_I(0, \beta_S S, 1) - V_{id}$ under the condition

$EU_{IL}(\beta_R R_C^*, \beta_S S_C^*) \geq U_{Ia}$

the expected utility of UTTO is:

$EU_{TL}(\alpha_R R_C^*, \alpha_S S_C^*) = \rho_l(S,\Omega)U_T(\alpha_R R, \alpha_S S, 1) + [1-\rho_l(S,\Omega)]\ U_T(0, \alpha_S S, 1) - V_{TI}$ under the conditions that her expected utility from her share of the license contract is nonnegative and the licensee's expected profit under that contract is nonnegative:

$EU_{TL}(\alpha_R R_C^*, \alpha_S S_C^*) \geq 0$ and $E\Pi_L(R, S) = \rho_l(S,\Omega)(\Pi - R) - S - K \geq 0$

the expected utility of university is:

$EU_{UL}((1-\alpha_R-\beta_R)R_C^*, (1-\alpha_R-\beta_R)R_C^*) = \rho_l(S,\Omega)U_T((1 - \beta_R - \alpha_R) R, (1 - \beta_S - \alpha_S)S, 1) + [1-\rho_l(S,\Omega)]\ U_T(0, (1 - \beta_S - \alpha_S)S, 1)$ under the condition that both TTO and the inventor's expected utilities are realized.

Appendix 2.2: Summary of the Chinese Patent Law

Standards of patentability	1. Inventions must meet requirement for novelty, utility, and non-obvious inventive step. 2. No requirement of disclosing prior art relating to application. 3. Invention is still considered novel for a six-month "grace period" after disclosure to the public.
Receipt	First-to-file
Procedure	1. Patent application is published for inspection and opposition 18 months after application. 2. Single-claim preferred, though multiple-claim allowed in specific situation. 3. Examination starts at the applicant's request, and request must be submitted within up to three years after application. 4. Foreign applicants must submit applications through Chinese registered attorneys.
Duration	1. Twenty years for inventions. 2. Ten years for utility models and industrial design.
Compulsory licenses	1. Government may require patentees to license technologies to others if needs for national security or emergency arise, and others make reasonable offer to implement the technologies.
Cross-licensing	Crossing-licensing allowed in China.

Source: The Patent Law of People's Republic of China, 2000; Sun (2003).

Appendix 2.3: Laws on university technology transfer and intellectual property

1. Technology contract law (1987, revised in 1999)
Presenting the engagement, fulfillment, change and termination of technology contracts; Identifying the rights and obligations of parties undertaking four types of technology contracts: technology development, technology transfer, technology consultation and technology service; Proposing the resolution for disputes on technology contracts.
2. Science and Technology development law (1993)
Designating S&T advancement as one of the most important components in China's economic development, promoting S&T activities under the market mechanisms, recognizing status of S&T employees, promising protection of IP rights and some freedom of scientific research, pooling more investment in R&D activities.
3. S&T achievements conversion enhancement law (1996)
A basic law on technology transfer, encouraging science sector to convert S&T achievements and transfer its technology in a more autonomous way (self-investment, transfer to others, allow others to use findings, joint conversion, accounting for findings as equity investment…) and securing IP rights in transfer operations (ownership and share of technological right and interest)[102]
4.Decisions on strengthening technology innovation, developing and industrializing high technology (1999)
Prioritize the development of some hi-technology, e.g. biotechnology, information telecommunication technology; promote university-industry linkage for commercializing university research achievement; provide fiscal and financial policies to support high technology industrialization.
5. Regulations on university IP rights management (1999)
Authorize universities to hold the ownership of on-duty inventions and require universities to establish IP office to manage university IP activities and reward inventors.

Source: Tang, 2006a; Bach *et al*., 2007.

[102] The law stipulates that "on the condition of not harming the national and social public interests, S&T results conversion to practical use can be conducted either voluntarily or according to agreement, and will enjoy the benefit while undertaking the risk".

Appendix 2.4 : Questionnaire on National Technology Transfer Centers

(Please choose the right answer and use √ in the pane. Multiple answers are possible)

1. Which is the predecessor of national technology transfer centers (NTTCs)?

□S&T achievements commercialization office

□Science research department

□No office linked with NTTC

□Others

2．To which administrative sector is NTTC subordinated?

□Subordinated to university S&T division (Kejichu)

□Subordinated to university assets management department

□Independent, in parallel with university S&T division (Kejichu)

□Subordinate to the government and the sponsored university

What are the sources of funding of NTTC?

□University

□Local government

□The Ministry of Education

□Former State Economics & Trade Commission

4．Who are the professionals in NTTC?

□Technical experts

□Marketing experts

□Patent experts

□Other managements

5．Where does the staff of NTTC come from?

□Public research institutions

□Enterprises

□Universities

□Governmental authorities

6．What is the role of NTTC?

□Help researchers file for patent applications

□Help university set up R&D platform on common technology with industry

□Exploiting university inventions

□Promote international technology cooperation and provide services for spinoffs

7．What is the characteristic of services of NTTC?

□Non-for-profit

□Payable services but non-for-profit

□For-profit

□Others

8．Do you think it is necessary to set up NTTC in your university?

□Not sure

□No, it can be replaced by the S&T achievements commercialization office

□Yes, it is necessary

□Not necessary

9． Have the patenting activities and technology transfer income of your university been changed post-NTTC as comparison to pre-NTTC?

□Remarkable increased

□No change

□Slightly increased

□Slightly decreased

10．Does the establishment of NTTC influence the existence of S&T achievements commercialization office?

□The S&T achievements commercialization office is repealed

□The S&T achievements commercialization office co-exists with NTTC and also shares staff with NTTC

□The staff of the S&T achievements commercialization office has totally turned into staff of NTTC

□Do not know

Appendix 2.5: Questionnaire on Science & Technology Achievements Commercialization Offices (STACOs)

(Please choose the right answer and use √ in the pane. Multiple answers are possible)

Does your university have a S&T achievements commercialization office (STACO)?

□Yes

□No

□In the building-up course

□In the planning course

2．To which university administrative sector is STACO subordinated?

□Subordinated to university S&T division (Kejichu)

□Subordinated to university assets management department

□Independent, in parallel with university S&T division (Kejichu)

□Subordinated to university science parks

3. When was the STACO set up in your university?

□In the 1980s

□In the middle of 1990s

□At the end of 1990s

□At the beginning of 21 century

4. Why does your university have no NTTC?

□It is the government's decision and our university has no decision power

□Our university has no sufficient research achievements

□The STACO plays the similar role as NTTC in our university

□Other reasons

5．Does your university expect that the STACO can be turned into NTTC?

□Yes

□No

□It does not matter

□Do not know

6．Where does the staff of STACO come from?

□Staff of university S&T division (Kejichu)

□Outsource professionals outside university

□University professors

□The three above sources

7．What is the role of STACO in your university?

□Help researchers file for patent applications

□Act as an intermediary between university and industry and transfer and diffuse technology from the academic world to the industrial sectors

□Market university inventions

□Provide services to spinoffs

8．Given the STACO is turned into NTTC, what would happen in the future?

□The government will increase investment in the sponsored university

□The speed of commercialization of university inventions will be accelerated

□The role of STACO will be strengthened

□Do not know

9．What is the characteristic of services provided by the STACO in your university?

□Non-for-profit services for university staff

□Payable services for non-university demanders but non-for-profit for university staff

□For-profit services for all types of demanders.

□Others

10．Do you think it is necessary to establish the STACO in your university?

□Not sure

□It can be replaced by NTTC

□Yes

□No

11．Have the patenting activities and technology transfer income changed in your university post- STACO as comparison to pre-STACO?

□Remarkable increased

□No change

□Slightly increased

□Slightly decreased

12．Does the creation of STACO strengthen the linkage between university and industry?

□Yes, marked strengthened

□No change

□Yes, slightly strengthened

□No, slightly decreased

13．If your university has a NTTC in the future, then what will happen next?

□The STACO will be repealed

□The STACO will co-exist with the NTTC

□The staff of STACO will turn into the staff of NTTC

□Do not know

List of abbreviations

ANVAR: Agence Nationale Pour la Valorisation de la Recherche
CAE: Chinese Academy of Engineering
CAS: Chinese Academy of Sciences
CD: Cooperation Development
CNRS: National Centre for Scientific Research
COEs: Cooperative Operation Enterprises
CRITTs: Centre Régionaux d'Innovation et de Transfer de Technologies
CSTSAR: China S&T Statistics Annual Report
DEA: Data Envelopment Analysis
DRRT: Regional Direction for Research and Technology
EI: Engineering Index
EPO: European Patent Office
EPST: Etablissements Publics à Caractère Scientique et Technique
GERD: Gross Expenditure of R&D
Innofund: Innovation Fund for Technology-based Small-Medium Enterprises
IP: Intellectual Property
IPRs: Intellectual Property Rights
ISTP: Index of S&T Proceedings
JPO: Japan Patent Office
LMEs: Large-Medium industrial Enterprises (LMEs)
MHER: Ministry of Higher Education and Research
MNCs: Multinational Companies
MOE: Ministry of Education
MOST: Ministry of Science and Technology
NIEs: Newly Industrialized Economies
NIS: National Innovation System
NNSFC: National Natural Science Foundation of China
non-UTBI: non-University Technology Business Incubators
NTTCs: National Technology Transfer Centers
OEM: Original Equipment Manufacturing
PPCs: Productivity Promotion Centers
PRO: Public Research Organizations
RIs: Research Institutes
SCI: Science Citation Index
SCIE: State Commission for Imports and Exports
SETC: State Economics & Trade Commission
SEZs: Special Economic Zones
SFE: Stochastic Frontier Estimation
SI: System of Innovation
SIPIVT: Suzhou Industrial Park Institute of Vocational Technology
SIPO: State Intellectual Property Office of the People's Republic of China

SME: Small-Medium Enterprises
SOEs: State-Owned Enterprises
SPC: State Planning Commission (SPC)
SSTC: State Science and Technology Commission
STIPs: Science & Technology Industrial Parks
TBIs: Technology Business Incubators
TMs: Technology Markets
TTO: Technology Transfer Offices
UI: University Incubators
UITT: University-Industry Technology Transfer
UREs: University-Run Enterprises
USP: University Science Parks
USPTO: US Patent & Trademark Office
UTTOs: University Technology Transfer Offices
VC: Venture Capital
WARF: Wisconsin Alumni Research Foundation
WTO: World Trade Organization

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Le Transfert de Technologies de l'Université vers l'Industrie dans le Système National d'Innovation Chinois

L'université est un acteur important du système national d'innovation (SNI). Dans les pays développés, l'université joue un rôle pour le maintien de leur compétitivité nationale. Dans les pays en développement, l'université trouve plutôt sa place dans l'établissement de cette compétitivité. La Chine, malgré son statut de pays en développement, est en train de rattraper son retard en matière d'innovation.

Cette thèse pose la question suivante : ***comment l'université joue-t-elle un rôle dans la promotion de l'innovation endogène de la Chine*** ? Afin de répondre à cette question, nous présenterons, dans cette thèse, une brève description de l'approche du SNI, des caractéristiques du SNI chinois et du système universitaire chinois. Notre recherche se concentrera ensuite sur le transfert de technologies de l'université vers l'industrie qui est considéré comme un moyen d'améliorer l'innovation endogène de la Chine. Nous insisterons sur la manière dont l'université utilise les centres nationaux de transferts technologiques (CNTTs) et les incubateurs pour transférer ses technologies.

Notre méthodologie de recherche est basée sur différentes sources qui intègrent à la fois des données quantitatives et qualitatives. Les données quantitatives ont été, dans l'ensemble, collectées à partir de documents publiés et d'archives et analysées par des modèles statistiques. Les données qualitatives ont été collectées lors de visites sur les sites et proviennent d'entretiens libres, de questionnaires et de sondages semi-structurés. Des études de cas ont également été utilisées dans cette thèse.

Nos résultats de recherche montrent que l'évolution du SNI Chinois a permis de promouvoir la création et l'exploitation des connaissances mais que les capacités absorptives et innovantes des entreprises chinoises ne sont pas suffisantes par rapport à celles des entreprises dans les pays développés. Ces observations nous permettent de situer le rôle d'université au niveau de la promotion de ces capacités des entreprises locales. Nous avons observé que l'université a contribué à surmonter les points faibles des entreprises dans le transfert de technologies, plus précisément dans la production de ressources humaines qualifiées et la création de nouvelles entreprises technologiques et innovantes.

En résumé, les universités ont renforcé leurs relations avec l'industrie parallèlement à l'évolution du système national d'innovation chinois. Dans la mesure où les entreprises locales disposent encore de faibles capacités d'absorption et d'innovation, les universités vont continuer à jouer un rôle important dans la promotion de la compétitivité des entreprises à travers le transfert de technologies. Les CNTTs ou assimilés et les incubateurs universitaires aideront les universités parrainées à atteindre cet objectif.

Mot clés: Système national d'innovation; Université; Industrie; Innovation; Bayh-Dole Act; Centres nationaux de transferts technologiques; Incubateur universitaire

Technology Transfer from University to Industry in the Chinese National Innovation System

Key words: National innovation system; University; Industry; Innovation; Bayh-Dole Act; National technology transfer centers; University incubators