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Restructuring

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R&D in China and the Implications for Industrial Restructuring

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R&D in China and the Implications for Industrial Restructuring

Abstract: The nation-wide introduction of foreign technology in China has been going on for over 20 years. This paper examines the R&D incentive of the Chinese innovators by analyzing the patent data for the period from 1985 to 1999. The following findings were obtained. First, individual innovators, as opposed to industrial enterprises and research institutes, have been supplying over 70% of all patent applications filed domestically. Second, innovators in China, including the industrial enterprises, have been devoting their R&D resources disproportionately to small innovations, rather than major ones. Third, the large and medium-sized enterprises are not yet the main force for innovation in China. The impacts of industrial structure on R&D incentive are emphasized. Regression analysis for 37 manufacturing industries in China shows that R&D output, measured by the number of patents per firm, is positively related to the eight-firm concentration ratio. I also analyze the microeconomic channels through which the vertical structure of an industry affects firm incentive to absorb imported technologies. “Excessive competition” and a low degree of vertical integration in Chinese industries are major factors leading to small-scale innovation, high propensity to purchase foreign technologies, and low propensity to absorb them. Establishing enterprise groups that are truly subject to market discipline can speed up the “imitation-first-and-then-innovate” process.

Journal of Economic Literature Classification Number: O31

Keywords: R&D, patent, industrial concentration, vertical integration

Proposed Running Head: R&D in China

1. Introduction

The Chinese government launched a nation-wide drive toward introducing foreign technology on a vast scale over 20 years ago, in the hope that Chinese firms, after absorbing the imported technologies, would eventually be able to innovate on their own and compete with firms from developed countries. How successful has China's "market-for-technology" policy been? How willing have Chinese enterprises been to imitate advanced foreign products and technologies? How willing and effective have they been in the area of inventing new products and technologies on their own?

This paper aims to provide a systematic analysis of innovation activity in China since its first patent law came into force in 1985. It investigates the extent to which Chinese innovators are willing to spend resources to conduct R&D activity, identifies major obstacles that have hindered Chinese enterprises' incentive to innovate, and examines the implications of the findings for further economic restructuring in China, particularly when it is preparing for its accession to the WTO.

After a very brief description of China's patent system in the next section, section 3 of the paper analyzes the types of the innovations that China's innovators have carried out during the 1990s. Using the data on domestic patent applications and approvals published by the Chinese government, I found the following patterns. In terms of the type of patents applied for, over 80% of the domestic applications were for small innovations (those generating utility models and external designs) and less than 20% were for major innovations (those leading to patents for invention). In terms of the type of innovators, over 70% of the domestic patent applications were filed by individual innovators, while the rest by industrial enterprises and research institutes and universities. Among the patents granted during the 1990s, over 60% went to individual innovators. Perhaps more striking is the fact that the above patterns have remained quite steady during the whole of the 1990s.

As for the large and medium-sized enterprises (LMEs), which are supposedly the main force for innovation in China, at least so the government hopes, there is no evidence that

they have reasonably strong incentive for innovation. As shown in section 4, the LMEs as a whole spent less than 0.5% of their annual revenues on R&D throughout the 1990s. Not surprisingly, the R&D output of the LMEs has also been low. During the entire year of 1999, for example, only one in every three LMEs in China submitted a patent application, and only one in every four was granted one. These figures for 1996 to 1998 were even lower: one in every four for patent application and one in every five for patent granting.

Section 5 of the paper focuses on the structural factors, such as the degree of industry concentration and vertical integration, that might have hindered Chinese firms' incentive to innovate. Regression results for 37 Chinese manufacturing sectors show a positive relationship between R&D output and eight-firm industry concentration ratio. Therefore, firms in more concentrated industries tend to be more productive at patented innovation. This finding is consistent with the Schumpeterian view that a high level of market concentration facilitates R&D activity. In a recent study, Jefferson et al. (2001) also found that the level of R&D effort of the large and medium-sized enterprises in China is positively related to the degree of industry concentration.¹ This empirical relationship, together with the fact that there has been "excessive competition" in most Chinese industries, helps explain the observed low R&D intensity in China. A policy implication of this finding is that increasing the degree of industry concentration can promote innovation activity in China.

Section 5 of the paper also emphasizes the impacts of vertical aspects of industrial structure on innovation. This vertical perspective is unique and crucial to China's long-time drive for its enterprises to first absorb foreign technologies and then innovate on their own. The key point of departure is the fact that absorbing imported technologies necessarily involves learning about the consisting parts and subsystems. It is difficult, for example, for a producer of a final product to fully understand the design and functions of the intermediate goods it uses to make the good, unless it itself manufactures these

¹ Jefferson et al. (2001) was based on a panel data set of approximately 20,000 large and medium-sized Chinese enterprises for the period of 1995-1999 and used one-firm and two-firm concentration ratios.

intermediate goods as well. Increased vertical integration can promote learning of imported technologies in two important ways. First, integrated enterprises are better equipped with the technical personnel and capability for digesting and absorbing foreign technologies. Second, and more importantly, successful learning of foreign technology by an individual firm often greatly benefits its upstream suppliers and/or downstream customers. Therefore, there is a tendency for “under-investment” in learning as the firm may not be able to fully appropriate the economic benefits of its effort in learning. Vertical integration can help internalize the positive externality among these learning activities and thus promote learning of imported technologies. In section 5, I make the arguments in detail and provide evidence to support them.

Scholars have made numerous studies of why Chinese firms have invested so little in R&D (see, for example, Shang and Shi (2000) and Ho et al. (1996) for detailed studies of R&D in China).² Various policy suggestions have been made for enhancing R&D incentive in China. Most of the attention, however, has been centered on such measures as direct government subsidy, tax credit for private R&D activity and new product sales, improving the enforcement of intellectual property right laws, and so on. Little attention has been paid on how to restructure China’s industries so as to make them more conducive to innovation by private firms. Stimulated by the classical Schumpeterian view and the experiences of the South Korean Chaebols, there have been discussions in recent years among Chinese scholars about the roles of large enterprise groups in promoting technological progress. These discussions have basically stayed at the level of the “deep pocket” argument of Schumpeter. The analysis of R&D incentive and industry structure in this paper goes beyond the general discussion to the microeconomic level and focuses on the channels that facilitate learning and absorbing imported technology. It is the author’s belief that restructuring the Chinese industries in relation to horizontal and vertical concentration is a more effective way to promote R&D in China compared to non-structural measures.

² Shang and Shi (2001) contains careful data analysis and various policy suggestions on how to promote R&D in China, while Ho et al. (1996) is an excellent positive study of technology transfer to and diffusion in China.

There have also been a few empirical studies of innovation in China in recent years. Jefferson et al. (2001) examined a panel data set of large and medium-sized enterprises in China for the period of 1995-1999. These authors studied the impacts of industry concentration, firm ownership, and capital intensity on R&D incentives of Chinese enterprises. While their findings on the relationship of R&D incentive and industrial concentration are similar to those of my paper, their approach differs from mine in two ways. First, the authors did not look at the composition of patent applications and innovators, as I do in this paper. Second, they are not concerned with the vertical aspects of industry structure. There are also other studies focusing on various aspects of R&D in China. For example, Sun (2000) and Liu and White (2001) both study the impacts of regional variables on innovation activity in China, whereas Hu (2001) examines the relationship between R&D and productivity growth in Chinese industries.

2. A short history of legal protection of innovation in China

In less than 20 years, China has made tremendous progress in establishing a legal system for the protection of innovations. China's first patent law and its implementing regulations were enacted in 1984 and came into effect in 1985. The patent law has been amended twice since. The first revision, undertaken in 1992, extended the patent length from 15 years to 20 years for invention patents and from 5 to 10 years for patents for utility models and external designs. The second revision, which was completed in September 2000, eliminated the provisions under the old law that prevented state-owned enterprises from trading their patents in technology markets. The second revision also introduced new provisions designed to make it more rewarding for enterprises' employees to innovate. Since the passage of the 1984 patent law, the central government has issued over 20 regulations and guidelines so as to promote innovation activity in China. Today's patent law in China is pretty much in line with the international standard. Up till now, China has acceded to all the international patent treaties and its laws on intellectual property rights meet the requirements of the WTO's agreement on trade related intellectual property rights (TRIPs).

China has put in place a fairly effective system for enforcement of the intellectual property right laws. China has adopted two procedural systems: judicially through the courts system and administratively through the relevant administrative authorities at the central, city, provincial, and county levels throughout the country. Intellectual property divisions have been established in the court of law in many major cities. Enforcement of the patent law, in particular, has been greatly improved in China since the early 1990s due to both the internal interest of China and external pressures from its major trading partners, such as the United States.³

R&D expenditure in China

Although still relatively low, the ratio of R&D expenditure to GDP in China has been growing steadily in the 1990s, as shown in Table 1 below. The figures include both private and government investments in R&D. In relative terms, R&D expenditure reached the lowest level in 1994, amounting to only 0.475% of China’s GDP in that year. After 1994, however, the ratio has been growing at quite an impressive rate.

Table 1: R&D Expenditure in China (in 100 million RMB at current prices)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
R&D expenditure	142.3	169	196	222	349	404.7	481.9	551.1	679
R&D/GDP	0.66%	0.63%	0.57%	0.48%	0.60%	0.60%	0.64%	0.69%	0.83%

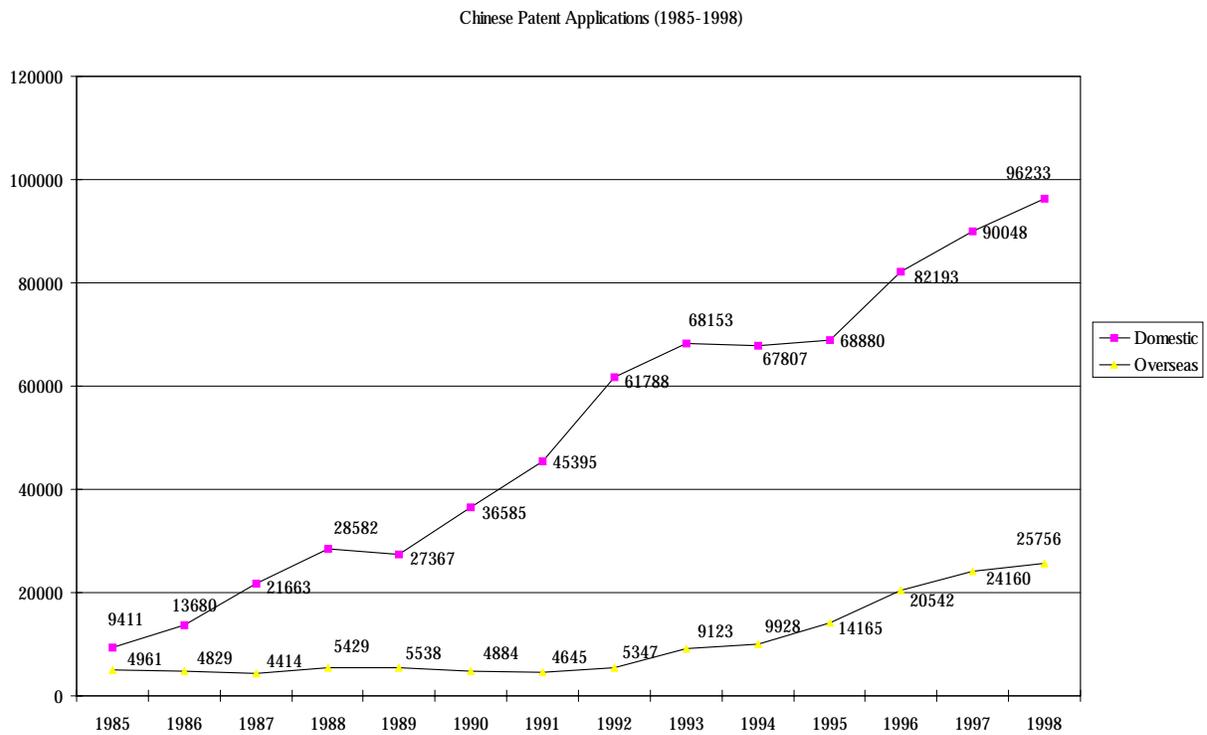
Sources: China’s Statistic Yearbooks.

China’s success at establishing a modern patent protection system is naturally reflected by R&D output. Figure 1 shows the total numbers of patent applications filed by both domestic and foreign inventors from 1985 to 1998. In 1985, a total of 14,372 applications were filed. The number reached 121,989 in 1998, having increased at an average annual rate of 17.88%. The annual growth rate of the total number of patent applications is 19.58% for domestic patents and 13.51% for foreign patents. The rapid growth in the number of patent applications can be attributed to several factors. First, China’s first revision of its patent law in 1992 substantially extended the protection period, as

³ See Lin (2001) for a detailed description and analysis of the patent system in China.

mentioned in the previous section. Second, since the early 1990s, China has greatly improved its enforcement of the laws on intellectual property rights.⁴ Third, a massive inflow of foreign direct investment to China, especially after Dong Xiao Ping’s “South Tour” in 1993, has led to an increasing demand on the part of foreign investors to register patents before they enter China’s market. As can be seen in Figure 1, the number of patent applications filed from overseas was 5,347 in 1992, but rose to 25,756 in 1998, having grown at an average annual rate of 29.96% during that period.

Figure 1. Patent Applications in China (1985-1998)



Source: China Patents & Trademarks, No. 2, 1998

Note: The domestic patent data for 1997 and 1998 included patents filed by Hong Kong.

3. Types of Innovations and Types of Innovators

In this section, I will examine in detail the compositions of the types of patents filed by domestic innovators in China and the types of these inventors. A study of such

⁴ Another contributing factor is China’s entry into the Patent Cooperation Treaty in 1994, which further facilitates overseas patent applications in China.

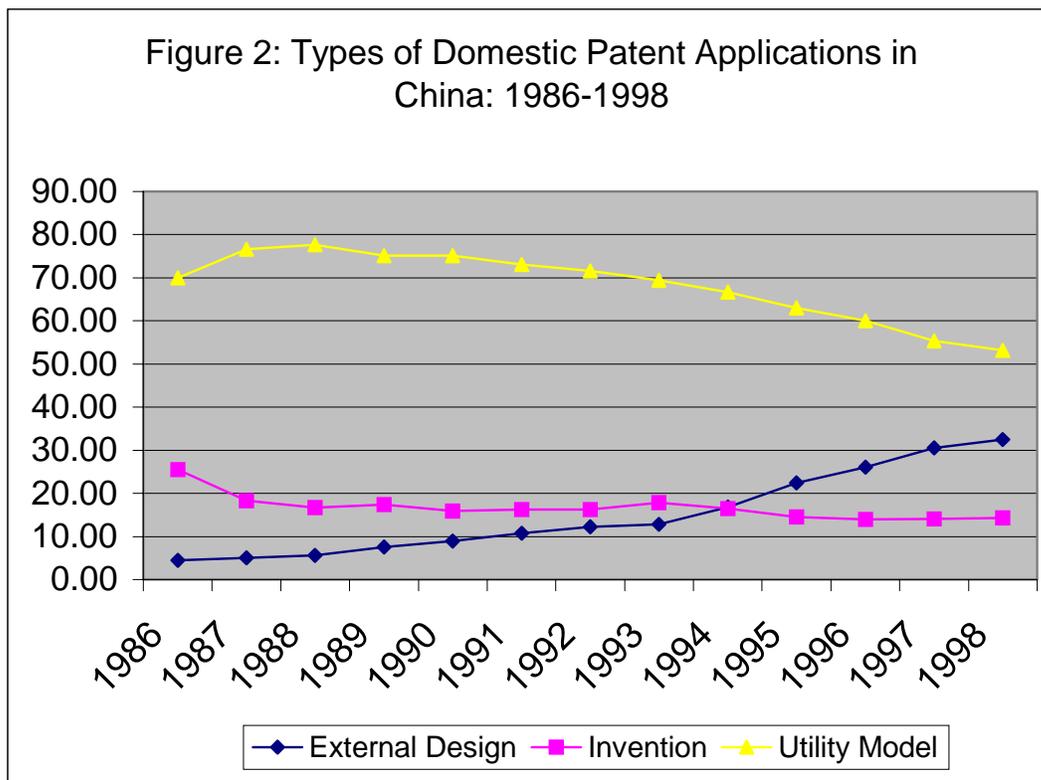
compositions and their evolutions over time can enhance one's understanding of the features of the innovation activities undertaken by Chinese inventors.

3.1 The Types of Innovations Undertaken

The current patent law of China divides patents into three categories: inventions, utility models, and external designs. The term of protection is 20 years for invention patents and 10 years for utility model patents and external design patents. Invention patents are regarded as major innovations. To obtain a patent for invention, an application must meet the requirements of “novelty, inventiveness, and practical applicability.” The applications for patents for utility models or designs, on the other hand, need only to pass an “initial examination” wherein the patent office simply checks for the completeness of the files and makes sure the same object has not been patented before.⁵

Figure 2 shows the distribution of applications for the three types of patents filed from 1986 to 1998. A striking observation is that the applications for major innovations (invention patents) accounted for less than 20% of the total number of domestic patent applications and were declining throughout the period, dropping to only 14.3% in 1998. The applications for utility model patents accounted for nearly 60% of the total from 1986 to 1998, although there was a decline in relative terms in recent years. Applications for external designs have kept increasing, representing over 30% of the total applications in 1998. Overall, one is led to conclude that Chinese innovators have devoted most of their R&D resources to small R&D projects that generate minor innovations such as utility models and external designs. One cannot help notice the very low and declining percentage of major innovations since 1994.

⁵ The patents for utility models and external designs under the Chinese patent system are different from utility patents and design patents in US patent law, both of which are for major innovations in the US system. The distinction of patent types (major versus minor innovations) in the Chinese system is similar to that in the patent law of Hong Kong or Australia where patents are divided into standard patents (with 20 years of protection) and short-term patents (with 8 years of protection). The short-term patents are designed to protect those innovations that do not meet the threshold requirements of a standard patent.

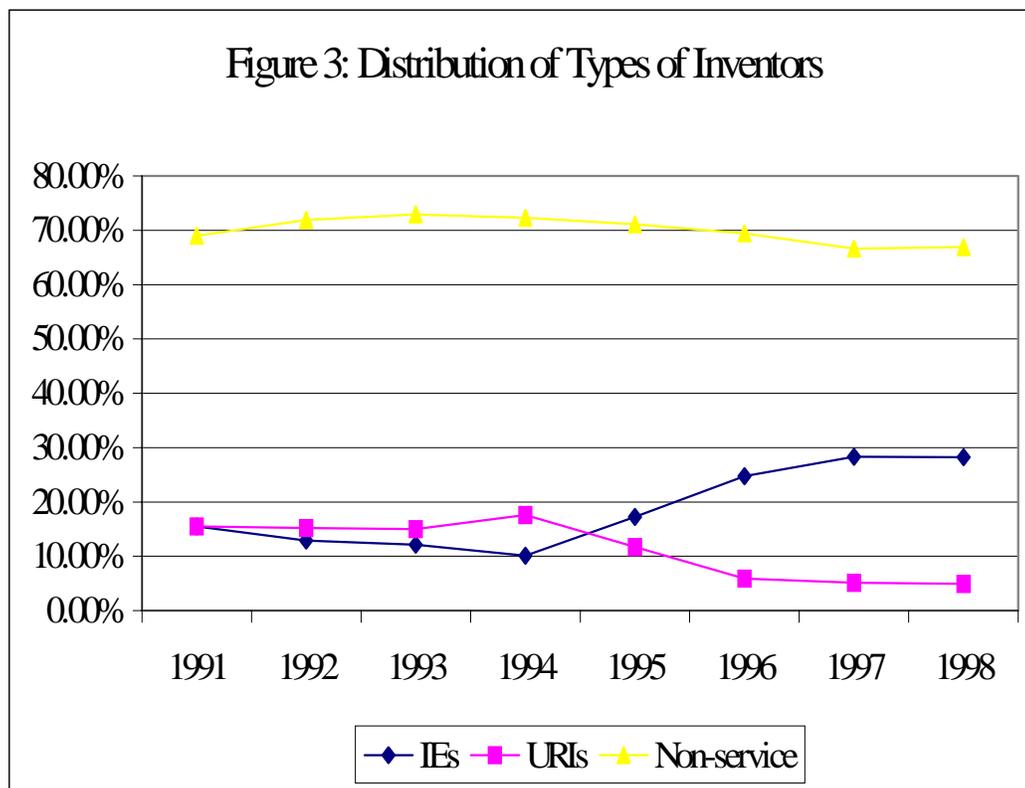


Source: China's Statistic Yearbook for Science and Technology, various years.

3.2. Types of Innovators

Under the current Chinese system, applicants for patents are divided into three basic categories: industrial enterprises, university and research institutions, and individuals. Industrial enterprises (IEs) devote resources to their R&D activity in order to come up with new products or new technologies. The inventions of the IEs, if patented, belong to the enterprises that discovered them. Usually, the output of the R&D activity by industrial enterprises can be readily used for production and leads to immediate commercial benefits to the innovators. The second category of innovators in China is universities and R&D institutes (URIs), which are mostly funded by the central or provincial governments, although funding from contracting with industrial enterprises has been increasing in recent years. These institutions employ well-trained scientists and engineers to conduct basic and applied research. The R&D output of the URIs can be of either academic or commercial value. The third category of inventors contains individuals

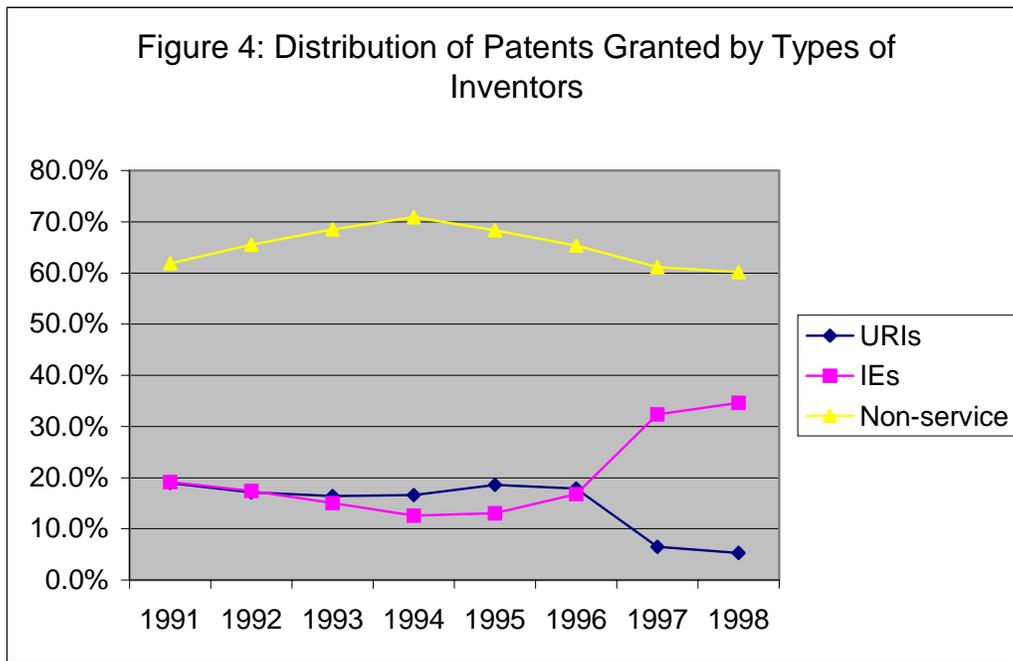
who use their own resources to engage in innovative activity. If successful, they can file, as they do almost all the time, for patent protection for their discoveries. These patents are termed non-service patents under the current patent system in China, reflecting that they are obtained through the sole effort of the individuals, rather than of their employers. (Patents belonging to the first two categories of inventors are called service-patents.) To exploit their discoveries' commercial uses, the individual inventors need to either sell their patents to commercial users or develop these inventions by setting up their own business.



Source: same as Figure 2

Figure 3 depicts the shares of patents filed during the period of 1991 to 1998 by each of the three types of inventors in China. As can be seen, the primary suppliers of patents in China in the 1990s were the non-service inventors who provided nearly 70% of the patent applications filed for every year during that period. The industrial enterprises, which the

Chinese government has been hoping would become the main force of innovation in China, contributed less than 15% of the total patent applications before the mid-1990s and less than 30% afterwards. Although the share of industrial enterprises increased after the 1995, this change, however, was mostly due to the decline in the contribution of the university and research institutions, rather than that of the non-service inventors.⁶ Individual inventors were consistently the main forces of innovation in China in the 1990s; at least in terms of the number of patent applications filed.⁷



In terms of patents granted, non-service inventors still remained the main suppliers of patents in the 1990s. In particular, about 60% of approved patents went to the non-service innovators throughout the 1990s. Industrial enterprises and university and research institutes each received around 20% of the total number of patents granted.

⁶ A plausible explanation for the increasing share of the IEs and the decreasing share of the URIs after the mid-1990s is the Chinese government's effort in recent years to encourage research institutes to merge with industrial enterprises. This explanation also applies to Figure 4 and Figure 5 below.

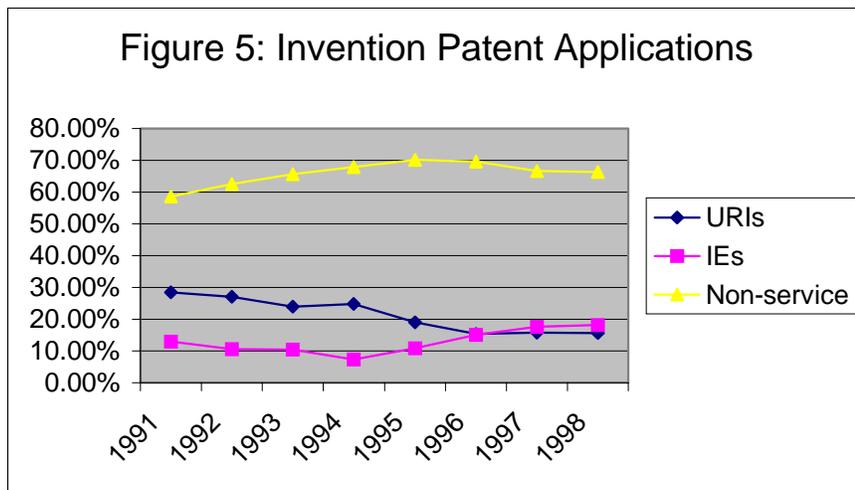
⁷ Note that service inventors (such as business firms) may choose not to file patent applications for their discovery for reasons such as their desire not to reveal technical details to their competitors. Non-service inventors do not seem to have such a motivation. The propensity to file patents is higher for non-service inventors as they usually do not have the capacity to commercialize their inventions by themselves.

The information revealed by Figures 2, 3, and 4 is summarized below.

Observation 1:

- *More than 80% of the domestic patent applications filed were for small innovations (utility models and external designs) since the passage of China's patent law in 1985.*
- *About 70% of the domestic patent applications filed in the entire 1990s came from individual innovators.*
- *Over 60% of the patents granted domestically went to individual innovators.*
- *The above patterns have been rather steady over time.*

From a consideration of the above patterns, one might be tempted to think that the dominant position of the individual inventors may just reflect the low quality of R&D projects undertaken by these individual inventors. This, however, is not necessarily the case.



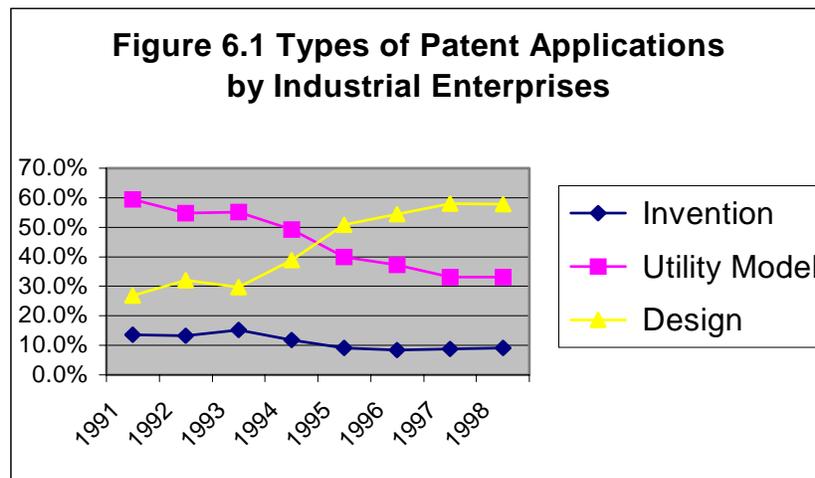
Source: Same as Figure 2

As Figure 5 shows, individual inventors supplied over 60% of the patent applications for invention patents (major innovations) throughout the 1990s. The relative contribution of

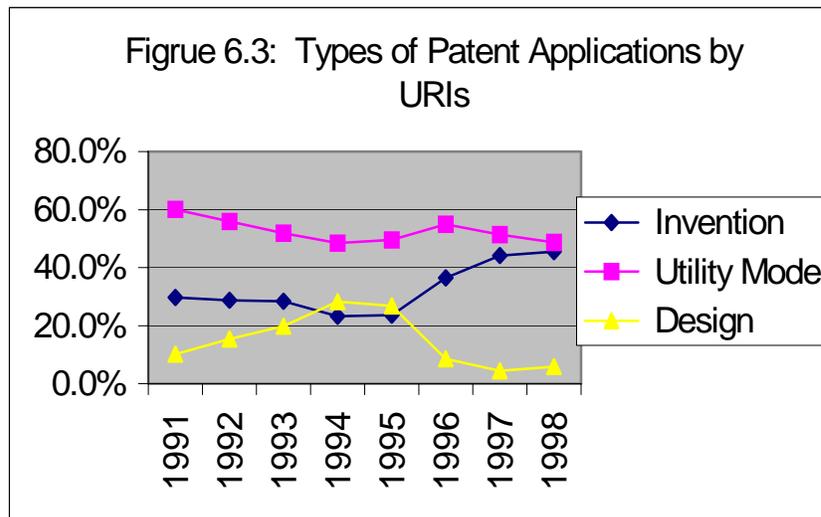
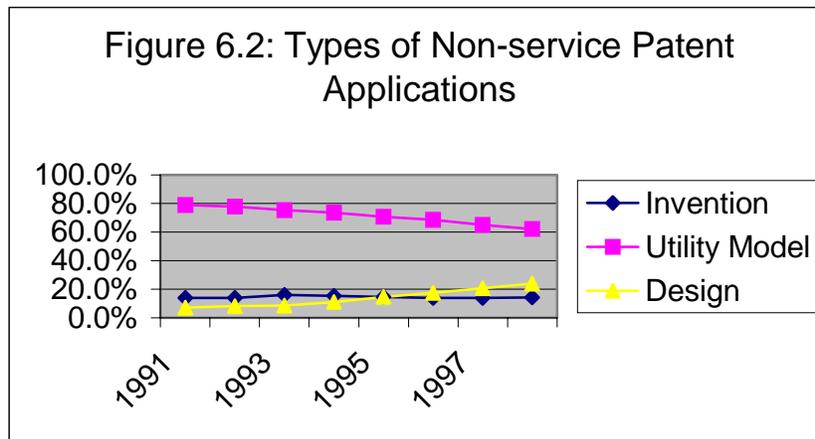
the IEs, although increasing after 1995, was consistently below 20%. Although not presented here, the compositions of patent applications for utility models and external designs show a similar pattern, with the share of non-service inventors being over 50% and 70%, respectively, remaining stable throughout the 1990s. In other words, individual innovators are as dominant in producing major inventions as they are in supplying the three types of patents as a whole.⁸

3.3 Composition of R&D Projects by IEs, URIs, and Non-service Innovators

To depict a clearer picture of the R&D portfolios of Chinese innovators, we next look at the types of patent applications filed by each category of innovator. Figures 6.1 to 6.3 show the type of distributions of the patent applications filed by the three innovator groups, respectively. On the whole, both the industrial enterprises and the individual inventors have devoted disproportionately more resources to small projects in the 1990s. In particular, over 80% the patent applications filed by the IEs were for utility models and external designs. The share of invention patents for the IEs was above 10% before 1995 but declined to less than 10% afterwards. For the individual inventors, the share of invention patent applications was persistently below 20% throughout the 1990s. The patents applications filed by the URIs, not surprisingly, were of higher quality than those of the other two groups, with the share of invention patents being below 30% before 1995 and then increasing to about 45% by 1998.



⁸ Of course, the number of patents is a crude measure of R&D productivity as it does not fully reflect the



Source: Same as Figure 2

The patterns in the above figures can be summarized as follows:

Observation 2:

- *Both the industrial enterprises and the non-service innovators have devoted most of their R&D resources to small projects. Only less than 10% of the patent applications filed by the IEs and less than 15% of the applications filed by the non-service innovators were for major R&D projects.*
- *The above patterns have been rather stable during the 1990s.*

commercial value of the patents.

3.4. *Small-scale innovative activities in China?*

Observations 1 and 2 reveal the following patterns of today's Chinese innovation system. First, the system is to a great extent *individual-based*, as opposed to enterprise-based like those in developed countries.⁹ Second, Chinese innovators, including industrial enterprises, invest a disproportionate amount of their R&D resources in small projects (utility models and external designs). The industrial enterprises are far from becoming the main force of innovation in China.

One problem with an individual-based system is that there are difficulties in realizing the commerce value of the patents of individual inventors. First, due to their limited R&D resources, discoveries of non-service innovators often cannot be directly commercialized. Re-test or redesign may be needed before these patented products or processes can be put to commercial use. This lack of marketability of patents discourages potential users from investing in these patented items. Second, the non-service patent holders must overcome the "matching problem" in finding the right partners. They may not have the resources needed to search a large pool of potential users. Also, they may face opportunistic behaviors on the part of potential users during the search process. Given that non-service patents are often not technically sophisticated, a potential user may "invent" a similar item on his own after learning about the patent during the negotiation process with the patent holder. This may lead the patent holder to unwillingly accept an unfavorable deal from a user rather than searching for the next one.

Third, there is always an informational problem in transactions involving patents. A patent holder usually possesses more information about the quality and workability of his patent, while the potential buyer may not be as convinced as the patent holder about the rate of return from investing on this patented item. This problem of asymmetric information becomes more severe when the patent "seller" is an individual rather than an institution. First, inventions by an individual may be perceived to be low quality. Also, an individual patent holder may simply physically disappear after receiving initial payments

⁹ For example, the ratio of patents granted to companies to that granted to individuals in the United States was about 2.8:1 during the 1980s. See The U.S. Science & Engineering Indicators – 1993.

and thus cannot be held responsible if the patent turns out to be of low value. Because of this, many potential commercial users in China prefer to deal with institutional rather than non-service patent holders.¹⁰ Even if a potential user is willing to invest in the patent, he may have difficulty acquiring bank loans – banks may perceive investing in a non-service patent as a risky project.

The potential difficulties in realizing the commercial value of a non-service patent can be seen from the transaction activities in China’s domestic technological market, which was incepted in the mid-1980s.

Table 2 Number of Transactions in China’s Technology Markets

	1991	1992	1993	1994	1995	1996	1997	1998
Total number of deals	208098	226470	245967	222356	221182	226962	250496	281782
Sold by non-service inventors	7588	7850	7962	11593	7309	7656	8866	9512
As % of the total	4%	3%	3%	5%	3%	3%	4%	3%

Source: China’s Statistic Yearbooks

Table 3 Value of Transactions in China’s Technology Markets (in 10,000 RMB)

	1991	1992	1993	1994	1995	1996	1997	1998
Total values	948063	1416182	2075540	2288696	2683447	3002045	3513718	4358228
Sold by non-service	13902	18544	40098	43037	52220	69941	64060	84851
As % of the total	1.5%	1.3%	1.9%	1.9%	1.9%	2.3%	1.8%	1.9%

Source: China’s Statistic Yearbooks

The above two tables show that only a very tiny portion of the patents filed and obtained by non-service innovators in China has been successfully exploited for commercial use in the 1990s. Only about 3% of the technology transactions were sold by individuals and partners, which accounted for less than 2% of the value of transactions throughout the decade. Therefore, although non-service innovators contribute a lot to China’s innovation

¹⁰ When dealing with individual patent holders, potential users often require letters from the employer of the innovator providing supporting information to the marketability of the patent. Due to legal considerations, these employers are often reluctant to provide such certification letters to patents not owned by them.

activity in terms of the number of patents applied for and granted, most of their patents still remain shelved and thus have not been able to realize their commercial value.

4. R&D by Large and Medium-Sized Enterprises (LMEs)

In 1999, there were a total of 22,276 large and medium-sized enterprises in China, of which 11,370 were state owned and 3,533 were the so-called “San Zi” enterprises (wholly foreign owned, equity joint ventures, and contractual joint ventures between foreign firms and Mainland Chinese firms). The rest included collectively owned and privately owned enterprises. In terms of production activity and output, the LMEs are undoubtedly the main force of today’s Chinese economy, as indeed they should be. The R&D performances of these LMEs, however, are perhaps not as impressive as one would expect. Table 4 below contains information regarding innovation activity of the LMEs during the 1990s.

Table 4 Innovation by the LMEs in China

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Number of LMEs	14935	16991	15000	20162	23026	24061	24024	23577	22276
with tech-institutes	7899	8576	9503	8817	9165	8179	7313	7220	7120
R&D expenditures / Sales revenue	0.49%	0.50%	0.50%	0.51%	0.46%	0.30%	0.52%	0.53%	0.60%
New products / Sales revenue	9.9%	10.5%	10.7%	10.2%	8.50%	10.0%	10.0%	11.7%	13.2%
Number of patent applications	-	-	-	-	-	4936	5896	6317	7884
Applications per firm	-	-	-	-	-	0.205	0.245	0.268	0.354
Number of patents granted	-	-	-	-	-	3085	3032	4208	5879
Grants per firm	-	-	-	-	-	0.128	0.126	0.178	0.264
R&D expenditures*	58.6	76.1	95.2	122	141.7	100.5	188.3	197.1	249.9
Expenses on buying foreign technology*	90.2	116.1	159.2	266.7	360.9	322.1	236.5	412.4	207.6
R&D : Buying Technology	0.65	0.66	0.60	0.46	0.39	0.31	0.80	0.48	1.2

* In 10 million RMB

Source: China’s Statistic Yearbooks for Science and Technology, 1995-2000.

The data for purchasing technology for the years from 1991 to 1995 are from Feng (2000), p. 216.

While the number of LMEs grew fairly fast during the period, the number of LMEs that had their own research institutes actually declined, especially after 1995.¹¹ In 1998, only

¹¹ This decline was likely due to the reorganization and consolidation of SOEs initiated by the central government in the mid-1990s. While the number of LMEs was growing, certain existing firms (including

30.6% of the LMEs had their own research institutes. In terms of R&D intensity, the LMEs spent just about half a percent of their annual revenues on R&D activities throughout the 1990s, except in the year 1999.

Given these low levels of R&D input, it is not surprising that the R&D output of the LMEs was also low. In particular, in 1996 the number of patents applied for per firm (for all three types of patents) was only 0.21, and the number of patents granted per firm was only 0.13. Although these two indicators improved in the years following 1996, still only about one out of every three LMEs filed a patent during the entire year of 1999, and only one out of every four was granted a patent in that year. One way to measure the value of R&D output of the LMEs is to look at the ratio of new product sales to the total revenues of the LMEs. As can be seen from the above table, only about 10% of the LMEs' revenues were derived from new product sales from 1991 to 1997. The ratio reached 11.7% and 13.2%, respectively, for the last two years of the decade.

It has been claimed that Chinese enterprises are much more willing to purchase technology from abroad than to innovate on their own. This claim is certainly supported by the data shown in the above table. Specifically, in all but the last years of the 1990s, the LMEs spent more funds buying technology from foreign countries than on their own R&D activities. The ratio of expenditure on R&D to that on purchasing technology from abroad was 0.65:1 in 1991. This ratio declined throughout the first half of the decade and bottomed out at 0.31:1 in 1996 before starting to rise in 1997. The year 1999 was the first time that the LMEs spent more on their own R&D than on purchasing foreign technology.¹²

their research institutes) may have been merged with one another. In fact, the number of technical engineering personnel employed by the LMEs increased between 1991 and 1998.

¹² But the figure for 1999 might not be comparable with those for the previous years due to institutional changes in China. In 1999, about 242 research institutes formerly pertaining to government ministries or provinces were spun off to merge with existing enterprises, or become independent entities, as part of China's effort to transform its central-planning research institute system into a market-oriented one. R&D expenditures for those research institutes were not included in the figures for the LMEs for the years prior to 1999.

The information on enterprises' own R&D versus their buying technology from abroad, along with the poor performance of R&D output in terms of patent numbers and new product sales, is consistent with the hypothesis that, on the whole, Chinese firms are technology buyers more than innovators.

5. R&D incentive and Industrial Structure

Commonly cited reasons for the weak R&D incentive among Chinese firms include the lack of physical resources and technical personnel, lack of information on market conditions, separation of research institutes and production units due to historical reasons, and a weak intellectual property legal system. Here, I highlight the following structural factors.

5.1 Low degree of concentration of Chinese industries

One feature of China's industries is their low degree of concentration. Table 5 presents information about eight-firm concentration ratios (CR8) in 37 Chinese industries in 1995. As can be seen, none of the industries had a CR8 above 80%. In fact, only one industry (petroleum and natural gas) had a concentration ratio above 50%, six industries had a CR8 index between 30% and 50%, and over half of the industries had CR8 indices below 20%.¹³

Table 5 also contains information about R&D expenditures as a percentage of total sales for the 37 manufacturing industries in China in the year 1995. It is striking that none of the industries spent more than 1% of annual revenues on R&D in that year. For most of the industries, the R&D/sales ratio was below 0.3%. Only seven of the industries had their R&D intensity ratios above 0.5%. On the R&D output side, Table 5 lists the number of patents applied for by and granted to the large and medium-sized enterprises in the 37 industries for the year 1996. With the exception of a few industries (coal mining,

¹³ Four-firm concentration ratio (CR4) is another commonly used measure of industrial concentration. I use CR8 here because of the low degree of concentration in Chinese manufacturing industries.

Table 5: Concentration Ratios and Patent Information for 37 Chinese Industries 1995-6

Industries	CR8	Ratio 1	Ratio 2	R&D/Sales
1 Coal Mining	20.3	0.43	0.27	0.10%
2 Petroleum and Natural Gas	72.36	13.88	9.71	0.77%
3 Ferrous Metals Mining	24.5	0.06	0.06	0.11%
4 Nonferrous Metals Mining	15.9	0.04	0.02	0.24%
5 Nonmetal Minerals Mining	5.9	0.05	0.01	0.36%
6 Logging & Transport of Wood	13.5	0.17	0.08	0.14%
7 Food Processing	5.3	0.05	0.02	0.04%
8 Food Production	9.9	0.26	0.21	0.07%
9 Beverage Production	8.6	0.22	0.17	0.13%
10 Tobacco Processing	37	0.09	0.08	0.12%
11 Textile	2.8	0.07	0.05	0.12%
12 Garments & Fiber Products	3.8	0.04	0.02	0.08%
13 Leather, Furs, & Related Product	2.9	0.05	0.06	0.15%
14 Timber & Straw Products	5.7	0.06	0.04	0.06%
15 Furniture Manufacturing	5.4	0.14	0.10	0.04%
16 Paper Making & Paper Products	5.3	0.03	0.01	0.22%
17 Printing & Record Medium Products	5.1	0.00	0.00	0.09%
18 Educational and Sports Products	8.1	1.75	0.71	0.02%
19 Petroleum Processing & Cooking	44.8	1.57	0.44	0.19%
20 Chemical Materials & Products	11.3	0.09	0.06	0.35%
21 Pharmaceutical Products	11.8	0.25	0.17	0.77%
22 Chemical Fibers	37.6	0.10	0.09	0.12%
23 Rubber Products	18.3	0.12	0.08	0.61%
24 Plastic Products	3.6	0.18	0.14	0.27%
25 Nonmetal Mineral Products	2.4	0.09	0.06	0.28%
26 Ferrous Metals Processing	30.2	0.80	0.61	0.17%
27 Nonferrous Metals Processing	13.3	0.15	0.10	0.20%
28 Metal Products	4.6	0.21	0.16	0.25%
29 Ordinary Machinery	6.5	0.19	0.12	0.62%
30 Equipment for Special Purposes	6.2	0.30	0.17	0.60%
31 Transportation Equipment	20.9	0.18	0.12	0.55%
32 Electric Equipment & Machinery	8.8	0.61	0.35	0.37%
33 Electronic & Telecom Equipment	14.7	0.26	0.12	0.38%
34 Instruments & Office Machinery	7.8	0.27	0.17	0.77%
35 Electric Power, Steam, & Hot Water	39	0.06	0.04	0.03%
36 Gas Supply	37	0.14	0.10	0.25%
37 Tap Water Production & Supply	24.8	0.02	0.01	0.19%

Source: The data on concentration ratios were computed based on *China's Statistic Yearbook* 1996 and *China's Statistics Yearbook for Large and Medium-size Enterprises* 1996. Concentration ratios for the years after 1996 are not available. The data on R&D are from China's Third Industrial Census (1995).

petroleum and natural gas, education and sports products, and petroleum processing industries), LMEs in most of the other industries on average submitted fewer than 0.3 patent applications, and received fewer than 0.2 patents. Next, I will argue that a low degree of industrial concentration is a major reason for the observed low R&D intensity in China.

The degree of horizontal concentration is a measure of how intense competition is in a given industry. The conventional wisdom (or the Schumpeterian view) is that industries that are more concentrated around a few giant firms are more likely to conduct R&D because the not-so-severe competition in the product market guarantees an attractive return on R&D investments. Arguments in support of the Schumpeterian view also include the following: (1) large companies have the resources needed to undertake innovation projects (the “deep pocket” argument); (2) with large research teams, big firms can enjoy economies of scale in knowledge production; (3) being more diversified, larger companies are more able to absorb the risks of R&D; (4) R&D output in one business line of a giant company can be used in other lines of its business; and (5) large companies often have a longer time horizon, which is particularly important for undertaking R&D projects.

Different from, but not contrary to, the Schumpeterian view is the modern view that firm incentive to innovate depends on the types of R&D projects to be conducted. For drastic innovations (those that can drive competitors out of business), smaller firms (or firms in industries with a lower degree of concentration) tend to have a stronger incentive to innovate. This is so because the lower the degree of concentration, the lower the current profits of each firm and thus the greater the gain from innovation. On the other hand, for incremental (or non-drastic) innovations, the larger the number of firms in the industry, the lower the profit post-innovation, and hence the less attractive the R&D projects to a given firm. Thus, consistent with the conventional view, for incremental innovations the incentive to innovate is negatively related to the degree of competition in an industry.

I believe it is safe to assume that innovations conducted by a typical Chinese enterprise are likely to be incremental, rather than drastic, since Chinese industries are currently at the stage of learning and imitating foreign technologies. Thus, based on the conventional wisdom, the following hypothesis can be made:

Hypothesis: *Industrial R&D incentives in China are negatively related to the degree of competition. That is, the R&D incentives are positively related to industrial concentration.*

Using the data from the Third National Industrial Census of 1995, I conducted simple regressions to test the above hypothesis. Below are the OLS regression results regarding R&D output, the number of patents in particular, and industry eight-firm concentration ratios for the 37 industries in Table 5:

$\text{Ratio 1} = 1.236327 - 0.181219(\text{CR8}) + 0.472847(\text{CR8})^2$	$\text{Ratio 2} = 0.859484 - 0.129213(\text{CR8}) + 0.332491(\text{CR8})^2$
$(5.3787) \quad (-8.4134) \quad (13.7394)$	$(5.2769) \quad (-8.4658) \quad (13.6340)$
R-square = 0.9107	R-square = 0.9074

Ratio 1: Number of patents applied for per firm in 1996
Ratio 2: Number of patents received per firm in 1996
CR8: Eight-firm concentration ratio in 1995

Therefore, both the number of patents applied for and received in 1996 were positively related to the CR8 ratio in 1995 for the range of the CR8 observed. The one-year time lag chosen in running the regressions is reasonable given that the approval process of patent applications in China usually takes about a year. These preliminary results indicate that firms in more concentrated industries tend to come up with more patents from their innovation projects, or that they are more capable of conducting R&D. This finding is

consistent with the Schumpeterian hypothesis.¹⁴ Using a large panel data set on large and medium-sized Chinese enterprises, Jefferson et al. (2001) found that the R&D intensity of the Chinese firms is positively related to the degree of industry concentration (CR1 and CR2). These results suggest that the Schumpeterian hypothesis holds in China.¹⁵

5.2 Vertical integration

Another major factor affecting R&D incentive is the vertical aspects of an industry. Given China's "imitate-first-and-then-innovate" strategy towards modernizing its technological system, the vertical structures of the industries are crucial for China. In particular, vertical relationships among firms in an industry determine those firms' technical ability and economic incentive for absorbing foreign technology. It also affects the "quality" of the purchased technology.

First, learning and absorbing foreign technology and products, by means of reverse engineering for example, is a complex process which involves various aspects and stages. The firms concerned must have both the technical capability and the economic incentive to engage in learning and absorbing imported technology. To comprehend the design of a product or a process, one needs to understand the function of each component and subsystem. An un-integrated producer of a product may not have the technical knowledge and capability necessary to produce the intermediate goods it uses, or to replicate the foreign-made production process using parts and subsystems supplied domestically.

Second, absorbing and imitating purchased technology or products by a domestic firm generates economic benefits not only to itself, but also to upstream suppliers and/or downstream users. The presence of such positive externality implies that firms may under-invest in learning, as they are able to fully appropriate the benefits of the learning activity. Therefore, a firm may not have a strong enough incentive to spend its resources

¹⁴ Regressions were also conducted in regard to the relationship between R&D intensity and the concentration ratio (CR8), but the results were not significant.

¹⁵ Lunn (1986) examined the impact of market structure on the number of patents granted to firms in the United States. He found that process patents are positively related to market concentration, which is consistent with the Schumpeterian hypothesis. New product patents are not affected (in a statistically significant way) by market concentration; they are more influenced, however, by industry advertising.

to learn about foreign technology, even if it possesses the required technical capability to do so.

Vertical integration can help solve both the above-mentioned coordination problem and the incentive problem, thus facilitating the learning of imported technology. A vertically integrated firm is more able to coordinate various learning activities pertaining to different stages of production. It would not have to worry that information gained from the various learning activities would leak to outsiders. The positive spillovers among these activities will be more effectively internalized within the integrated firm. Thus, giant enterprise groups tend to have a greater incentive to imitate imported technologies and then further innovate based on the imitations.¹⁶

There is evidence to support the above arguments that vertical integration can increase firms' ability and incentive to absorb foreign technology. Ho et al. (1996) presented case studies of foreign technology transfer in the textile, machinery equipment, and electronics sectors in Jiangsu province. According to Ho et al., a common difficulty faced by the Chinese firms in absorbing purchased technologies is that individual enterprises do not have the ability to digest and imitate these equipment and processes because they are only the users. In successful cases in Ho et al., domestic upstream suppliers of similar inputs (and/or provincial research institutes) had to be involved in absorbing purchased technology, often with local government agencies coordinating the activities.¹⁷ In a recent survey of 967 Chinese firms by Shao (1997), enterprises were asked to list important external factors affecting the success rate of R&D. Shao found that "support from suppliers and/or customers" was the most-cited determinant (mentioned by 58.9% of the firms surveyed), while 58.4% of the respondents cited "government support," 42.8% cited "cooperation with research institutes," and so on. The 2000 China Industrial

¹⁶ One may argue that a firm can seek a joint effort from its suppliers in order to realize the potential economic gains that could be derived. But given the nature of the innovative activity involved, transactions in such a cooperation would be very high, due to the problem of "hold-up" for example, as emphasized by Williamson (1975) and other scholars. This is particularly true given the weak intellectual property right system in China.

¹⁷ This role of the government as a coordinator, however, has been diminishing as economic reform continues and business enterprises become more and more independent of the governments.

Development Report (p. 237) also reported evidence that vertically integrated firms tend to conduct more innovative activity.

Third, the vertical structure of an industry affects to a certain extent the “quality” of the technology purchased from abroad, which in turn affects the degree of difficulty absorbing such technology. In particular, a vertically integrated industry tends to choose “proper technology,” whereas a vertically separated firm has a stronger incentive to go for “too advanced technology” which cannot easily be made compatible with complementary inputs produced domestically. To illustrate this point clearly, suppose a domestic firm is considering purchasing a form of technology (an assembly line) for making cars. Should the firm choose a model that requires importation of all the necessary auto parts? Or should it choose a “low quality model” that can make use of some parts, say tires, supplied by domestic firms? Since importing parts squeezes out domestic supply, the first choice imposes a cost on a domestic firm that produces tires by itself. A vertically separated firm, on the other hand, does not face this “replacement costs,” and, hence, is more tempted to purchase too advanced technology. This in turn may lead to low investment in absorbing the purchased technology because the technology is too complex for the domestic firms to learn and absorb.

Although it is hard to measure quantitatively the degree of vertical integration of an industry, there is scattered evidence that the degree of vertical integration in Chinese manufacturing industries is low. Consistent with this is the fact that Chinese firms have a very weak incentive to absorb foreign technology. In 1998, for instance, the ratio of expenditure on buying foreign technology to that on absorbing it was 14:1 for large and medium-sized enterprises.

5.3 Availability of foreign technology and strategic consideration

One feature of today’s Chinese economy is the persistently high availability of foreign technology ready to be imported to China, as multinational companies all try to enter the China market. In fact, the Chinese government has on many occasions required technological licensing as a precondition for foreign firms to enter China’s market. This

abundant supply of foreign technology shifts the trade off between buying technology and innovating on one's own in favor of the purchasing option. Relative to innovating on one's own, purchasing technology is less risky and returns can be realized quickly. Because of this, a "crowding out effect" may exist in China: importing foreign technology has "squeezed out" domestic innovation projects. The propensity to purchase foreign technology is thus very high for Chinese firms. If all rival firms are choosing to buy technology, it does not pay a firm to conduct its own R&D project as such projects often take a long time to finish. A firm undertaking its own R&D project would mean a loss of market share to rival firms in the short run. Therefore, the corresponding Nash equilibrium is that all firms choose to buy technology. According to a recent survey of the automobile industry, purchasing equipment was ranked as *the* most important channel for obtaining advanced technology.¹⁸

5.4 Policy Implications: Encourage Consolidation of Industries

The government policies toward innovation in China have been mainly "non-structural": policies instruments that have been used include direct R&D subsidization, providing tax credit for sales revenues generated from new products, setting lower limits for expenditure on technological development and upgrading, and so on. The analysis of R&D effort and patent data in the first half of the paper suggests that these non-structural approaches have had only limited effects. More attention should be paid to how to design *industrial structures* that are conducive to R&D. Specifically, China should increase the level of industrial concentration, both horizontally and vertically. Increased concentration on the horizontal level will stimulate innovation as the Schumpeterian view argues, and as the preliminary regression analysis in this paper suggests. More integrated firms are more capable of internalizing the positive externalities (or spill-overs) uniquely present in the "learning-imitating-innovating" game.

A study of how to restructure Chinese enterprises and to increase industrial concentration would be complex, and is beyond the scope of this paper. Some general arguments,

¹⁸ The survey, conducted in 1995, covered a range of 131 auto/auto part makers in China. Following the purchasing of equipment, other means of acquiring technology include, in order of importance, exchange with other enterprises, purchase of patents, and contract R&D. See Zhang (1998).

however, can be presented. I am not suggesting here the use of industrial policy of any sort. A higher degree of industrial concentration (horizontal or vertical) can be achieved through the working of the market system. Given the current widespread low degree of concentration in Chinese industries, many firms are operating below their efficient scales. Thus, there should exist a demand for industrial consolidation among the Chinese firms. Indeed, mergers and acquisitions have been happening in China, especially since the early 1990s. As summarized in Jefferson and Rawski (2001), the mergers and acquisitions in China fall into two categories. Market-mediated transactions aim at commercial objectives, such as achieving economies of scale. Government-directed restructuring, on the other hand, has been motivated by policy objectives such as limiting social instability arising from layoffs and bankruptcies, and building large enterprise groups that can compete successfully in global markets.

I agree with Nicolas Lard that China “ought to be relying on a much more competitive market to drive out inefficient firms and allow some natural consolidation to take place.”¹⁹ Industrial consolidation should not be seen as just a means by which business firms can seek market power, or as a way by which domestic firms can prepare themselves for the forthcoming battles with new competitors once China joins the WTO. Better utilizing economies of scale in R&D activity is also an important driving force for firms to merge with one another.²⁰ The stimulating effect of increased industry concentration on innovation should not be overlooked. As argued in Jefferson and Rawski (2001), it is important that China should let the industrial consolidation process proceed naturally, and not copy South Korea’s model of Chaebols. China should build up its enterprise groups, which are truly subject to market competition rather than protected by preferential government treatment. The role of the government should be to create, by clearly defining property rights, by establishing a modern system of financial markets, and by removing regional protectionism and other forms of barriers, a market environment in which economically efficient enterprise restructuring can take place.²¹

¹⁹ Quoted in Restall 1997: A22.

²⁰ For example, some of the recent mergers and acquisitions in the automobile industry were motivated by R&D considerations. See Tai Guo Po, 2 February 2001.

²¹ See also Smyth (2000) for discussions of whether China should build up giant enterprise groups.

6. The Impact of China's Accession to the WTO on Innovation in China

It is likely that China will enter the WTO by the end of 2001. Upon its entry into the WTO, China will follow the general principles of the WTO as well as the terms of the bilateral agreements China has reached with major WTO member countries. China's accession to the WTO will have a great impact on the innovation activities of Chinese firms due to the increased competition in the China market, removals of government policy and regulations on technological transfers to China, and stricter enforcement of intellectual property right laws.

The WTO's general agreements, such as the agreement on trade related investment measures (TRIMs) and the agreement on trade related intellectual property rights (TRIPs), must be observed by all member countries of the WTO. Under the agreement on TRIMs, the local content requirements that the Chinese government has often set for foreign investment in certain industries will be removed. China can no longer require foreign investors to set up plants for parts and subsystems for the production of final products in China and transfer the technology accordingly. Although the laws on intellectual property rights in China are already in line with the standards set in the agreements on TRIPs, China's access to the WTO will surely help improve the enforcement of these laws, due to the existence of the intellectual property rights dispute resolution channels of the WTO.

As foreign goods and investments will be able to enter China's markets freely and various forms of government protection (tariffs, quotas, subsidizes, etc.) that certain Chinese industries have been enjoying will be removed, Chinese enterprises will face fierce competition after China enters the WTO. Increased competition will further erode the profitability of many already struggling Chinese firms. In the short run, Chinese industries will become less concentrated as new firms enter. However, there have been noticeable signs of consolidation among Chinese industries as they prepare for the shocks of China's accession to the WTO. For example, there has been a merger frenzy in the automobile industry and the electronic appliance industries since early 2000 (Tai Gung Po, 9 January 2001 and 8 February 2001). Mergers and acquisitions can help firms realize

economies of scale in R&D activity, enabling them to more effectively absorb foreign technology.

In addition to its effect on industrial concentration, China's entry into the WTO will impact innovation in the nation through its impact on technology transfers to China by foreign firms. As impressive as it has been, China's attraction of foreign investment and technology in the past two decades has been to a great extent due to the Chinese government policy and regulations that have aimed at importing advanced technology. Various laws and regulations in China require technology transfer of foreign companies when deciding their applications for investment in China. There have been reports over the past several years of some foreign companies being "forced" to transfer technology to China in exchange for access to its enormous market.²² A recent survey of some EU firms revealed that 46% of the technology transfers to China by these EU firms were because of the government policies and regulations requiring local sources and/or technology transfer.²³

With China's forthcoming accession to the WTO, existing barriers on foreign investments in China will soon be removed and technology transfers to China will be on a voluntary basis. For example, in the bilateral agreement between China and the United States, China agreed it would not condition foreign investment or import approvals on technology transfer or on conducting R&D in China, and that requirements as a condition for investment approval or importation, and the terms and conditions of any transfer of technology, will be agreed between the parties to a contract and not imposed by the government. China also agreed that it would eliminate requirements mandating that the Chinese partners in a joint venture gain ownership of trade secrets after a certain number of years.²⁴ Local content requirement will not be permitted under the TRIMs. With the removal of the policy requirements, Chinese enterprises will lose an important channel of obtaining foreign technology, namely "forced technology transfer."

²² See "U.S. Commercial Technology Transfers to the PRC," 1999, a research report by the Bureau of Export Administration and the Office of Strategic Industries and Economic Security of the United States.

²³ See Bennett et al. (2000).

There is, however, a bright side to China's entry into the WTO in regard to innovation by Chinese firms. In the past, technology transfers to China have also been either motivated by normal business considerations, such as market expansion or responses to pressures from rival firms. According to a survey on EU firms by Bennett et al. (2000), when asked what were the reasons for technology transfer to China, 80% of the companies cited market access, 57% cited cost advantage, 48% cited "company globalization strategy," and 33% cited responses to competitors' moves (actual or potential). These factors will of course remain as the main motivators of technology transfer to China. In fact, as more and more foreign companies enter the China market and competition intensifies, foreign investors are more likely to transfer more advanced technology to China. The enhanced incentive for technology transfer will bring many forms of advanced technology to China.

7. Concluding Remarks

It is a remarkable achievement that China established a modern patent system in less than 20 years. However, a patent system itself, although necessary, is not sufficient for enterprises to be willing to undertake innovation activity. As presented in the first half of the paper, China's innovation activity in the past 15 years has been primarily on a small scale, aimed at small R&D projects (utility models and external designs, as opposed to inventions). Industrial enterprises have not yet become the main force of innovation in China. Even when they are equipped with technology purchased from abroad, Chinese firms must develop the capability to innovate on their own in order to compete successfully in the world's markets. There are yet to be any indications of this happening persistently and on a reasonable scale in China.

Factors affecting firm incentive to invent are many. This paper has emphasized the roles of such structural factors as the degree of industrial concentration and vertical organizations in facilitating industrial R&D. There is empirical evidence supporting the

²⁴ See the sector papers by the Washington Council on International Trade, http://www/wcit.org/Chinawto_sectorpapers.htm.

Schumpeterian hypothesis, namely that the incentive to innovate is positively related to the degree of market concentration. I have also analyzed the microeconomic channels through which the vertical structures of an industry induce the learning and absorbing of imported technology. My analysis indicates that a sensible thing for China to do is to restructure its industries both horizontally and vertically so as to create industry structures that are more conducive to innovation. Specifically, more concentrated industrial structures can promote innovation, and more vertically integrated enterprises can encourage and facilitate the learning and absorbing of foreign technology.²⁵ Industrial restructuring in this direction can speed up the now two-decade long “imitate-first-and-then-innovate” process. Non-structural policy instruments, such as R&D subsidization and tax credit for innovation, have perhaps already reached the limit when it comes to stimulating R&D activity by Chinese enterprises, and the effects of industry structures on innovation should receive more attention from policy makers in China.

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²⁵ By increasing industrial concentration, I do not mean completely transforming an industry into a monopoly. On the contrary, I believe that competitive pressure is an important force that drives firms to innovate. My argument is that the current degree of industrial concentration in China is too low (Table 5), and that R&D incentive will be enhanced if proper industrial consolidation takes place but rigorous competition is still present.

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